Flood risk management plan for the Meuse international river basin district, 2nd cycle of the Directive on the assessment and management of flood risks (2022-2027)

December 2021

English not being one of the IMC's official languages, the English version of this report is not an official translation and is only provided to make this report more widely available.

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AEPF: approximate envelope of potential floods

AMICE: Adaptation of the Meuse to the Impacts of Climate Evolutions

CERFACS: Centre Européen de Recherche et de Formation Avancée en Calcul scientifique (=European Centre for Advanced Research and Training in Scientific Computing)

DREAL: Direction Régionale de l'environnement, de l'aménagement et du logement (French Regional Directorate for the Environment, Planning and Housing)

DSCLIM: open-source software that performs statistical disaggregation of climate scenarios using a method based on weather patterns and analogues

EDF: Electricité de France

FRD: Directive on the assessment and management of flood risks

FRMP: Flood Risk Management Plan

GCM: Global Climate Models

IFRMP: International Flood Risk Management Plan

IMC: International Meuse Commission

IPCC: Intergovernmental Panel on Climate Change

IRBD: International River Basin District

KMI: Koninklijk Meteorologisch Instituut van België (=Royal Meteorological Institute of Belgium)

KNMI: Koninklijk Nederlands Meteorologisch Instituut (=Royal Meteorological Institute of the Netherlands)

LAWA: Bund/Länder-Arbeitsgemeinschaft Wasser (=German Federal/State Working Group on Water)

PFRA: Preliminary Flood Risk Assessment

PRUDENCE: Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects

RCM: Regional Climate Models

SAFRAN: Système d’Analyse Fournissant des Renseignements Adaptés à la Nivologie(=Analysis system providing information adapted to snow conditions)

SPW: Service Public de Wallonie (=Public Service of Wallonia)

WFD: Water Framework Directive

WG: Working Group

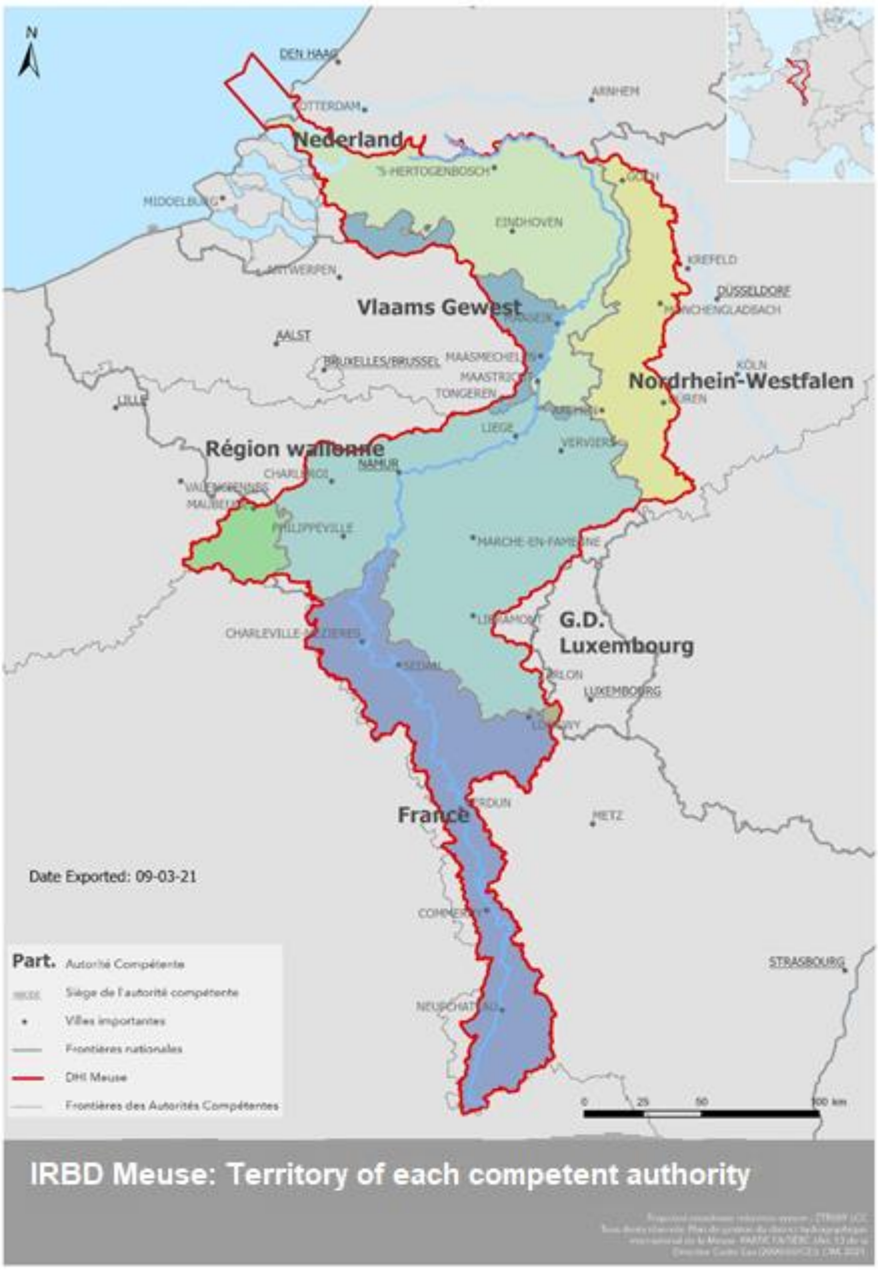
WG H: Working Group Hydrology/Floods

1. Introduction

1.1 Context, mandate and objective of the report

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (hereinafter Flood Risks Directive "FRD") aims to reduce the negative consequences for human health, the environment, cultural heritage and economic activity associated with floods in the Community.

The Meuse River and its tributaries form the Meuse International River Basin District (IRBD). It involves five EU Member States (France, Luxembourg, Belgium, Germany and the Netherlands). Multilateral coordination in the IRBD Meuse takes place within the framework of the International Agreement on the Meuse, signed in Ghent in 2002, whose Contracting Parties are France, Luxembourg, the Belgian Federal State, the Walloon Region, the Flemish Region, the Brussels-Capital Region, Germany and the Netherlands (Map n° 1).



Map 1 : IRBD Meuse: competent authorities

This agreement concerns international coordination both for the implementation of Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive WFD) and for other areas, such as flood protection in the IRBD Meuse.

In order to meet the international coordination obligations of the FRD[1], the States and Regions whose territory is part of the IRBD Meuse decided at the IMC plenary assembly on 7 December 2007 in Charleville-Mézières that:

- international coordination would take place within the International Meuse Commission (IMC),
- the International Flood Risk Management Plan of the IRBD Meuse (IFRMP Meuse) would be composed of the national and/or regional management plans and an international part.

During the first cycle of the implementation of the FRD, the EU Member States of the IRBD Meuse have:

- identified, in accordance with article 5, paragraph 1, by 22 December 2011 the areas with potential significant flood risk;

- drawn up flood hazard and flood risk maps for the areas referred to in Article 5(1) of the FRD with potential significant flood risk by 22 December 2013 in accordance with Article 6(1);

- drawn up a first IFRMP for the international Meuse district in accordance with chapter IV by 22 December 2015.

During the second cycle of the implementation of the FRD, the EU Member States of the IRBD Meuse have:

- reviewed and updated in accordance with article 14, paragraph 1 by 22 December 2018 the areas with potential significant flood risk;

- reviewed and updated in accordance with article 14, paragraph 2 by 22 December 2019 the flood hazard and flood risk maps;

- reviewed and updated in accordance with article 14, paragraph 3 by 22 December 2021 the IFRMP for the IRBD Meuse.

Based on these considerations, the states have prepared the second IFRMP for the period 2022-2027. In doing so, they took into account the provisions of Article 14 and Annex B of the FRD, but also the results of the exchange of information on the implementation of the national plans and the recommendations of the report of 26.02.2019 from the Commission to the European Parliament and Council on the implementation of the FRD for the first FRMPs.

The IFRMP and the management plans drawn up by the States/Regions in application of article 7 of the FRD constitute the IFRMP of the IRBD Meuse. This roof report has been built up as a result of national and regional work and ongoing exchanges within the IMC, enabling an overall compatibility and coherence to be assessed. It attests to the coordination of the measures that have a transboundary impact, in order to respect the principle of solidarity[2].

[1] Article 8(2) of the FRD

[2] Article 7(4) of the FRD

1.2 International Meuse Commission and international Coordination

The International Meuse Commission (IMC) was established in 2002 with the signing of the International Meuse Agreement (Ghent Agreement). The objective of the agreement is to achieve sustainable and integrated water management in the Meuse River Basin District. It came into force on 1 December 2006.

The main tasks of the IMC are to coordinate the obligations of the WFD, to coordinate the obligations of the FRD and to issue advice and recommendations to the Parties for the prevention and control of accidental pollution (warning and alert system).

International coordination for the implementation of the FRD involves several steps and specific requirements:

- by exchanging relevant information in the preparation of the preliminary flood risk assessment;
- by exchanging information prior to the preparation of the flood hazard and flood risk maps;
- by coordinating the preparation of the IFRMP[3].

The technical work of multilateral coordination was carried out within the Working Group Hydrology / Floods (WG H) to be submitted for approval to the Plenary Assembly (PLEN), the only body competent to adopt the documents or reports presented by the working groups (Figure 1).

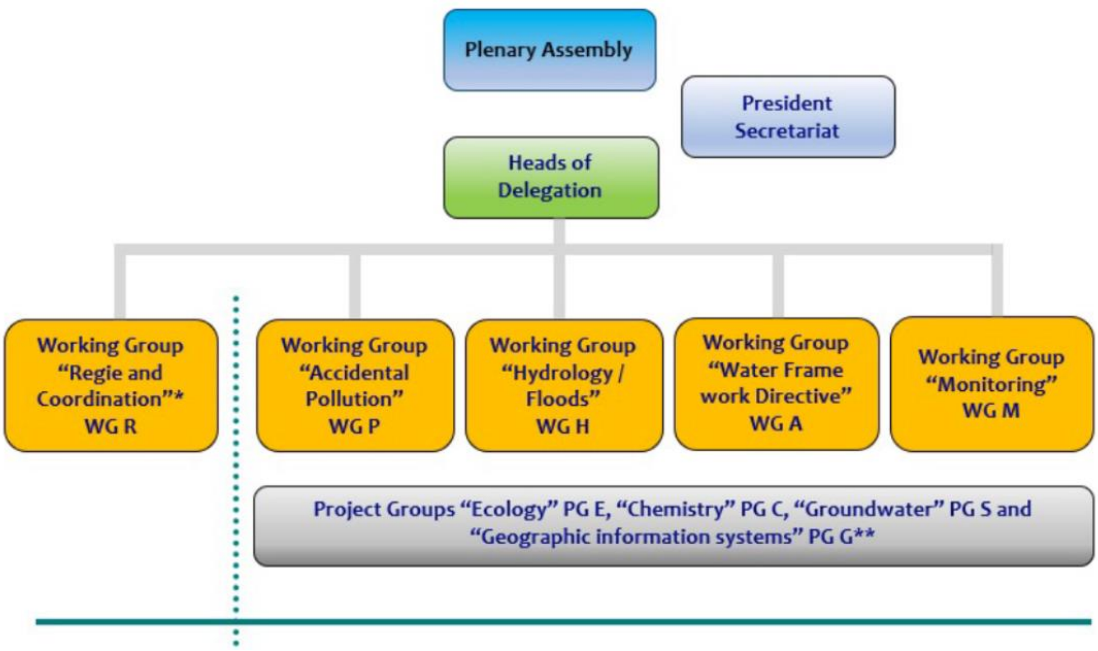


Figure 1: IMC organisation chart

The IMC adopted the following reports:

- 20 March 2019: the "Report (Minond/18-9def) on the review and update of the preliminary flood risk assessment in the International Meuse River Basin District" available at http://www.meuse-maas.be/CIM/media/DI/Rapport-art-4-et-5_DRI_Minond_18_9def_f.pdf ;

[3] Articles 4(2), 5(2), 6(2) and 8(2) of the FRD

- 19 March 2020: the "report (Minond/19-16def) on the exchange of information prior to the review and, if necessary, the updating of the flood hazard and flood risk maps in the international Meuse river basin district" available at http://www.meuse-maas.be/CIM/media/DI/Rapport-art_6_DI_Minond_19_16def_avec_annexes_f.pdf ;

1.3 From the Meuse flood action plan to the Meuse IFRMP

The floods of 1993 and 1995 caused significant material and immaterial damage in the States and regions located in the Meuse and Rhine River basins.

Following these exceptional floods, the Ministers for the Environment of the European Union countries bordering the Meuse and Rhine rivers (France, Luxembourg, Belgium, Germany and the Netherlands) stated in the Arles Declaration of 4 February 1995 that measures should be taken as soon as possible to reduce the risk of flood damage in the future. Transnational action plans were to be developed in this respect for both the Rhine and the Meuse River basins.

The International Commission for the Protection of the Meuse (ICPM) set up under the Charleville-Mézières Agreement (26 April 1994) having noted, on 29 November 1995, that the subject of flooding was not covered by the terms of the agreement, it was decided to set up a specific international working group to address this issue. The Working Group for Flood Prevention in the Meuse River Basin (GTIM) was therefore set up.

France, the Walloon and Flemish Regions of Belgium and the Netherlands were part of this group. The ICPM, the Land of North Rhine-Westphalia and the Grand Duchy of Luxembourg had the status of observers. The formalisation of this working group was achieved by an exchange of letters between the competent national and regional authorities.

Following the signing of the Ghent Agreement in 2002, this specific working group was replaced by the Working Group on Hydrology/Floods (WG H) of the International Meuse Commission (IMC).

The objective of the IMC Flood Action Plan was to develop a coherent set of short-, medium- and long-term measures to avoid or minimise flood damage in the Meuse basin. The operational objective of the Plan was to reduce the risk in the long term.

Taking into account the principles and objectives mentioned above, as early as 1998, the Meuse Flood Action Plan proposed a range of general measures[4] :

- National and regional policy and regulatory measures (mapping, building adaptation…)

- Awareness-raising measures (local emergency services, crisis situations, insurance …)

- Water retention measures (infiltration and runoff control, storm water basins, separation of sewage systems…)

- Measures in the river system (restoration of natural watercourses, flood control basins, flood expansion areas, increase in flow capacity…)

- Direct protection measures (dykes)

- Forecast and warning systems.

[4] http://www.meuse-maas.be/open.asp?t=pubs&id=1316 / http://www.meuse-maas.be/open.asp?t=pubs&id=22

The summary of transnational measures of the international flood risk management plan, published on 22 December 2015, grouped the measures into 3 themes:

- Measures associated with the international and relevant coordination of measures with a transboundary impact (information exchange, consultation, communication)

- Measures associated with the improvement of flood forecasting and warning (multilateral agreement on data exchange and flood forecasting)

- Measures associated with the improvement of systemic knowledge of flood risks (facilitate the exchange of data necessary for the development or improvement of hydrological or hydraulic models, facilitate the exchange of studies based on these models).

Directive 2007/60/EC of the European Parliament and of the Council on the assessment and management of flood risks (FRD), adopted on 23 October 2007, follows the same logic, placing emphasis on prevention, protection and preparedness, taking into account the likely effects of climate change on the occurrence of floods.

The following figure, based on the "Schematic diagram of the flooding mechanism" from the Meuse Flood Action Plan (Progress Report 1995-2002), presents the principles for the genesis of flooding by river overflow which is the subject of the coordination work (Figure 2). It also establishes the link between this action plan and the FRD.

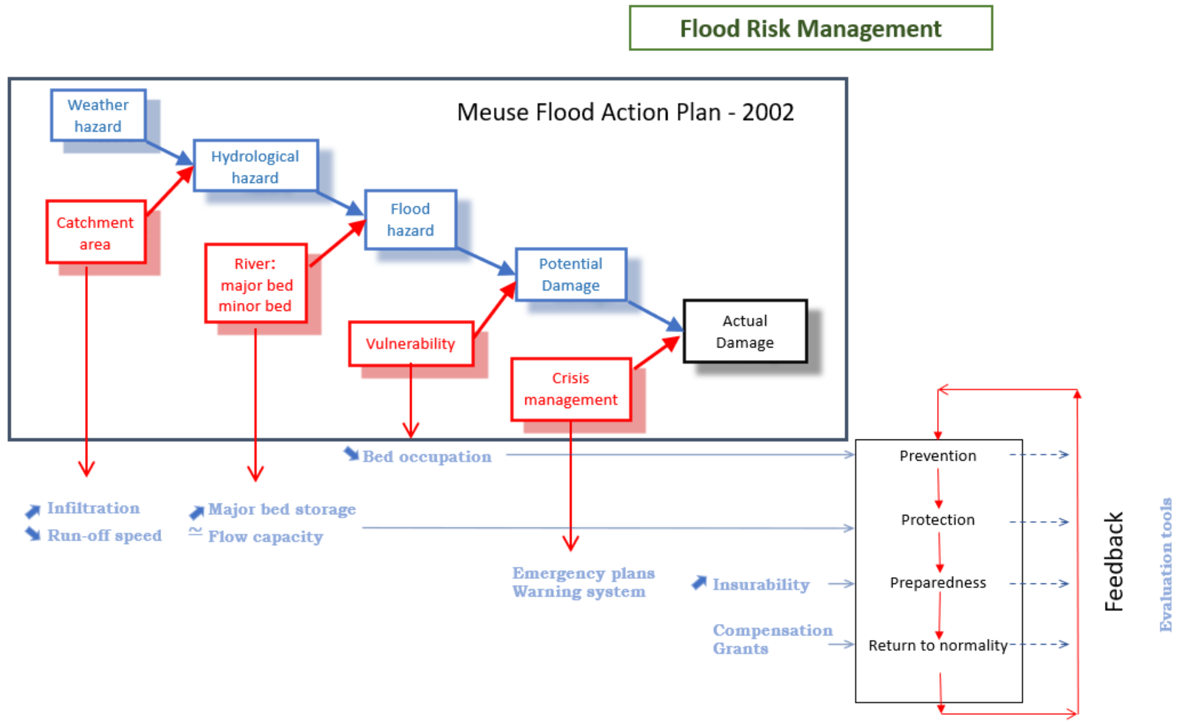


Figure 2: Schematic diagram of the flooding mechanism

1.4 Description of the river basin

The total area of the Meuse IRBD is 34,347 km² with a population of approximately 8.8 million.

The Meuse River rises at an altitude of 384 m in Pouilly-en-Bassigny in France. From its source to its mouth in the Netherlands, it is 905 km long.

The most important sub-basins of the Meuse IRBD are the following tributaries: Chiers, Semois, Lesse, Sambre, Ourthe, Gueule, Rur, Niers, Geer, Dommel and Marcq. Several of these sub-basins are transboundary.

The main characteristics of the basin are summarised in Table 1.

Further details are given in the national and regional reports.

Table 1 : main characteristics of the Meuse IRBD

	Area (km²)	Population (x 1000 inhabitants)	Length of watercourse (km) (catchment > 10 km²)
France	8,919	671	3,305
Luxembourg	75	62	22*
B- Wallonia	12,278	2,285	4,860
B- Flanders	1,601	440	273
Netherlands**	7,500	3,500	2,288
Germany	3,976	1,897	1,567
TOTAL	34,349	8,855	12,315

** This information relates to the length of the surface water body and not the length of the watercourse.*

*** Including 1 transitional and 1 coastal water body*

Table 2 : impact of floods on populations and areas (the areas indicated are areas with a potential significant flood risk)

Impact of floods		FR	LU	WL	FL	NL	DE
Affected population	Frequent flood	4,970	10	32,748	4,231	3,000	4,900
	HQ100	18,760	40	118,915	10,387	107,000	11,630
	Extreme flood	30,800	349	346,879	19,886	501,000	42,520
Affected area (km²)	Frequent flood	56.1	0.17	181.09	60.86	277	57
	HQ100	63.1	0.48	737.84	92.55	891	86
	Extreme flood	71.6	0.93	1,059.36	127.82	1,638	174

The Meuse catchment area covers not only several states and regions, but also several geographical zones.

For the purposes of this report, it has been divided into three zones on the basis of geomorphological characteristics (Map 2).

Zone 1

This area, located south of the Charleville-Mézières-Arlon line, consists of limestone, marl and sandstone. These sedimentary rocks were formed during the Jurassic and Triassic (≈ 150 to 200 million years ago). The layers were tilted during the Tertiary (≈ 50 million years ago). This eventually led to the formation of a declivity cuesta with wide valleys.

The permeability of the rocks varies with the dip of the strata. In this area, the Meuse has a relatively low slope. The Chiers and the upstream part of the Semois also cross this area. The hillsides are generally wooded and the valleys are mostly used for cereal crops and livestock. Apart from the population concentrations around the main towns on the banks of the Meuse (Charleville-Mézières, Sedan and Verdun), the population density in this part of the catchment is relatively low

Zone 2

It includes the territory north of the Charleville-Mézières-Arlon line and south of the Namur-Aachen axis.

In general, this zone consists of low-permeability rocks formed during the Paleozoic (≈ 250 to 600 million years ago). The exception is the Carboniferous karstic limestone (≈ 300 million years ago), which is concentrated in the Charleroi-Dinant-Liège triangle (Condroz). The high plateaus of the Ardennes massif are relatively flat. The Meuse and its tributaries, such as the Sambre, Viroin, Lesse, Ourthe, the downstream section of the Semois and the upstream section of the Rur, have cut furrows in the heightened massif. The tributaries therefore have a steep gradient and the river valleys are generally narrow and deep. Large areas of the Ardennes are covered by forests for timber production. On the plateaus, there is agriculture and extensive livestock farming. This zone is relatively sparsely populated, except for the part located on the Charleroi-Namur-Liège axis.

Zone 3

This zone includes the territory north of the Namur-Aachen line.

On the southern edge of zone 3 (Namur-Maastricht-Aachen triangle), limestone and marl from the Cretaceous period (≈ 75 million years ago) are exposed. This hilly zone covers a large part of the Mehaigne, Geer and Gueule catchment areas. In terms of landscape characteristics, this zone is comparable to zone 1. In the Meuse catchment area in the North of Maastricht, "young", unhardened sedimentary rocks are exposed; the alluvium was largely brought in by the Meuse itself. This zone is almost flat.

Between Maastricht and Roermond, on the border between Flanders and the Netherlands, the Meuse flows freely, giving it a natural dynamic. Navigation is via the Juliana Canal. Further downstream, the Meuse becomes a typical plain river. The Meuse is dammed up along its entire length from the confluence with the Nierce. The Rur, the Nierce and the Dommel also flow here.

Most of this zone is used for agricultural purposes. Along the banks and to the east of the Meuse, there are mainly cereal crops. To the west of the Meuse (province of North Brabant), it is mainly corn and grassland. Especially in the west of this zone, the agricultural land is drained by ditches or other drainage techniques.

The Meuse flows into the North Sea through the Haringvliet flushing locks. Dunes and dikes provide protection against flooding from the sea.

Map 2 : Zoning of the Meuse basin into 3 zones based mainly on geomorphological characteristics

1.5 Climate and hydrology

The climate in the Meuse IRBD is mainly temperate oceanic. Sometimes the continental component dominates with high pressure giving hot, dry summers and harsh, dry winters. But most of the time, the oceanic regime brings depressions and wet and cool weather in all seasons.

The Meuse is a typical example of a rain-fed river. The high flows of the river are usually found in winter and spring. Flow variations can be abrupt and lead to floods lasting from a few days to several weeks.

The recent flood of the Meuse in July 2021 is a good example. In the summer of 2021, a large low-pressure zone in parts of the Ardennes, the Eiffel and southern Limburg caused more than 150 mm of precipitation in 48 hours and up to 275 mm on the Hautes-Fagnes plateau, which corresponds to a return time of 1,000 years. This extreme precipitation event caused large-scale floods of rivers and tributaries in Wallonia (e.g. Vesdre, Ourthe, Amblève, Lesse, Lhomme, Meuse), North Rhine-Westphalia (e.g. Erft, Rur), Rhineland-Palatinate (e.g. Ahr) and in the southern part of the Netherlands (Geul, Roer, Meuse). This resulted in many deaths and considerable damage to buildings and infrastructure.

In most of the Meuse basin, water levels are determined by rainfall, the geometry of the river and the facilities (dams and locks) that have been put in place to allow navigation on the Meuse. Near the mouth of the Meuse into the North Sea, the tides are important and can therefore cause high water levels in the river.

1.6 Floods

Floods are the temporary submergence by water of land that is not normally submerged. This includes floods from rivers, mountain streams and intermittent streams as well as floods from the sea in coastal zones[5].

Only river floods have been the subject of international consultation within the framework of the IMC. Floods from the sea or from estuaries have not been developed because they only concern the Netherlands and are taken into account in the Dutch FRMP.

Other types of floods (e.g. stormwater) have not been the subject of international consultation within the framework of the IMC work because local coordination is more relevant than international coordination on these issues.

1.7 Timetable

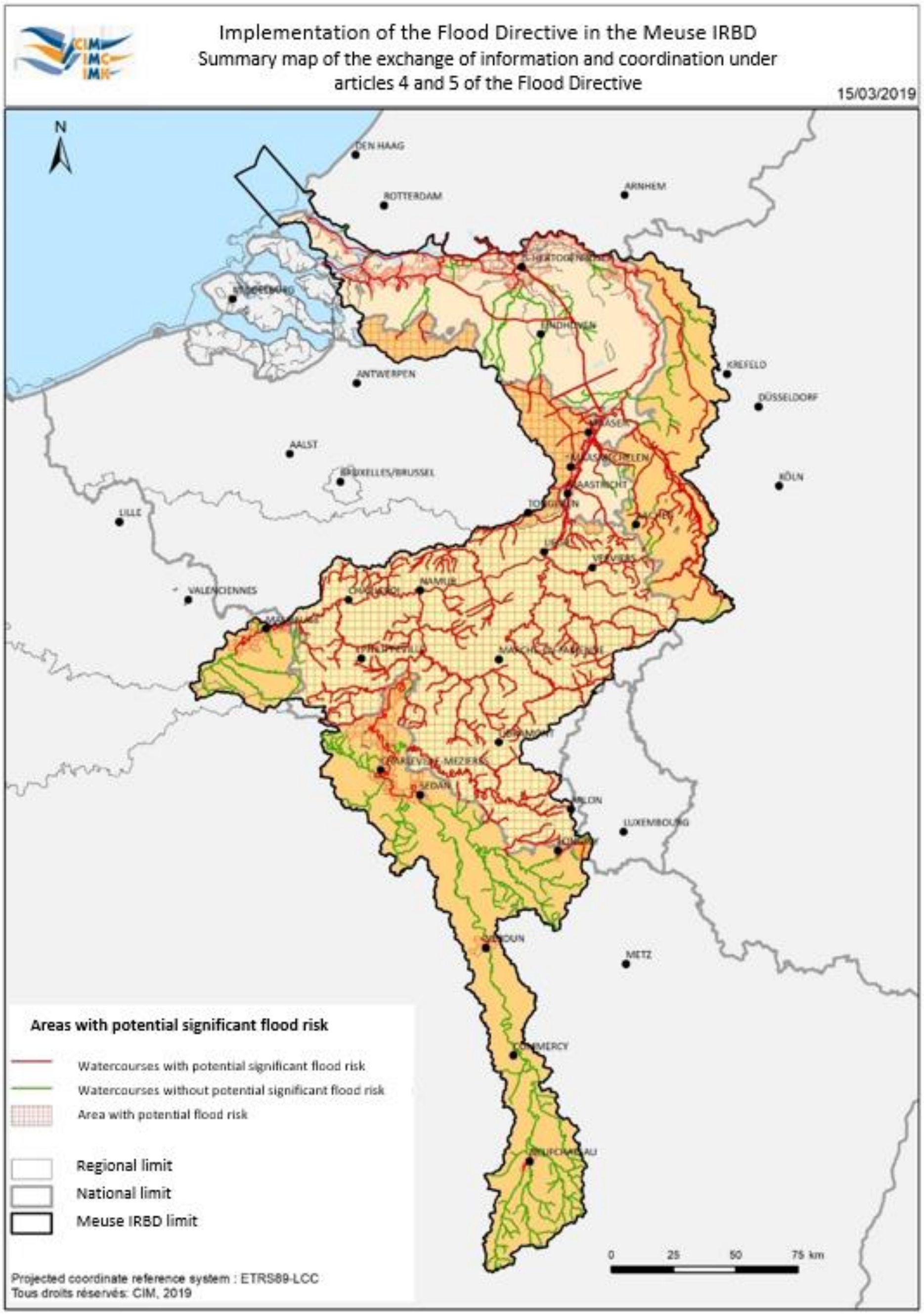
The implementation of the 2nd cycle of the FRD by each State / Region of the IRBD took place in several steps, according to a precise timetable:

- 22/12/2018: carrying out a preliminary flood risk assessment based on available or readily derivable information (art. 4) and/or following the assessment and decisions of the Member States on the use of transitional measures (art. 13, 1)
- 22/12/2019: establishment of flood hazard maps and flood risk maps (art. 6)
- 22/12/2021: publication of a single FRMP coordinated at the level of the IRBD or the FRMPs of the States and regions covering each national or regional portion of the Meuse IRBD and coordinated at the level of the Meuse IRBD (art. 7 and 8).

2. Conclusions of the preliminary flood risk assessment

Map 3, taken from the Minond/18-9def report, distinguishes the States and/or Regions that have carried out a preliminary flood risk assessment in accordance with Article 4 of the Flood Directive. It also shows the zones or watercourses in the Meuse IRBD with a potential significant flood risk.

[5] Article 2(1) of the FRD



Map 3：summary of the exchange of information and coordination under Articles 4, 5 and 13 of the Flood Directive

The table in Annex 1 gives an overview of the transboundary rivers selected or not as areas with potential significant flood risk. The differences between the rivers selected on either side of a border can be explained by the methods used and by issues that may be different in each State or Region.

2.1 France

In 2011, the areas selected in France under Article 4 of the FRD were selected on the basis of an approximate envelope of potential floods (AEPF) as well as local interest to act criteria.

For the 2nd cycle of the Flood Directive, the review of the Preliminary Flood Risk Assessment (PFRA) has led to a minimal revision without recalculation of the AEPF. In addition to the floods by overflowing rivers which were taken into account in the Preliminary Flood Risk Assessment of the 1st cycle through the AEPF, the PFRA of 2018 presents an informative map on the rising water table.

The updating of the list of areas identified under article 5 is based on the expertise of the State services:

- new local knowledge when it exists,

- requests for modification made by the stakeholders in the implementation of the Flood Directive during the concertation process.

Following this process, the modification of the list of areas identified under Article 5 is decided after consultation with the stakeholders concerned and those involved in the Flood Directive implementation process.

2.2 Luxembourg

The preliminary flood risk assessment in Luxembourg is carried out in accordance with Article 4 of the Flood Risk Directive. The methodology is based on the LAWA principles (recommendations for the verification of the preliminary flood risk assessment and flood areas according to the EU Directive (2017)).

All watercourses that have been qualified as areas at risk during the first cycle of the FRMP are analysed. The assessment was based on previous studies to determine the flood risks for Luxembourg (Article 13.1(a) and 13.2)). In addition, two other water courses were included in the risk analysis.

The risk analysis is based on the inventory of potential assets to be protected in the flood areas (ten-year flood, one-hundred-year flood, extreme flood). The assets to be protected can be divided into different categories, namely the environment, people and material damage. If there is a defined critical number of assets to be protected in the flood area, the watercourse is classified as a risk zone.

2.3 Wallonia

For the first Flood Directive implementation cycle, Wallonia applied Art. 13 since it already had at the time the flood hazard map (version 1 of 2007) indicating that its entire territory was impacted by flood risks.

For Cycle 2, Wallonia carried out the preliminary assessment of the Flood Directive as referred to in Art. 4.

It therefore selected historical flood events that had a significant impact at the time they occurred and that have a real probability of recurring in the future. In Wallonia, the pivotal year chosen is 1993. Thus, all historical floods prior to 1993 and considered as significant are reported in the preliminary assessment in the form of a listing including the date of the event and a brief description of the event. Historical floods after 1993 are described in much greater detail, particularly with regard to the analysis of the negative consequences of these events. In total, 12 post-1993 flood events have been selected for in-depth analysis.

Wallonia has also analysed future floods and their potential impacts. This analysis responds to Article 4.2 (d) of the Directive. As required by the Directive, the influence of climate change as well as long-term territorial development are taken into consideration. In order to analyse the potential negative consequences of future floods, the map layer representing the extent of the flood areas for the Qextreme scenario has been cross-referenced with the main urban planning tool in Wallonia, at regional level, i.e. the Sector Plan. The main purpose of the Sector Plan is to define land use at a scale of 1:10,000, in order to ensure the harmonious development of human activities and to avoid the excessive use of land. This choice therefore fully integrates long-term territorial development. Furthermore, as explained above, the use of the extreme scenario of flood zones (Qextreme) integrates climate change and is intended to become the scenario with a return period of 100 years by 2100. In the case of the runoff concentration axes, a buffer zone of 20 metres around the axis was applied in order to perform the analysis.

The preliminary assessment led to the following result for Wallonia: all the communes of the Walloon Region, i.e. the 262 communes, have already experienced at least one flood event since 1993, either by river overflow or by runoff. The 15 sub-catchment areas of Wallonia are therefore considered as areas at potential flood risk.

2.4 Flanders

In contrast to the first cycle (art. 13.1), Flanders carried out the preliminary flood risk assessment in accordance with art. 4. The preliminary flood risk assessment was based on:

1. an analysis of the floods that have actually occurred (historical analysis) based on data from the Disaster Fund and the insurance companies, and

2. on an analysis of potential future floods, namely modelled floods (predictive analysis).

As Flanders has flood modelling covering almost the entire territory, the preliminary flood risk assessment will be based mainly on predictive analysis. The flood hazard maps and the LATIS tool were used to determine the economic, social, ecological and cultural impact for 3 flood scenarios (high probability, medium probability and low probability). The historical analysis was mainly used to validate the results.

Autonomous developments such as climate change have been taken into account by reviewing general trends and assessing the impact on the results of current situation analyses. The main consequence of climate change is an increase in the probability of floods over time, while socio-economic growth increases the severity of the consequences of a flood.

The predictive analysis shows that almost all Flemish municipalities are confronted with a significant flood risk. The historical analysis confirms this conclusion. Moreover, it appears that the flood risk in Flanders may increase significantly as a result of climate change and changes in land use. Therefore, it was decided to identify the entire Flemish territory as a zone with a potential significant flood risk again. Within the framework of the integrated approach to water management in Flanders, it was decided to select the 11 river basins (10 in the Scheldt catchment area and 1 in the Meuse catchment area) as flood risk management areas, thus continuing to ensure the integration of the FRMPs into the basin management plans. Significant sources of floods are river floods (including naturally fed canals), marine floods and stormwater floods (including the deficient capacity of urban and rural stormwater drainage systems). Floods due to failing infrastructure or from drainage systems have been excluded due to their limited impact and unpredictability. Significant floods due to groundwater can only occur in Flanders in the mining subsidence zone. The Limburg Conversion Company ensures that groundwater is continuously drawn off in these zones, thus controlling the flood risk.

2.5 Germany

The recommendation 'Procedure for the preliminary flood risk assessment under the Directive on Flood Risk Assessment and Management' developed by the LAWA working group forms the sole basis for the development of the preliminary assessment in Germany.

In accordance with these recommendations, all relevant available or readily derivable information was used to draw conclusions regarding the potential significant flood risks. The harmonised working method for Germany in the LAWA working group is applied to the rivers in the Meuse catchment area in North Rhine-Westphalia on the basis of the results of the preliminary flood risk assessment (PFRA) 2011.

This approach was based on the river network that also forms the basis of the WFD (catchment area of more than 10 km²), i.e. rivers that have experienced floods in the past and for which there is still a risk of future floods with significant negative consequences according to expert opinion. All major rivers and tributaries were included in the approach.

he preliminary risk assessment considered the following different types of floods as significant on the basis of Art. 2, para. 2 of the FRD: *Fluvial Floods* and *Flooding from Groundwater* in alluvial zones. *Pluvial floods* caused by heavy precipitation are not defined as a significant risk, but as an ordinary risk, as these events can occur anywhere and at any time. *Flooding from Artificial Water-Bearing Infrastructure* is not considered significant.

The whole process was supervised by water management experts and the results were considered definitely plausible.

The report on the "Review and update of the preliminary risk assessment under the second cycle of the EU FRD and update of watercourses at risk" of December 2018 contains a text part with a description of the criteria of importance and the procedure as well as four annexes with detailed information. The report and maps can be found at:

https://www.flussgebiete.nrw.de/system/files/atoms/files/hwrm_nrw_vorlaeufige_bewertung_final.pdf

2.6 Netherlands

For the 1st cycle, the Netherlands applied the transitional provision of the Directive (Art. 13, 1b) and produced maps for the whole territory. For the 2nd cycle, the Netherlands carried out a preliminary flood risk assessment as referred to in article 4 of the Directive. Both past floods and possible future floods are addressed in this preliminary assessment. Historical floods with significant effects have been listed in the Netherlands. Model calculations and the knowledge of water managers are used to determine the potential negative consequences of future floods. This approach is followed both for the situation where land is protected against floods by a storm surge barrier (dunes, reservoirs, locks, dams, dikes) and for the situation where water can freely enter the land. In the first situation, there is a potential significant flood risk for areas protected by primary storm surge barriers against floods from the main river system (such as the North Sea, the Rhine and the Meuse). National standards apply to these protective structures. Areas protected against floods from regional rivers by (secondary) protective structures subject to regional standards also have a potentially significant flood risk. In the second type of situation, there is also a range of rivers that may represent a potential significant flood risk. Floods from transboundary regional rivers fall into this group. The main course of the Meuse and the transboundary waters have been coordinated with Germany, Wallonia and Flanders.

A first analysis was devoted to floods that can result directly from intense precipitation (pluvial floods) without surface water intervention. A follow-up study is needed before conclusions can be drawn from this first study. Floods from sewage systems and groundwater overflow do not constitute a potential significant flood risk.

3. Exchange of information prior to the elaboration of flood hazard and flood risk maps

In accordance with the Flood Directive, the states of the Meuse IRBD have produced flood hazard maps and flood risk maps. The exchange of information required for this purpose for the transboundary rivers took place during the bilateral meetings and was the subject of an IMC summary (Minond/19-16def). These exchanges concerned the flows used by the States for the 3 flood scenarios to be mapped.

3.1 France

In France, there has been no update of the maps made in the first cycle of implementation of the FRD.

The maps and presentation reports are available at the following links:

- http://www.grand-est.developpement-durable.gouv.fr/cartographie-des-surfaces-inondables-des-tri-a15506.html (Meuse catchment area)

- http://www.hauts-de-france.developpement-durable.gouv.fr/?Cartographie-des-TRI (Sambre catchment area)

For the record, the following areas with a potential significant flood risk are concerned by the preliminary exchange (art. 5 of the Flood Directive):

- the Chiers at Longwy on the border with Luxembourg and Belgium (Wallonia)

- the Meuse between Sedan and Givet at the border with Belgium (Wallonia)

- the Sambre from Leval to Jeumont at the border with Belgium (Maubeuge flood risk area)

3.2 Luxembourg

Luxembourg has started to update the flood hazard maps and flood risk maps for the new rivers of the Meuse basin selected in 2018 (Chiers).

The draft maps are available on the website: https://www.geoportail.lu/.

The water lines were created from 1D and 2D hydraulic models.

The portion of the Chiers located outside Luxembourg territory has not been mapped.

However, these are not the final maps, but only a draft that has been made available during the public consultation for comments. After evaluation of these comments, the maps will be finalised and published on the Geoportal.

3.3 Wallonia

The elaboration of the maps of flood hazard and flood risk is carried out on the basis of a methodology approved by the Walloon Government and in coherence with the realisation of the flood hazard map, a reference tool for providing advice in terms of delivering permits in Wallonia.

The flood hazard maps produced for Wallonia concern floods due to river overflow and those due to runoff. They are drawn up on a scale of 1/10000 for the following scenarios:

- T025 scenario with a 25-year return period;
- T050 scenario with a 50-year return period;
- T100 scenario with a 100-year return period;
- T_extr scenario with extreme return period.

For the floods by river overflow component of these maps, different sources of data are used:

- hydrological statistics
- results of hydraulic modelling
- field observations;
- the results of the hydropedological method;
- the geological layer of the Holocene.

This has enabled the delineation of flood areas. Climate change is taken into account through the extreme scenario shown on the flood hazard maps.

For the runoff flood component of these maps, the data sources used and fed into a hydrological model are:

- digital field model;
- soil types and land use;
- local rainfall statistics.

This allowed the generation of runoff axes and the calculation of peak flows.

Given the different data sources available, it was necessary to define integration rules in order to establish consistent and reproducible maps. For this purpose, automated procedures were developed.

The flood risk maps consist of the flood hazard areas for each scenario and the risk receptors (issues) identified in these areas. The risk receptors or issues are human, economic, environmental and heritage.

Prior to their publication and approval by the Walloon Government, these maps are subject to an environmental impact assessment and a public enquiry.

Exchanges of information prior to this update have been undertaken with the neighbouring Regions / States, in accordance with Annex 1.

3.4 Flanders

Flanders develops flood hazard and flood risk maps for floods that can have a range of different origins:

- fluvial floods, which are floods caused by rivers, including naturally flowing channels
- Coastal floods, floods of maritime origin
- Pluvial floods, which are floods caused by intense rainfall, including the capacity deficit of urban and rural stormwater systems

Flood hazard maps are maps that describe the "physical properties" of floods, such as flood outlines, water heights and flow speeds.

Flood risk maps are the maps that map the consequences for humans, ecology, economy and cultural heritage. The Flemish risk maps include:

- the indicative number of inhabitants potentially affected,
- the type of economic activity in the potentially affected area,
- polluting installations and protected areas potentially affected,
- particularly vulnerable establishments (hospitals, care facilities, etc.),
- linear infrastructure; roads, railways and bus lines,
- critical infrastructures (energy and water supply, fire brigade, civil protection, etc.).

In addition, 4 types of damage and risk maps are produced using a specific GIS tool:

- Economic impact
- Social impact
- Ecological impact
- Impact on cultural heritage

The maps are developed for both the current climate and the future climate up to 2050. All maps are made available through a portal.

3.5 Germany

The "Recommendations for the Preparation of Flood Hazard Maps and Flood Risk Maps" developed by the Federal/Länder Working Group on Water (LAWA) form the uniform basis for the preparation of flood hazard maps and flood risk maps in Germany. Following these recommendations, largely uniform maps were produced in terms of content and design, which fit together across Länder borders.

The maps in North Rhine-Westphalia refer to floods caused by surface waters. In addition to the flood hazards (flood extent), the flood-related adverse effects are to be depicted in them. For this purpose, the following are presented:

- the (indicative) number of inhabitants potentially affected,
- the type of economic activities in the potentially affected area,
- installations as defined in Annex I of Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (IED Directive), and potentially affected protected areas as defined in Annex IV(1)(i), (iii) and (v) of Directive 2000/60/EC,
- impacts on cultural heritage.

The maps are coordinated with the expert public (districts and municipalities, water associations) prior to publication.

3.6 Netherlands

For the primary flood protection facilities, the Netherlands switched in 2017 from a standardisation based on the probability of occurrence of water levels to a standardisation based on the probability of flooding. In the second cycle of the FRD, the Netherlands chose to develop maps for protected areas based on currently available flood probabilities. This is in contrast to the first cycle of the FRD, when the standard probability of occurrence of water levels was used for protected areas. The reason for this change is that the maps produced under the FRD should make citizens aware of the risk to which they are currently exposed.

Based on the preliminary risk assessment and the identification of areas with a potential significant flood risk, the Netherlands draws up maps representing floods from rivers and lakes (fluvial), from the coast (sea water) and from shipping channels (Artificial Water-Bearing Infrastructure).

The entire coastline of the Meuse basin lies within the Netherlands and the influence of the North Sea water levels, including possible sea level rise, on the water levels in the Meuse and Rhine is limited to the Netherlands.

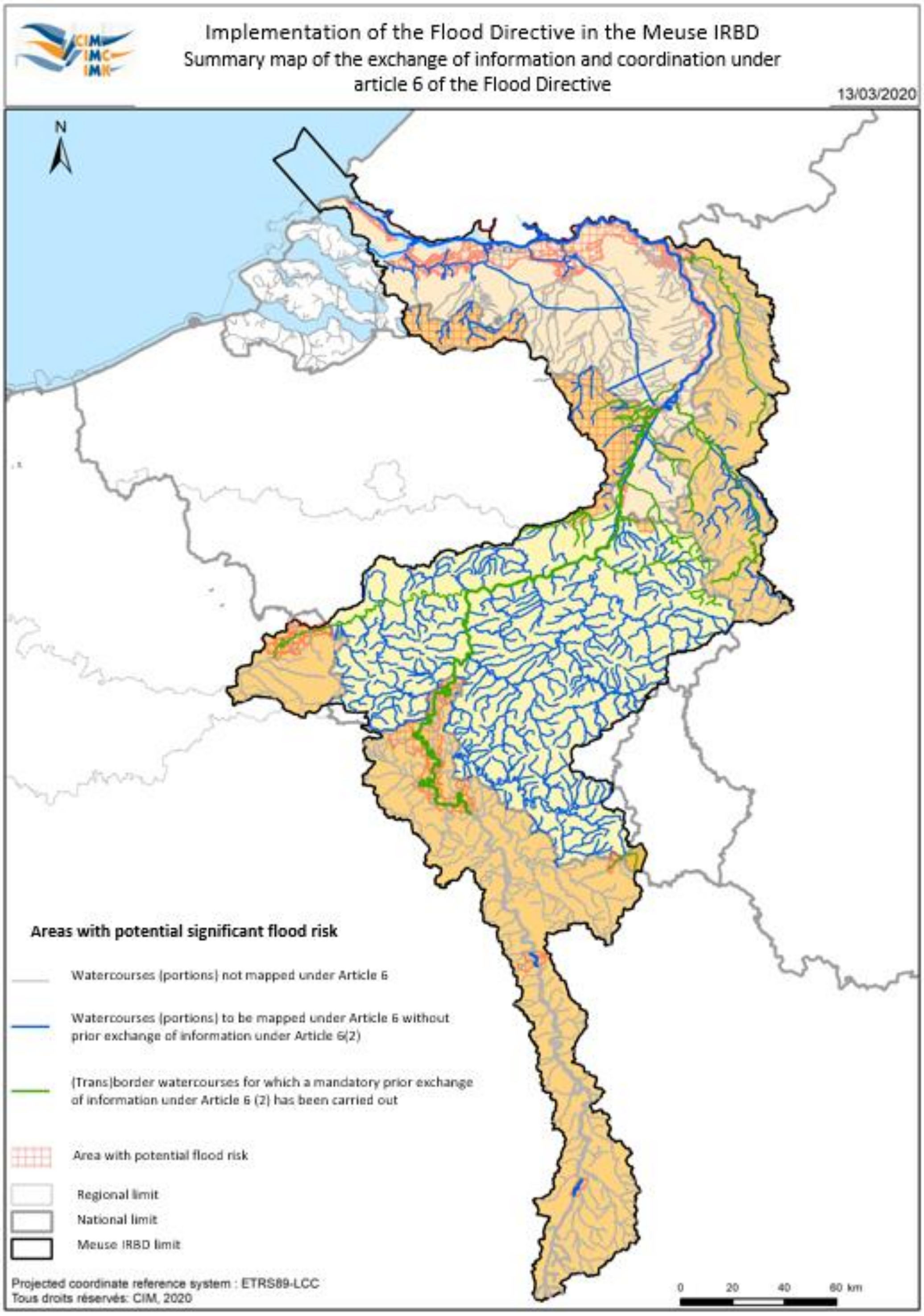
Based on the flows calculated with KNMI climate scenarios, extreme flows will increase and, for example, a 100-year flood scenario will occur more often in the future. The Netherlands takes climate change into account when taking flood risk management measures.

The table in Annex 2 gives an overview of the (trans)boundary rivers with a potential significant flood risk in the Meuse IRBD. In addition, the table shows the hydrological assumptions on which the flood hazard maps of these rivers are based, for the different flood scenarios[6].

This table documents the coordination for drawing up the flood hazard maps in the Meuse IRBD.

Map 4 gives an overview of the exchange of information prior to the drafting of flood hazard maps.

[6] Article 6(3) of the FRD



Map 4: Summary of the exchange of information under Article 6(2) of the FRD

4. Principles for objectives and measures

For the objectives and measures included in this IFRMP, a clear distinction is made between the strategic level, the general level of synthesis of the Meuse IRBD and the operational level of implementation of the States/Regions members of the IMC.

4.1 Provisions of the Directive on the assessment and management of flood risks (FRD)

The objectives set for flood risk management in this IFRMP for the Meuse IRBD must take into account the principles mentioned in the FRD and the recitals that led to its adoption.

A concerted and coordinated basin-wide approach to flood risk management should contribute to reducing the risk of flood damage[7].

Floods throughout the EU are diverse in nature and the damage caused by them can vary from one State and region to another. Therefore, the objectives of flood risk management are set by the Member States themselves and be based on local and regional circumstances[8]. This is in line with the principle that each state is responsible for setting objectives on its territory.

The roof report is based on national and regional contributions. The focus is on transboundary aspects, solidarity and measures with a transboundary impact.

The FRMP focuses on prevention, protection, preparedness and return to normality.

The solidarity highlighted by the FRD is based on the following two principles:

- Member States shall not include measures that may have negative transboundary impacts unless they have been coordinated between the Member States concerned and an agreed solution has been found.
- Member States should be encouraged to seek a fair sharing of responsibilities where flood risk management measures are jointly decided for the common benefit[9].

4.2 Objectives at strategic level

The strategic objective of the FRD is to reduce the potential negative consequences of a flood on human health, the environment, cultural heritage and economic activity.

Flood risk can only be managed effectively if the risk is actually known, if it can be assessed in practice, if the necessary preventive measures are taken in time and if the right response is made quickly in a crisis situation.

Flood risk management must be sustainable and integrated with other European policies. The management strategy to be achieved must be environmentally sustainable, economically balanced and socially acceptable.

To this end, flood risk management must be based on the key principles of shared responsibility, solidarity and proportionality, and synergy with other EU policies.

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[7] Recitals 3, 5, 6, 13, 15 and 17 of the FRD
[8] Recital 10 of the FRD
[9] Article 7 (4) and recital 15 of the FRD

4.2.1 Efficient sharing of responsibilities, based on subsidiarity

There is no absolute safety in the case of natural disasters (e.g. extreme floods) and it is therefore necessary to learn to live with certain remaining risks.

The aim is to find the most relevant level of public action, so that what can be done more effectively at local level is not done at a higher level. This principle of mobilising actors at the most relevant level should also allow the specificity of the territories to be taken into account.

The objective is also to make a large public aware of the flood risk and to anchor this awareness in people's minds. Added to this is the preparation of disaster management activities in flood situations and the restoration/recovery after a flood.

4.2.2 Solidarity against flood risks

Solidarity between actors is strengthened and affirmed, in particular in order to avoid the effects of floods being displaced onto other territories by protection measures taken by one party without prior joint agreements, and also to try to distribute responsibilities fairly when, in the context of flood risk management, measures are taken jointly for the common benefit.

4.2.3 Proportionality of actions: set a programme of priorities based as far as possible on a cost-benefit analysis

The FRMP establishes priorities between the measures to be implemented, taking into account the available human, technical and financial resources of all the actors concerned, on the one hand, and the expected results and benefits, on the other.

The objectives must be differentiated according to the frequency of the events under consideration: each aspect of an objective and/or measure must be defined considering the relevance in terms of frequency and scale of the event.

4.3 Transnational objectives of the Meuse IRBD

• Objective 1: International coordination and relevant coordination of measures with transboundary impact;

• Objective 2: Improved flood forecasting and warning;

• Objective 3: Improved systemic knowledge of floods.

5. Summary of transnational measures

5.1 Measures related to Objective 1: International and relevant coordination of measures with transboundary impact

All Contracting Parties to the IMC agree to (from the IFRMP 2015):

- exchange information on new national policies on flood risk prevention;
- identify planned measures that are likely to have an influence in a State/Region located in the Meuse IRBD;
- consult with the party (parties) concerned prior to the formal adoption of draft measures that may have a negative impact;

- communicate the conclusions of this consultation to the IMC as a concrete result of the international coordination provided for in Article 8 of the FRD;
- record the exchange of information and the conclusions in an IMC report.

To this end, the measures in the European list have been assessed within the IMC to determine the types of measures that have a potential transboundary effect and the desired form of coordination (see Annex 3).

The table presents for each type of measure the desired form of international coordination or exchange within the Meuse IRBD:

- measure or type of measure for which coordination or exchange of information is not required;
- measure or type of measure for which an exchange of information is required;
- measure or type of measure for which multilateral coordination is required either according to the provisions of the FRD or because of the added value of such coordination.

This classification will form the basis for the measures to be considered at the level of the Meuse IRBD in the framework of art. 7(4) in this second IFRMP.

5.2 Measures related to Objective 2: Improving flood forecasting and warning

Flood forecasting and warning is a valuable means of reducing flood damage by providing timely safety for people and property potentially at risk.

However, flood forecasting or warning requires real-time measurements of hydrological conditions (water levels and/or flows) on the rivers concerned and their tributaries.

Hydrological measurements are combined with meteorological measurements to produce flow forecasts.

The States/Regions of the Meuse IRBD are all the more dependent on the availability of real-time measurements of hydrological conditions as they are located on the downstream parts of the rivers, as the evolution of flows depends on what is happening upstream.

The monitoring of these hydrological conditions is ensured by the networks of measuring stations whose maintenance, repair, calibration, replacement or even development represent a significant financial cost for the States / Region concerned.

A description of the organisation of the flood forecasting services in the Meuse IRBD is available in Annex 7.

The development or improvement of flood forecasting or warning tools in the States/Regions of the Meuse IRBD depends on the availability of historical and real-time measured hydrological data.

In this context, the services responsible for hydrometry and flood forecasting or warning in the States/Regions Parties to the IMC concluded on 19 July 2017 a multilateral agreement for the exchange of hydrological data and forecasts (heights, flows) based on the following conditions/principles:

- he maintenance of the current organisation of flood warning and forecasting
- free exchange and no additional costs
- reciprocity of exchanges
- non-dissemination of information to third parties.

The flood forecasting services of the Meuse IRBD met on 16 and 17 September 2021 and proposed to update the list of stations for which data are exchanged. In addition, the French delegation wished to receive the hydrological forecasts produced by the Dutch services for the French sub-basins and the Flemish delegation was in favour of receiving the forecasts produced by the French services at Chooz. Finally, it was proposed that the Luxembourg and French delegations cooperate in order to benefit from flood forecasts at the Pétange station on the Chiers. All the proposals resulting from this seminar are listed in Annex 8.

5.3 Measures related to objective 3: Improving systemic knowledge of flood risks

The meteorological conditions that cause the overflow of the rivers of the IRBD do not know the administrative borders of the States or Regions party to the IMC.

Rather, they create a dependency between upstream and downstream and make international cooperation necessary, because this is the only way to develop instruments for flood analysis and forecasting, based on solid technical bases (flood hazard maps, flood risk maps...), which allow, for the present and the future, in view of the expected climate change, the management of crises on the one hand, and the setting of priorities and technical, financial and political decisions in the field of flood risk management on the other hand.

In this context, the States/Regions party to the IMC agree to:

- facilitate the exchange of validated topographic, pedological, meteorological and hydrological data (if available) necessary for the development or improvement of hydrological or hydraulic models;
- facilitate the exchange of studies carried out on the basis of these models in order to compare their results;
- these exchanges must respect the property rights linked to these data, models and results;
- these exchanges must not generate additional costs for the State / Region from which these data, models and results are produced.

In this context, it should also be mentioned that the University of Liège, in collaboration with the Dutch knowledge institute Deltares, regularly organises an international symposium on the Meuse, which deals with hydrology, among other things.

6. Cost-benefit analysis

Cost-benefit analyses are carried out by each state/ region. The methods used vary between states/regions. There is no common method for the Meuse basin.

For most states/regions of the Meuse IRBD cost-benefit analysis is only carried out for structural measures.

7. Evaluation of progress in achieving the objectives

In order to monitor the status and progress of the implementation of the measures in the Meuse IFRMP, the IMC states/regions have agreed on a number of monitoring indicators which are listed in the following paragraphs.

WG H of the IMC is responsible for monitoring the implementation of the IFRMP.

7.1 Monitoring indicators for Objective 1: International coordination and relevant coordination of measures with transboundary impact

7.1.1 New national policies on flood risk management

a) France

Since the FRMP 2016 - 2021 was drawn up, there have been regulatory changes in French law concerning flood risk management:

- The recognition of a specific competence relating to the management of aquatic environments and protection against floods (GEMAPI) was introduced into the environment code by the so-called "MAPTAM" law of 27 January 2014. This text shifted the exercise of this competence to the municipalities and public establishments of inter-municipal cooperation. Several laws/decrees have accompanied the implementation of this so-called "GEMAPI" competence.
  Among these, the decree of 12 May 2015, known as the "dike decree", defines two types of flood protection works: "diking systems" and "hydraulic works". The competent structure for flood protection must first define the area to be protected and the level of protection.

- Systematic consideration of the failure of diking systems and the development of failure scenarios for structures (deletion or breach) as part of the preparation of risk prevention plans (PPR) by the decree of 5 July 2019.

b) Wallonia

In December 2016, the Walloon Government approved amendments to the regulatory part of Book II of the Environment Code, containing the Water Code. Including art. 277, highlighting the priority of infiltrating rainwater on the plot in the framework of the general regulation of urban wastewater treatment.
A new decree on watercourses came into force in Wallonia on 15 December 2018. This new decree repeals the law of 28 December 1967 on non-navigable watercourses and the law of 5 July 1956 on the water authorities (Wateringues).

The objective of this decree is to establish a global and transversal legal framework for the integrated, balanced and sustainable management of Walloon waterways. This management must henceforth take into account the multifunctional character of watercourses, i.e. reconcile their hydraulic, ecological, economic and socio-cultural functions.

In this perspective, Wallonia has equipped itself with a planning and coordination tool for watercourses. These are the PARIS (Programmes d'Actions sur les Rivières par une approche Intégrée et Sectorisée= Action Programmes on Rivers by an Integrated and Sectorised Approach). Each PARIS sector is assessed and the managers determine and prioritise the issues (hydraulic, economic, ecological and socio-cultural). They assign management objectives and then plan the actions to be carried out to achieve these objectives. One PARIS per sub-catchment area is established and these bring together in a single document all the information and planned interventions on the watercourses for a period of 6 years. The first PARIS period also covers the period 2022-2027.

c) Flanders

On 3 April 2020, the Flemish Government adopted the third policy note on water. This policy note outlines the Flemish Government's vision for an integrated water policy and contains an overview of the main water management issues. The vision text of the third water policy paper is structured around 3 strategic objectives, which cover 6 issues and are then translated into a series of more specific objectives that indicate what the Flemish Government wants to achieve and how. The 2nd strategic objective concerns the aim of multi-level water security and drought risk management through prevention, protection and preparedness. The third issue under this strategic objective concerns the sustainable reduction of flood risks

The objectives of sustainable flood risk reduction are as follows:

- mitigate the effects of climate change
- limit the damage caused by floods
- raise awareness of flood risk and encourage action
- giving water the space it needs
- reducing surface runoff of water and sediment

d) Germany

As part of the implementation of the EU Flood Risk Management Directive, the state-specific flood risk management plans (FRMPs) first drawn up in 2015 will be updated by December 2021. However, in contrast to the 1st cycle, coordinated FRMPs between the federal states, i.e. linked to river basins, will be developed in the 2nd cycle. Consequently, the interests of North Rhine-Westphalia are also taken into account in the updating of the national FRMPs.

The preparation of these plans is coordinated by the respective offices of the river basin community (Flussgebietsgemeinschaft - FGG) with the participation of the federal states concerned. The German Meuse River basin is located exclusively in North Rhine-Westphalia (NRW). In this respect, the district government of Cologne is responsible for the preparation of the Meuse FRMP, without any coordination with the other federal states. However, the Meuse FRMP is being drawn up in close accordance with the specifications agreed at national level and is based on the work on the Rhine FRMP in particular.

There is a regular exchange with the Netherlands through the German-Dutch Standing Commission on Border Waters and a flood working group in which transboundary issues are discussed. In addition, the Netherlands and Wallonia participate via public participation in the preparation of the FRMP by the district government of Cologne.

e) Netherlands

Since 1 January 2017, the Netherlands have new safety standards for primary flood defences, which have been incorporated into the Water Act. The aim of these new standards is to achieve a basic protection level of 1/100,000 in the Netherlands in areas protected by primary defences by 2050. This means that in 2050, the risk of death from flooding in these areas may not exceed 1/100,000 per year for each individual.

The new standards are based on a flood risk approach. This means that not only the flood probability is taken into account, but also the possible consequences (damage, losses) of a flood. The higher the potential consequences, the higher the flood defence standards. By 2050, all flood defences in the Netherlands must meet these new legal standards. The standards are expressed in terms of the maximum allowable flood probability per dike section. The standards are divided into nine classes ranging from 1/100 to 1/1,000,000.

In order to comply with the new flood protection standard in 2050, most of the flood defences in the Netherlands will have to be raised and strengthened. The programming of the reinforcement of flood defences is done in the framework of the Flood Protection Programme (HWBP). In this programme, the Rijkswaterstaat and the water boards work together to make the Netherlands safe from water-related risks in 2050.

The Integrated River Management (IRM) programme was launched in 2019. This programme will establish an integrated vision for the river area. With this programme, the Netherlands want to work towards sustainable river management. In the coming years, a new policy will be developed for the hydraulic capacity and land use of rivers.

7.1.2 Measures identified that are likely to have an influence in another State / Region located in the Meuse IRBD and results of multi- or bilateral consultations between States / Regions party to the IMC on measures likely to have a negative influence in another State / Region located in the Meuse IRBD.

Table 3 : number of measures from the 1st FRMPs identified as likely to have an influence in another State / Region located in the Meuse IRBD

Aspects of flood risk management		FR		WL		VL		NL		DE		Total	
		Ongoing	Concerted	Ongoing	Concerted	Ongoing	Concerted	Ongoing	Concerted	Ongoing	Concerted	Ongoing	Concerted
Prevention	flood risk modelling and assessment [(a)]	0	1	1	1	0	0	1	0	0	0	2	2
	flood vulnerability assessment	0	0	0	0	0	0	0	0	0	0	0	0
	maintenance programmes or policies [(b)]	0	0	1	1	0	0	0	0	0	0	1	1
Protection	Natural flood management / runoff and catchment management	0	0	0	0	0	0	0	0	0	0	0	0
	Water flow regulation	1 (c)	0	1 (c)	0	1 (d)	0	1 (d)	0	0	0	4	0
	Channel, Coastal and Floodplain Works	0	0	0	0	3 (e)	0	3 (e)	0	0	0	6	0
	Surface Water Management	0	0	1	1	0	0	0	0	0	0	1	1
	Other measure	0	0	0	0	0	0	0	0	0	0	0	0
Preparedness	Flood Forecasting and Warning [(f)]	1	1	1	1	1	1	1	1	1	1	5	5
	Emergency Event Response Planning/ Contingency planning	0	0	0	0	0	0	0	0	0	0	0	0
Recovery & Review	Lessons learnt from flood events	0	0	0	0	0	0	0	0	0	0	0	0
	Total	2	2	5	4	5	1	6	1	1	1	19	9

(a) Flood risk modelling and assessment (FR- WL): Chiers, Messancy, Gueule in progress (WL-NL); Houille achieved

(b) Maintenance programmes or policies (WL): meeting via the River Contracts

(c) Flow regulation (WL): Interreg project Chiers, Messancy

(d) Flow regulation (NL-VL): This concerns the Thorn-Wessem measure. This measure shares a border with Flanders. Thorn-Wessem is a dike reinforcement project, in which the existing water storage capacity is maintained despite the planned dike reinforcement.

(e) Channel, Coastal and Floodplain Works (NL-VL):

• In recent years, the Grensmaas project has been implemented in the Netherlands. The Grensmaas project includes the widening of the river, the strengthening of the dikes and the relocation of the dikes. To a large extent, these interventions have already been completed. The coordination of the Grensmaas project took place within the Flemish-Dutch Bilateral Meuse Commission.

• The new Dutch dike standards (2017) will result in a large number of dike sections in the Netherlands being raised over the next few decades (to be completed by 2050 at the latest). This will result in higher water levels on a large part of the Meuse River in the area shared by the Netherlands and Flanders. To compensate for this, the Netherlands will implement a number of so-called system operation measures (increasing water storage or flow capacity), which will limit this effect of rising water levels. This issue was discussed in the bilateral Flemish-Dutch Meuse Commission.

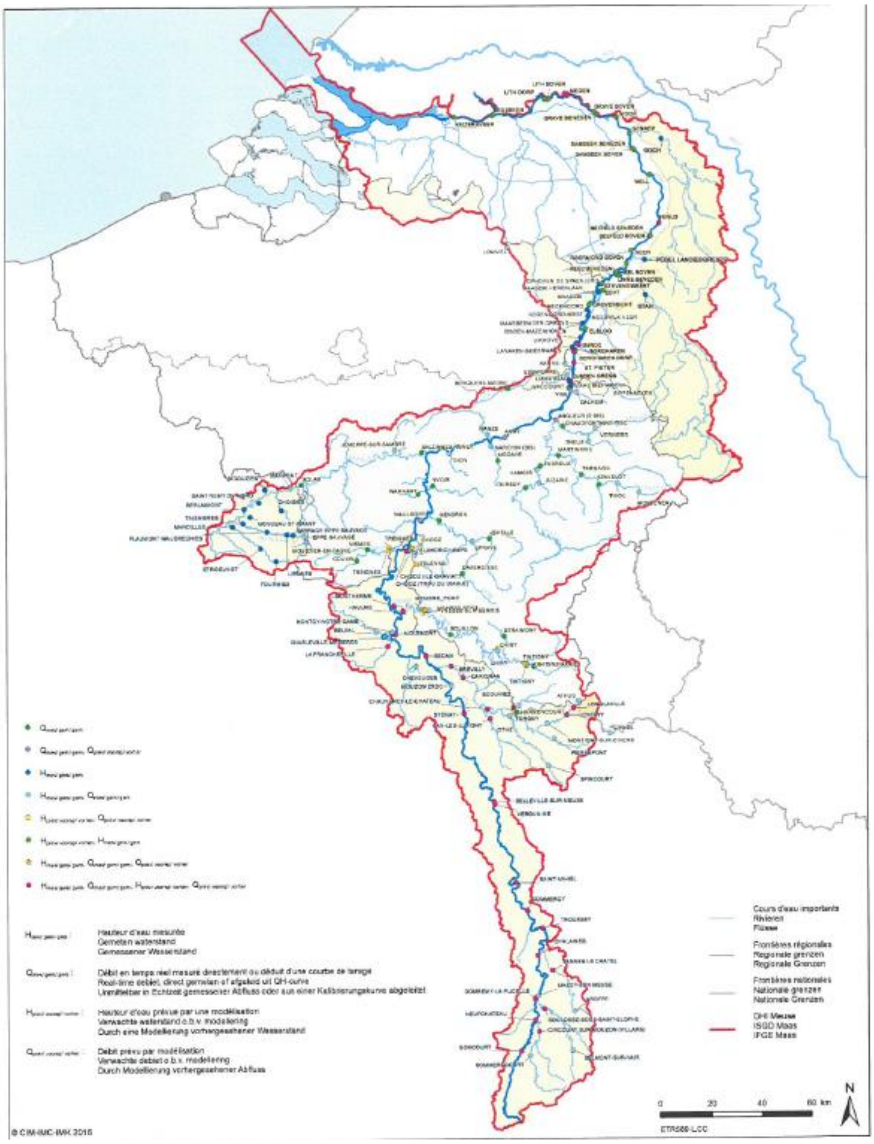
• This measure concerns Thorn-Wessem. The route of the Dutch dike to be reinforced is connected to the route of the Flemish dike. The connection will be subject to consultation. In addition, coordination is underway on the stability of the so-called "Koningssteendam" dam on the Dutch-Flemish border, which is important for the hydraulic load of the Dutch flood defence downstream near Thorn-Wessem.

(f) Flood forecasting and warning: data and flow exchange (Agreement on data exchange and flood forecasting within the Meuse IRBD).

7.2 Monitoring indicators for Objective 2: Improving flood forecasting and warning systems

Objective 2 is monitored using the following parameters:

- results of the agreement on data exchange and flood forecasting within the Meuse IRBD that came into force on 19 July 2017 (e.g. number, location and type of observation or reporting stations concerned by data exchange);



Map 5: stations of the agreement on data exchange and flood forecasting within the Meuse IRBD

Table 4 : number of monitoring and flood forecasting stations within the Meuse IRBD

	Water level	Flow	Water level forecasting	Flow forecasting
Luxembourg	1	1	0	0
France	59	42	33	33
Wallonia	28	52	0	9
Flanders	12	3	0	0
Netherlands	28	6	28	6
Germany	3	0	0	0
Total	131	104	61	48

- results of technical exchanges;

During the seminar of the flood forecasting services of the Meuse IRBD on 16 and 17 September 2021, it was proposed that the flood forecasting and hydrometric services should meet more regularly in order to promote exchanges on subjects such as the floods of the past years, to draw up a balance sheet of the exchange of data and to inform each other on any current technical subject. The organization of joint gauging or technical visits with demonstration of the tools used would also make it possible to improve the exchanges. All the proposals resulting from this seminar are given in Annex 8

- other actions carried out to improve flood forecasting / warning (tools developed or used jointly, joint exercises, etc.).

Other proposals resulting from the seminar of the flood forecasting services in September 2021 include the creation of a directory of services and the grouping of all the hydrological stations of the Meuse IRBD on the same tool (Webgis and/or LHP). All the proposals resulting from this seminar are listed in Appendix 8.

7.3 Monitoring indicator for Objective 3: Improving systemic knowledge of flood risks

Objective 3 is monitored using the following parameters:

- type of data exchanged by the IMC States/Regions such as the exchange of information prior to the elaboration of flood hazard and flood risk maps (chapter 3 + Annexes 1 and 2) and the exchange of available knowledge on climate change; a summary of the available studies on the potential effects of climate change on the evolution of flood flows has been made in paragraph 9.2 completed by Annex 6; the minutes of the joint IMC - ISC Workshop on Climate Adaptation is also available on the IMC website (Mregie/16-5).

- products and tools produced jointly by the States/Regions of the IMC: in this context, a retrospective analysis of the floods of the Meuse IRBD has been carried out in Annex 5.

8. Communication, information and public consultation

As for the WFD, the IMC carried out a public consultation at the level of the Meuse IRBD, via its website from 29 April to 29 September 2021, in order to inform the population of its plan and the content of the roof report.

The procedures for communicating, informing and consulting the public in accordance with the obligations of Articles 9 and 10 of the ID were respected.

The IMC Secretariat received two reactions to the public consultation. Aquawal noted the assessment of the effects of climate change made in the IFRMP and questioned the compatibility and inter-calibration of the climate and hydrological models used in the States and Regions of the Meuse IRBD. On the other hand, it suggests "the possibility of setting up an international system for coordinating means of intervention in the event of a major crisis”.

Chapter 9 of the IFRMP summarises the climate change adaptation strategies of the states and regions of the Meuse IRBD and the available studies on the potential effects of climate change on the evolution of flood flows. In all these studies, the hydrological models are calibrated with measured meteorological and hydrological observations in order to reproduce as closely as possible the flows measured at the stations of the basin states/regions. These studies carry out calculations with the hydrological models using weather conditions simulated in the past by the climate models in order to ensure the reliability of the results. The use of climate projections for the future, which may differ from one State to another, depends on their availability at the time of the projects, the data used by the hydrological models used and the specific objectives of each study. However, they try to cover the range of weather conditions expected in the future. Concerning the second point, the management of rescue and intervention means is the responsibility of the civil protection services of each State/Region and is therefore not part of the competence of the IMC. However, the exchange of data that currently exists between the hydrometric and flood forecasting services enables all the partners to be better informed of what is happening upstream of their territory. The proposals for the development of cooperation in these two fields, which came out of the flood forecasting services exchange seminar, will enable the cooperation between these services to be strengthened in the future.

With regard to Aquawal's suggestion of an international system for coordinating the means of intervention in the event of a major crisis, it can be answered that this already exists within the EU: UCPM, the EU Civil Protection Mechanism. When the scale of an emergency exceeds a country's response capacity, it can request assistance through the UCPM. Through this mechanism, the European Commission plays a key role in coordinating the response to disasters in Europe and elsewhere in the world. The Emergency Response Coordination Centre (ERCC) is at the heart of the EU's civil protection mechanism and coordinates assistance to countries hit by a disaster. For example, during the floods in Belgium in July, Austria, Italy and France provided assistance through the UCPM. The Czech Republic also offered assistance, but Belgium did not accept this offer (due to the longer travel time to Belgium and the expectation that the floods would soon be over). ERCC was also present on site at all times with a local officer. In addition, there are also bilateral response mechanisms. In July 2021, for example, Luxembourg and the Netherlands helped Belgium. Germany also offered assistance, but this was not necessary.

The second reaction was made by Sportvisserij Nederland. It asks that the IFRMP be adapted with a balanced strategy between flood control and restoration of the natural functions of rivers and wetlands. The preamble of chapter 4.2 clearly states that "Flood risk management must be sustainable and integrated with other European policies. The management strategy to be achieved must be environmentally sustainable, economically balanced and socially acceptable".

This is exactly what the analysis table of the links between the FRD and the WFD aims at.

Sportvisserij Nederland also wishes to see "international agreements on water retention and the maintenance of sufficient space in the entire catchment area" and "binding agreements" for "the disposal of floating waste" proposed in the IFRMP. As stated in chapter 1 of the document, the "roof report has been built up as a result of national and regional work and ongoing exchanges within the IMC to ensure overall compatibility and consistency". This document is therefore not intended to propose new international agreements.

9. Addressing the effects of climate change

Almost all meteorological research institutes in the Meuse basin predict global climate change. Even rapid and effective protective measures would not be able to prevent the climate change that is taking place, since, for example, the effects of the carbon dioxide released into the atmosphere today will continue for another 30 to 40 years and will contribute to warming. Furthermore, with current global energy needs, it is impossible to reduce emissions to zero, as each combustion process produces additional CO_2.

9.1 Summary of national climate change adaptation strategies

9.1.1 France

The French national climate change adaptation plan 2018-2022 predicts more intense precipitation, even in regions where the annual amount of precipitation will decrease, increasing the risk of floods.

In the Rhine-Meuse basin, according to the climate change mitigation and adaptation plan and and based on EXPLORE 2070 data, the frequency of heavy rainfall events is likely to increase. The cost of damage resulting from repeated runoff and landslides may increase. The flood discharge volumes of the watercourses for floods with return periods of 10 to 20 years are likely to increase.

To face the challenges of climate change, Europe, France and the Basin Committees have adopted strategies and/or plans for adaptation to climate change. The tools used by France are described in detail below.

The National Climate Change Adaptation Plan 2018-2022 (NCCAP2)

Published in December 2018, the national climate change adaptation plan 2018-2022 aims to limit the negative impacts of climate change on human societies and the environment. Its general objective is to implement the necessary actions to adapt, by 2050, the territories of metropolitan and overseas France to the expected regional climate changes.

The plan is based on the assumption that temperatures will rise by 1.5 to 2°C worldwide compared to the 19th century.

The NCCAP-2 is composed of 58 actions to be implemented over 5 years. These actions cover 6 areas:

- the actions in the "Governance" area aim to effectively link the national and territorial levels and to involve society in the implementation and monitoring of the NAPCC-2, with particular attention to the overseas territories; they will ensure coherence between adaptation and mitigation and strengthen the legal and regulatory framework for adaptation;

- the proposed actions are based on the best scientific knowledge and on raising the awareness of the entire population of the need to combat and adapt to climate change ('Knowledge and information' area);

- many actions aim to protect people and property from climate risks ("Prevention and resilience" area) and to prepare economic sectors for the expected changes ("Economic sectors" area), which will support the evolution and strengthen the potential for job creation and innovation;

- the actions give priority to nature-based solutions wherever possible ('Nature and Environment' area);

- Finally, some actions aim to benefit from the experiences of other countries and to strengthen the capacities of French actors to support developing countries in their own climate change adaptation policies ("International" area).

Plan for adaptation and mitigation of water resources to climate change - Rhine-Meuse basin

The Rhine-Meuse basin plan for adaptation and mitigation of water resources to climate change was adopted by the basin committee on 23 February 2018.

Like the NAPCC-2, the Rhine-Meuse basin plan emphasises nature-based solutions and the development of the territory's resilience to extreme events (drought, floods).

These flagship actions still need to be translated into operational actions and reflected in the intervention programmes of the basin's actors and the territorial climate air-energy plans (PCAET) of the inter-municipalities and the initiatives taken by the economic actors, the associative world, the citizen with the support of the State and its agencies.

9.1.2 Luxembourg

To prevent the negative consequences of climate change, the Grand Duchy of Luxembourg developed and published in 2018 the "Strategy and action plan for adaptation to climate change in Luxembourg 2018-2023" (MECDD, 2018).

In the framework of the climate adaptation strategy, changes in temperature, precipitation and extreme events were examined and the expected impacts on the Grand Duchy, split into biosphere, soil and hydrosphere, were presented. For the 13 most important sectors in the Grand Duchy, the expected climate impacts that could play a role in the coming decades due to the associated risks are identified. The 13 sectors are construction and housing, energy, forestry, infrastructure, crisis and disaster management, land use planning, agriculture including plant and animal health, human health, ecosystems and biodiversity, tourism, urban areas, water balance and water management, and the economy in general.

Subsequently, measures were developed for each of these areas. Finally, an attempt was made to link the climate adaptation strategy to other strategies such as FRMP. As such, an effort was made to create synergies and find measures that serve both objectives. Table 5 presents the measures identified in the adaptation strategy.

Table 5 : Climate adaptation strategy: FRMP area

Sector	**Measure**
Construction and housing	Adapting building standards to more extreme climatic conditions and expected changes. Development of a guidance document on "climate-proof buildings".
Energy	Review and adapt existing energy infrastructure in terms of vulnerability to extreme events.
Infrastructure	Identification of critical infrastructure and implementation of measures to reduce vulnerability. Integrating climate change into the design of new infrastructure.
Crisis and disaster management	Adaptation of emergency services (police, rescue and fire brigade) to changing climatic conditions. Continuous monitoring of natural hazard processes and events, as well as development and improvement of methods and technologies for detecting new natural hazard processes. Integration of climate change into the design of stormwater, wastewater and drinking water systems. Development of robust and adaptable protection systems.
Land use planning	Intensification of research activities on the forecast of extreme weather events and identification of the implications for the different sectors of agriculture.
Urban areas	Review of urban infrastructure in relation to increasing extreme weather events and development of structural adaptation concepts.

Water balance and water management	Consideration of heavy rainfall events in the second flood risk management plan. Shading measures through riparian planting.

9.1.3 Wallonia

Belgium, through the National Climate Commission (NCC), adopted its "National Adaptation Strategy" at the end of 2010 with the aim of being able to propose an operational action plan for 2012. This action plan results from the merging of the action plans of the three regions and the federal government. In this context, Wallonia, through the Walloon Air and Climate Agency (WACA), commissioned a study in 2011 to draw up an exhaustive assessment - characterisation, current vulnerabilities, future vulnerabilities - of Wallonia according to seven themes: agriculture, water, infrastructure/land use, health, energy, biodiversity and forests. An extensive consultation of experts enabled the identification of the main measures to be implemented in order to adapt Wallonia to climate change.

The national plan was adopted on 19 April 2017 by the NCC. It contains about ten measures with a national scope (development of new common climate scenarios, development of a national platform on adaptation, ...) that complement the measures contained in the regional plans and in the federal contribution. The development of the plan was coordinated within the CABAO working group. The plan was submitted to the various Belgian entities and to the consultative opinions. It can be downloaded from the NCC website.

Regional plans and other initiatives exist in the three Regions and at the Federal level.

The Walloon regional plan is the AIR-CLIMATE-ENERGY plan (PACE plan) which was adopted on 21 April 2016 by the Walloon government.

The PACE 2016-2022 contains 142 measures to reduce greenhouse gas emissions and other air pollutants, improve air quality and adapt to the impacts of climate change. The various sectors of activity are concerned: agriculture, industry, transport, housing, etc.

PACE is the central instrument for implementing the Climate Decree adopted by the Walloon Parliament in February 2014.

9.1.4 Flanders

On 9 December 2019, the Flemish Government definitively approved the Flemish Energy and Climate Plan 2021-2030. This plan is the strategic framework for climate mitigation for the next ten years. The plan also appoints the Flemish Adaptation Plan 2021-2030 as part of the Flemish Climate Policy Plan 2021-2030. The adaptation plan builds on the measures and results from the current Flemish Adaptation Plan 2013-2020 with the aim of further strengthening Flanders' resilience to the effects of climate change and adapting to the expected effects. The starting point here is the strengthening of the resilience and robustness of the environment. Work is also continuing on mapping Flanders' vulnerability to climate change, based on previously obtained results and further insights. Adapting to the effects of climate change requires a comprehensive, integrated approach, across the various sectors, whereby synergies are sought between adaptation and mitigation, and with other policy goals.

The adaptation plan will focus on the following pillars:

- Preservation and expansion of open, unpaved space
- A climate-adaptive space, society, buildings and (mobility) infrastructure
- Minimising risks of water shortage and flooding
- Maximising green-blue networks
- Climate-adaptive industry and agriculture

In Flanders, the amount of precipitation may rise to +38% during the winter months by 2100. It will not rain more often, but it will rain more heavily. Winters will therefore become wetter in the future, which may lead to more frequent and more extensive river floods. At the same time, summer storms will be more intense and more frequent. These may cause an increase in mainly urban flooding, and more erosion and mudslides.

The high-impact scenario shows that the probability of flooding in Flanders could increase by a factor of 5-10 by 2100.

- In concrete terms, this means that areas which are currently flooded with a medium probability (100-year flooding) may in future be flooded with up to 10 yearly floods.
- Areas which are currently flooded once every ten years may then be flooded almost every year.
- Floods may also become more extreme because the higher discharge causes peak water levels to increase. On average, an increase in maximum flood levels of 22 cm is expected in Flanders. Locally, these may even rise to a little over 1 m. Areas with, for example, sharply sloping upstream valleys or dense urban drainage systems are the most sensitive.

9.1.5 Germany

Since 2008, the German Strategy for Adaptation to Climate Change (GSA) has been assessing the risks of climate change in Germany, identifying possible need for action, defining goals and developing adaptation measures together with the Länder and other stakeholders: https://www.bmu.de/themen/klima-energie/klimaschutz/anpassung-an-den-klimawandel/. In this context, the LAWA report "Impacts of Climate Change on Water Management" was produced in 2017 and is currently being updated.

Accompanying the GSA is an "Adaptation Action Plan" (AAP)[10], the second update of which (AAP III) was published in 2020 with the GSA progress report. For the "Water Cluster", the AAP III provides, among other things, for the development of products that can be used nationwide: Guidelines for the creation of hazard and risk maps for local heavy rainfall events, for decentralised rainwater management and for heat load plans; a real-time model for groundwater recharge; a database for the recording of extreme events and the damage they cause; a design for the early warning system of the German Weather Service (GWS) before heavy rainfall; quality standards for the reuse of water, for example in agriculture or for irrigation.

On watercourses that have been developed as waterways and are owned by the federal government, as well as their floodplains, renaturation is to be promoted through the German Blue Belt federal programme[11]. In this context, greater emphasis is to be placed on nature-based solutions and more natural floodplains and retention areas are to be created. The

[10] https://www.bmu.de/download/zweiter-fortschrittsbericht-zur-deutschen-anpassungsstrategie-an-den-klimawandel
[11] https://www.blaues-band.bund.de/Projektseiten/Blaues_Band/DE/00_Home/home_node.html

establishment of ecological continuity and climate proofing on federal waterways are also included here as planned adaptation measures.

Since 2011, the state of North Rhine-Westphalia has been conducting climate impact monitoring with a total of 30 indicators from 7 environmental areas. In order to be able to describe the possible influences of climate change on the water balance, data is regularly collected, in particular on precipitation, water temperature, evapotranspiration, groundwater levels and groundwater recharge, the climatic water balance (the difference between precipitation and evapotranspiration) and the mean discharge of water bodies.

The following trends emerged in this context by the end of 2019:

- Winter precipitation increases, mean and maximum water body temperature increases, mean annual water body discharge decreases, groundwater level (annual mean, as well as summer and winter) decreases, groundwater recharge decreases and evapotranspiration (annual mean) increases.

  The specialised information system can be viewed at: https://www.lanuv.nrw.de/kfm-indikatoren/index.php?mode=liste&aufzu=0,

  The report for the year 2016 is available at: https://www.lanuv.nrw.de/fileadmin/lanuvpubl/3_fachberichte/fabe74.pdf

9.1.6 Netherlands

In 2017, the Dutch government adopted the National Climate Adaptation Strategy (NAS). The NAS outlines how the Netherlands is adapting to climate change. The Delta Programme elaborates on this for water safety, freshwater availability and spatial adaptation. Some of the measures in the Delta Programme focus on flood risk management (see also chapter 6).

In the Delta Act, the Netherlands has stipulated that there is a Delta Commissioner who advises the government on the programming of measures in the Delta Programme. The aim is for the Netherlands to be climate-resistant and water-resistant in good time. The Delta Act also ensures the multiyear financing of measures via the Delta Fund.

The Delta Commissioner, together with the Dutch authorities and in consultation with civil society organisations, the business community and knowledge institutes, has set out a roadmap for flood protection policy and spatial adaptation. The government has anchored this in national policy. The roadmap will be reviewed and adjusted every six years, based on new insights into climate change and socio-economic changes.

Based on predictions by the Intergovernmental Panel on Climate Change (IPCC), the Royal Netherlands Meteorological Institute (KNMI) is developing climate scenarios for the Netherlands. These climate scenarios outline how the Dutch climate is likely to change in 50 to 100 years' time. These KNMI scenarios form the starting point for national policy. The KNMI scenarios are based on a global average temperature increase of 1 to 2°C in 2050 and 1.5 to 3°C in 2085 compared to 1981-2010.

For the Meuse, all KNMI climate scenarios lead to increased discharges in winter due to increased precipitation intensities. Flood discharges are expected to increase by 10 to 20%, depending on the reference year and climate scenario under consideration.

The expected impact of climate change on high water discharges will be taken into account when reinforcing Dutch flood defences to comply with the new flood protection standards in 2050.

9.2 Summary of available studies on the potential effects of climate change on the evolution of flood discharges (see Annex 6)

Forecasting the evolution of frequent, average and extreme flood flows, which are used to draw up flood hazard and flood risk maps for rivers, is a real challenge.

A joint approach by all the States/Regions and various partners of the Meuse basin has been carried out with the aim of understanding the effects of climate change on the hydrological cycle: this is the Interreg IV B Amice project (Adaptation of the Meuse to the Impacts of Climate Evolutions) carried out between 2009 and 2012.

An analysis based on the climate information used at national level was carried out in order to develop common flow scenarios for the Meuse. However, it appears that there is considerable uncertainty regarding future flows. There are various reasons for this, including the margin in the climate model projections of temperature and precipitation variations due to uncertainties in the future development of greenhouse gas concentrations, and the propagation of uncertainties along the modelling chain from the climate model to the calculated flow.

9.2.1 AMICE (Adaptation of the Meuse to the Impacts of Climate Evolutions)

Within the framework of the AMICE project, a synthesis of available studies on climate change was carried out between 2009 and 2010.

The aim of this action was to identify possible impacts of climate change on the hydrological regime of rivers in the Meuse basin in the near future (2021-2050) and in the distant future (2071-2100).

All studies analysed show fairly clear trends for the Mediterranean region (very strong temperature increase and precipitation decrease) and the Scandinavian region (strong temperature increase and precipitation increase). As the Meuse basin lies between these two regions, and depending on the models used, the Meuse basin becomes drier or experiences an increase in precipitation.

The AMICE partners observed clear heterogeneities between the climate scenarios from the four national parts of the basin. In order to keep the flows consistent from upstream to downstream, especially at the borders, a transnational scenario was established. For this purpose, the national trends were weighted according to the area of each sub-basin (Table 6).

Table 6 : weighting coefficients used to create the transnational seasonal trends

	Drainage area (km²)	Weighting coefficient
France	10.120	0,31
Walloon	10.880	0,33
Flanders & Netherlands	8.662	0,26
Germany	3.338	0,10
Transnational Meuse	**33.000**	**1,0**

Flow calculations were carried out for 9 hydrological stations in the international Meuse basin (see map 6).

Map 6: Hydrological calculation points used in the AMICE project

For the transnational scenario, the variation in flows is logically homogeneous throughout the basin (see Table 7 with an increase for the wet scenario in blue and a decrease for the dry scenario in red). These trends are more pronounced for the end of the century.

Table 7 : evolution of the 100-year flood discharge according to the transnational scenario

		Meuse St-Mihiel	Meuse Stenay	Meuse Montcy	Meuse Chooz	Meuse Sint Pieter	Lesse Gendron	Vesdre Chaud-fontaine	Rur Stah	Niers Goch
Qhx100	2021-2050	1.12	1.12	1.12	1.12	1.14	1.19	1.08	1.02	1.11
		0.96	0.96	0.96	0.96	0.95	0.98	0.90	0.88	0.89
	2071-2100	1.27	1.27	1.27	1.27	1.33	1.55	1.27	1.10	1.24
		0.89	0.89	0.89	0.89	0.91	0.90	0.81	0.61	0.71

One of the main gaps in the AMICE project is the study of extreme rainfall in small basins.

Climate scenarios predict that these extreme events will occur more frequently. But this phenomenon is hardly known in the Meuse basin. There is no monitoring or detailed analysis of their frequency and causes. It is also very difficult to predict the location and intensity of these events, and even more difficult to model them. Therefore, the AMICE partners have only mentioned that extreme precipitation events may become more frequent in the coming century (Christensen & Christensen, 2003 – Intensification of extreme European summer precipitation in a warmer climate. Global and Planetary Change, 2004, 44, 107–117).

9.2.2 New knowledge available since AMICE

a) KNMI'14 study

Based on the new forecasts published by the Intergovernmental Panel on Climate Change (IPCC), the Royal Netherlands Meteorological Institute (KMNI) has drawn up four new climate scenarios for the Netherlands, known as KNMI'14, for the periods 2050 and 2085.

Table 8 from the report "Implications of the KNMI'14 climate scenarios for the discharge of the Rhine and Meuse - Comparison with earlier scenario studies" shows the calculated evolution of frequent flood discharges at the Borgharen station with the KNMI'14 scenarios.

Table 8 : frequent flood discharges at Borgharen for the 4 KNMI'14 climate scenarios in 2050 and 2085, and for the current climate (i.e. the reference situation)

Return period	Reference	$2050G_L$	$2050G_H$	$2050W_L$	$2050W_H$	$2085G_L$	$2085G_H$	$2085W_L$	$2085W_H$
[years]	[m^3/s]	[m^3/s]	[m^3/s]	[m^3/s]	[m^3/s]	[m^3/s]	[m^3/s]	[m^3/s]	[m^3/s]
10	2260	2570	2490	2470	2570	2480	2470	2600	2740
30	2740	3090	3000	3000	3080	3000	2960	3140	3300
100	3180	3590	3470	3480	3550	3500	3420	3640	3850
300	3540	3980	3870	3890	3900	3890	3770	4060	4300
1000	3860	4360	4200	4210	4210	4260	4060	4390	4680
3000	4080	4740	4500	4520	4540	4580	4390	4680	4950
10000	4350	5010	4720	4770	4730	4900	4580	4920	5210
30000	4590	5180	4870	4940	4910	5060	4760	5090	5370

b) Explore 2070

The study project called "Explore 2070 project" financed by the French Ministry of Ecology took place from June 2010 to October 2012 in order to assess the potential impacts of climate change on surface water resources over the future time period 2046-2065 in comparison to the present time reference period 1961-1990 based on the A1B scenario of the IPCC 4th assessment report.

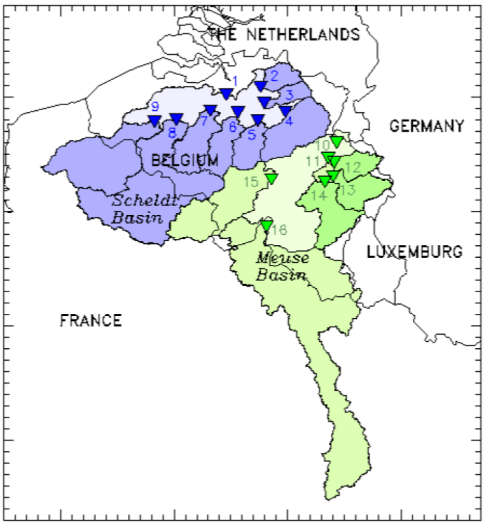
Table 9 shows the evolution calculated at the Chooz - Ile Graviat station of the average monthly flows and the maximum annual daily flow (QJXA) for the return periods 2 years, 10 years and 20 years.

Table 9 : median, minimum and maximum values at Chooz of the relative evolutions between the periods 1961-1990 and 2046-2065 of QJXA2, QJXA10 and QJAX20 calculated with the GR4J model (yellow) and the Modcou model (green) with the 7 climate models of the EXPLORE 2070 project

CRUES							
		QJXA2		QJXA10		QJXA20	
Qobs POD (m^3/s)		628		960		1087	
Qsim (climat obs) POD (m^3/s)		657	538	1129	854	1310	974
Δ	min (%)	−17	−17	−15	−10	−15	−10
	med (%)	−3	+1	+3	+7	+7	+10
	max (%)	+11	+15	+34	+31	+39	+35

c) CCI-HYDR

The "CCI-HYDR" research project carried out by the Catholic University of Leuven and the Royal Meteorological Institute of Belgium from 2005 to 2010 aimed to study the impact of climate change on extreme events in rivers in the Belgian parts of the Meuse and Scheldt basins and wastewater collection facilities (see figure 3 in the article "Climate change and hydrological extremes in Belgian catchments" by Baguis, P., Roulin, E., Willems, P., Ntegeka, V., published in 2010 in the journal *Hydrology and Earth System Sciences Discussions*).



	Watershed	Outlet	Area (km^2)
			Scheldt Basin
1	Scheldt	Antwerp	18801
2	Kleine Nete	Grobbendonk	590
3	Grote Nete	Hulshout	468
4	Demer	Diest	1908
5	Dijle	Wilsele	896
6	Zenne	Eppegem	1096
7	Dender	Confluence	1389
8	Bovenschelde	Asper	5810
9	Leie	St Baafs	3506
			Meuse Basin
10	Meuse	Visé	20588
11	Ourthe	Angleur	3627
12	Vesdre	Confluence	708
13	Amblève	Martinrive	1068
14	Ourthe	Tabreux	1616
15	Sambre	Namur	1964
16	Meuse	Chooz	10120

Figure 3 : stations calculated in the framework of the CCI-HYDR project

Figures 4 and 5 show the evolution calculated for the Meuse station at Visé of the average monthly flows and the number of days per month for which the daily flow is higher than the Q95 (= flow exceeded 95% of the time in a year).

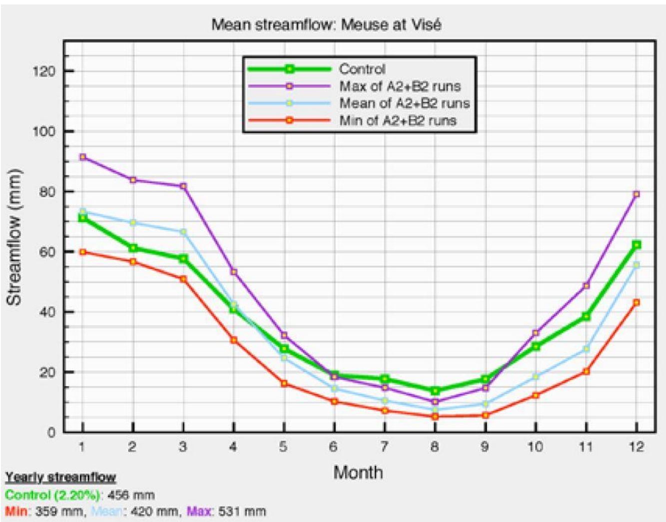


Figure 4 : evolution of the average monthly flows (in green the values obtained by modelling for the past period taken as reference, in blue, purple and red the average, minimum and maximum values obtained in the future with the climate scenarios)

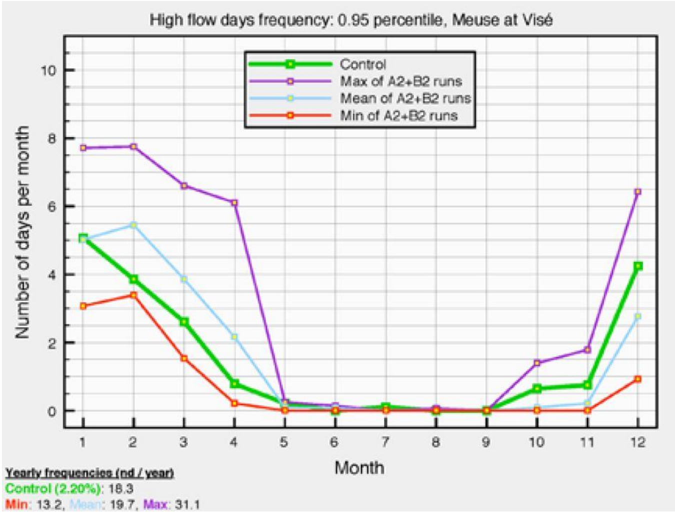


Figure 5 : evolution of the number of days per month for which the daily flow is higher than the Q95 (in green the values obtained by modelling for the past period taken as reference, in blue, purple and red the average, minimum and maximum values obtained in the future with the climate scenarios)

d) CORDEX and HydroTrend

The "COordinated Regional Climate Downscaling EXperiment and beyond" project for Belgium (CORDEX.be) seeks to further refine the results of the general circulation models that led to the IPCC Fifth Assessment Report at the regional scale. The overall aim of this local project is to bring together current Belgian research in the field of climate modelling in order to create a coherent scientific basis for future climate services in Belgium.

The data from this project are daily data that include values for maximum and minimum temperature, precipitation, relative humidity, solar radiation and wind speed. These data are available for a reference period from 1975 to 2005. They are also available between 2007 and 2100 for three emission scenarios from the latest IPCC report.

In addition to these climate change projects, HydroTrend aims to detect and analyse trends in the amplitude and frequency of flood flows in Wallonia.

For this purpose, the annual maximums and values exceeding a certain threshold (POTs-peaks over threshold) were extracted from the data of 84 gauging stations.

These results show that the instability of flood flows should be considered in hydrological analyses. This could have repercussions for flood management in Wallonia, since the results of the frequency analyses are used, among other things, in the sizing studies for flood control structures and for flood hazard maps.

e) CHIMERE 21

The main question of this project was: "What are the future impacts of climate change on the flows of the French part of the Meuse?".

The objectives of the CHIMERE 21 project were to:

- assess the evolution of the climate in the Meuse catchment area in the 21st century using the latest available climate simulations produced in the framework of the fifth report of the Intergovernmental Panel on Climate Change (IPCC).

- assess the impacts of climate change on the flows of the French section of the Meuse River.

- consider and evaluate the various sources of uncertainty used to establish these diagnoses.

The project was funded by the Rhine-Meuse Water Agency and involved experts from INRAE (formerly Irstea), Météo-France, EDF, the University of Lorraine and the DREAL Grand-Est.

Evolution of flows

The analysis of future flows in the Meuse at Chooz indicates a probable strong increase in flows during the winter period by 2071-2100 with RCP 8.5 (Figure 6). These changes are directly linked to the increase in autumn and winter precipitation, which is less significant with RCP 4.5.

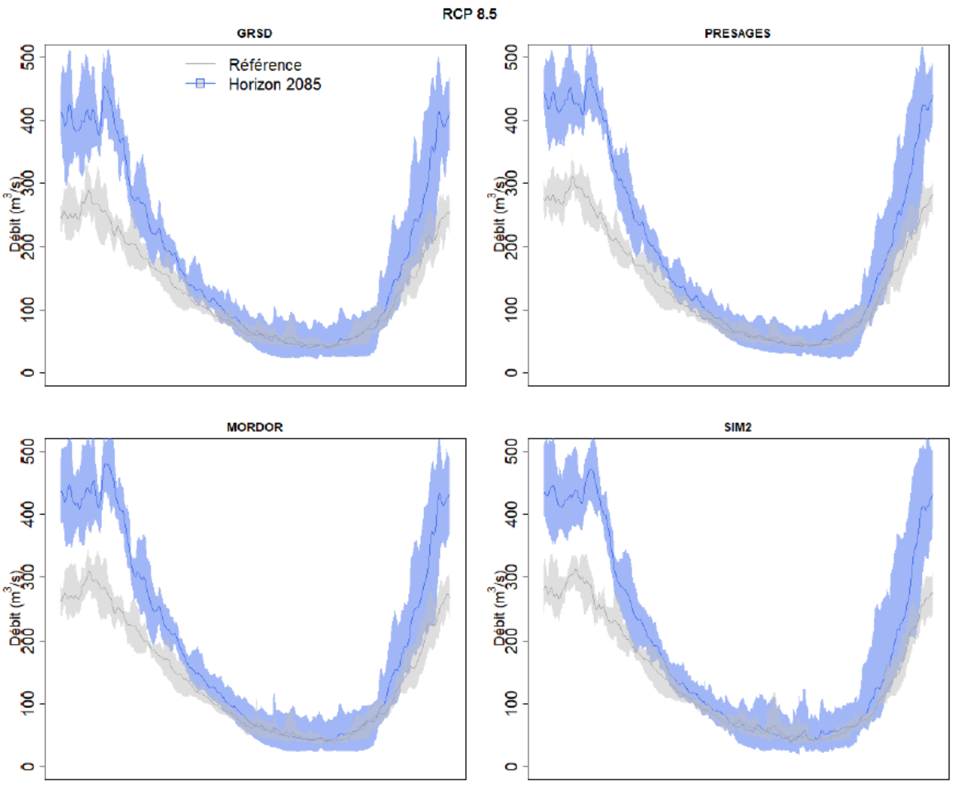


Figure 6 : Evolution of simulated flows for the Meuse at Chooz by all the hydrological models within the framework of RCP 8.5 for the 2085 horizon (2071-2100 period) and over the historical period (1976-2005).

However, there are spatial differences in the Meuse basin. The increase in flood flows is indeed notable downstream of the basin (Figures 7 & 8).

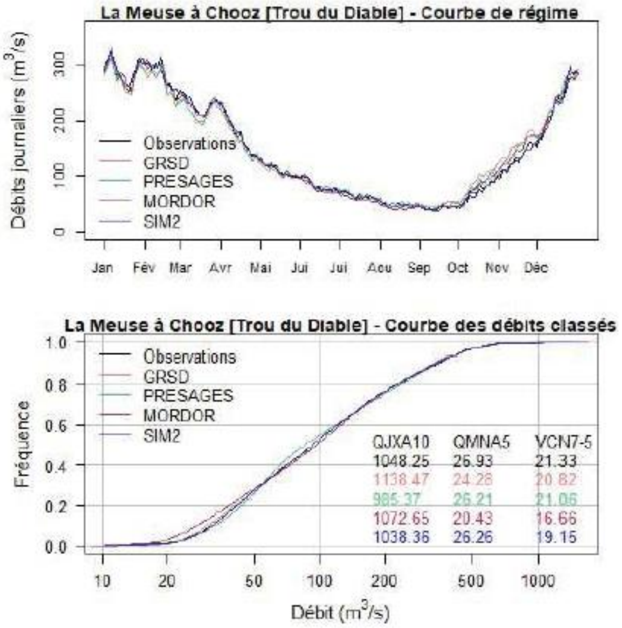


Figure 7 : Average interannual regime (top) and curve of classified flows (bottom) observed (in black) and simulated (in colour) by the hydrological models calibrated on the regime for the Meuse at Chooz. The observed (in black) and simulated (in colour) hydrological indicators are indicated at the bottom right of the lower graph: QJXA10, QMNA5, VCN7-5.

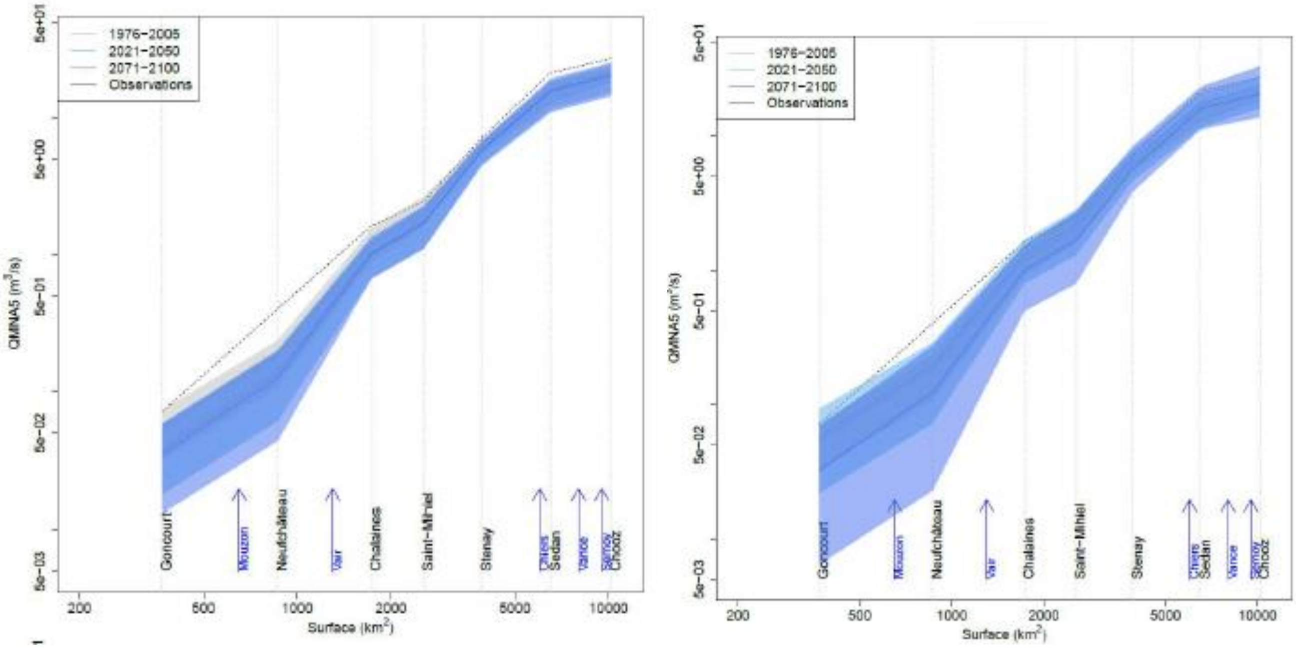


Figure 8 : Hydrological profile of the Meuse River representing the flood flows (QJXA10) observed over the period 1976-2005 and projected over three periods: 1976-2005, 2021-2050 and 2071-2100. On the left, the RCP 4.5, on the right, the RCP 8.5. All hydrological models, calculated over the total period and the regime, are combined.

10. Coordination with other EU policies

The IMC plays a coordinating role in achieving the objectives of the WFD and the FRD. In this context, it acts as a platform for the exchange of information and the necessary coordination at the level of the Meuse IRBD.

In the context of updating the roof part of the WFD management plan for the Meuse River basin district, it was decided that floods would be dealt with in the IFRMP. However, coordination between the two Directives and the implementation of their programme of measures is necessary to exploit synergies and ensure the achievement of the environmental objectives of article 4 of the WFD.

To this end, a review of the potential synergy between measures that can be implemented to manage or reduce flood risks and the achievement of the environmental objectives of surface water bodies under Article 4 of the WFD has been carried out.

Annex 4 gives an overview of the results of this review, which are described in more detail in the "Report on the coordination between the Flood Directive and the Water Framework Directive in the international river basin district of the Meuse" (unpublished working document). As a result of this work, it is proposed that priority be given to measures that have synergy with the environmental objectives of the WFD.

11. List of competent authorities and regional, national and international coordination structures

Germany

Ministerium für Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen

Emilie-Preyer-Platz 1

40479 Düsseldorf

Deutschland

http://www.flussgebiete.nrw.de

http://www.umwelt.nrw.de

Belgium

Flemish Region

Coördinatiecommissie Integraal Waterbeleid

Dokter de Moorstraat 24-26

9300 Aalst

België

http://www.integraalwaterbeleid.be/

Walloon Region

Gouvernement wallon

Cabinet du Ministre Président

Rue Mazy, 25-27

5100 Jambes (Namur)

Belgique

http://www.gov.wallonie.be

France

Sambre

Monsieur le préfet coordonnateur de bassin Artois Picardie

2, rue Jacquemars Giélée

59039 Lille

France

mailto:secretariat@nord-pas-de-calais.pref.gouv.fr

Meuse

Madame la préfète coordonnatrice de bassin Rhin Meuse

5, Place de la République

67000 Strasbourg

France

Luxembourg

Ministère du Développement durable et des Infrastructures

4, place de l'Europe

L- 1499 Luxembourg

Luxembourg

mailto:info@mddi.public.lu http://www.mddi.public.lu

Netherlands

Ministerie van Infrastructuur en Waterstaat

Postbus 20901, 2500 EX Den Haag, Nederland,

https://www.rijksoverheid.nl/ministeries/ministerie-van-infrastructuur-en-waterstaat

12. Contact points for reference documents

Germany

Ministerium für Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen

Emilie-Preyer-Platz 1

40479 Düsseldorf

Deutschland

http://www.flussgebiete.nrw.de

Belgium

Walloon Region

Service public de Wallonie

Agriculture Ressources naturelles Environnement

Directions des Cours d'eau non navigables

Avenue Prince de Liège, 7

5100 NAMUR

Belgique

Service public de Wallonie

Mobilité Infrastructures

Direction de la Gestion hydraulique

Centre Perex - Rue Del Grète, 22

5020 NAMUR

Belgique

pgri.inondations@spw.wallonie.be

https://inondations.wallonie.be

Flemish Region

Coördinatiecommissie Integraal Waterbeleid

Dokter de Moorstraat 24-26

9300 Aalst

België

http://www.integraalwaterbeleid.be/

France

Sambre

DREAL Hauts-de-France

44, rue de Tournai - CS 40259

59019 LILLE Cedex

France

https://www.hauts-de-france.developpement-durable.gouv.fr

Meuse

DREAL Grand Est

2 rue Augustin Fresnel - CS 95038

57071 METZ Cedex 03

France

http://www.grand-est.developpement-durable.gouv.fr

Luxembourg

Administration de la gestion de l'eau

1, avenue du Rock'n'Roll

L - 4361 Esch-sur-Alzette

Luxembourg

https://eau.gouvernement.lu

Netherlands

Ministerie van Infrastructuur en Waterstaat

Postbus 20901, 2500 EX Den Haag

Nederland

https://www.rijksoverheid.nl

Annex 1: Exchange of information: Article 6 of the FRD

Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD	Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD
FRANCE			WALLONIA		
La Chiers	Selected Longlaville Longwy, Mont St Martin and Rehon	No	La Chiers	Selected	Yes
Le ruisseau du Coulmy	Not selected	Not relevant	Le Cussigny	Selected (lower risk)	Yes
La Base Vire	Not selected	Not relevant	La Vire	Selected	Yes
Le Ton	Not selected	Not relevant	Le Ton	Selected	Yes
La Thonne	Not selected	Not relevant	La Thonne	Selected (lower risk)	Yes
La Marche	Not selected	Not relevant	Le Williers - La Marge	Selected (lower risk)	Yes
Le ruisseau de l'Aulnois	Not selected	Not relevant	La Tremble (in Muno)	Selected (lower risk)	Yes
La Goutelle	Not selected	Not relevant	La Goutelle (in Sugny)	Selected (lower risk)	Yes
La Semoy	Not selected	Not relevant	La Semois	Selected	Yes
Le ruisseau de Saint Jean (affluent Semoy)	Not selected	Not relevant	Le ruisseau de Saint Jean (tributary Semoy)	Selected (lower risk)	Yes
Ruisseau de Stol	Not selected	Not relevant	La Stole (tributary La Hulle)	Selected (lower risk)	Yes
La Hulle	Not selected	Not relevant	La Hulle	Selected (lower risk)	Yes
La Houille	Not selected	Not relevant	Houille	Selected	Yes
Ruisseau de Scheloupe	Not selected	Not relevant	Ruisseau de Scheloupe	Selected (lower risk)	Yes
Le Massembre	Not selected	Not relevant	Le Massembre	Selected (lower risk)	Yes
La Meuse	Selected in Neufchâteau, Verdun, Thierville-sur-Meuse and Belleville-sur-Meuse as well as Bazeilles in Givet	No	La Meuse	Selected	Yes
R. de Prailes	Not selected	Not relevant	R. de la Jonquière	Selected (lower risk)	Yes
Le Viroin	Not selected	Not relevant	Le Viroin	Selected	Yes
Ruiseau Deluve	Not selected	Not relevant	Ruisseau de Luve	Selected (lower risk)	Yes

Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD	Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD
Ruisseau d'Alyse	Not selected	Not relevant	L'Alisse (near Fumay)	Selected (lower risk)	Yes
R. du Fond de Pernelle	Not selected	Not relevant	Forge du Prince (near Bruly)	Selected (lower risk)	Yes
Eau noire	Not selected	Not relevant	Eau noire	Selected	Yes
R. de Sainte Anne	Not selected	Not relevant	Sainte Anne (Eau Noire)	Selected (lower risk)	Yes
Helpe majeure	Not selected	Not relevant	Helpe	Selected (lower risk)	Yes
Thure	Not selected	Not relevant	Thure	Selected	Yes
Hantes	Not selected	Not relevant	Hantes	Selected	Yes
Sambre	Selected from Leval to Jeumont	No	Sambre	Selected	Yes
FRANCE			**LUXEMBOURG**		
Chiers	Selected Longlaville Longwy, Mont St Martin and Rehon	No	Chiers	Selected	Yes
WALLONIA			**LUXEMBOURG**		
Chiers	Selected	Yes	Chiers	Selected	Yes
WALLONIA			**FLANDERS**		
Geer	Selected	Yes	Jeker	Selected	Yes
Rigole d'Awans	Selected (lower risk)	Yes	Ezelbeek	Selected	Yes
Exhaure d'Ans	Selected (lower risk)	Yes	Exhaure d'Ans / Beek	Selected	Yes
Berwinne	Selected	Yes	Berwijn	Selected	Yes
Le Biek (tribut. Voer)	Selected (lower risk)	Yes	De Beek (tribut. Voer)	Selected	Yes
Gulp	Selected (lower risk) NB: < 10 km²	Yes	Gulp	Selected	Yes
WALLONIA			**GERMANY**		
Iterbach	Selected (lower risk)	Yes	Iterbach	Not selected	Not relevant
Inde	Selected (lower risk)	Yes	Inde	Not selected	Not relevant
Vesdre	Selected	Yes	Weser	Not selected	Not relevant

Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD	Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD
Roer	Selected (lower risk)	Yes	Rur	Not selected	Not relevant
Schwalmbach	Selected (lower risk)	Yes	Perlenbach	Not selected	Not relevant
Olefbach	Selected (lower risk)	Yes	Olef	Not selected	Not relevant
WALLONIA			**NETHERLANDS**		
Meuse	Selected	Yes	Maas	Selected	Yes
Gueule	Selected	Yes	Geul	Selected	Yes
FLANDERS			**NETHERLANDS**		
Gemeenschappelijke Maas	Selected	Yes	Gemeenschappelijke Maas	Selected	Yes
Gulp	Selected	Yes	Gulp	Selected	Yes
Voer	Selected	Yes	Voer	Selected	Yes
Jeker	Selected	Yes	Jeker	Selected	Yes
Itterbeek / Witbeek	Selected	Yes	Thornerbeek	Selected	Yes
Abeek - Grote Lossing/ Uffelsche beek	Selected	Yes	Uffelsche beek	Selected	Yes
Zuid-Willemsvaart	Not selected	Not relevant	Zuid-Willemsvaart	Selected	Yes
Dommel	Selected	Yes	Dommel	Not selected	Not relevant
Mark	Selected	Yes	Boven Mark	Not selected	Not relevant
Merkske	Selected	Yes	Merkske	Not selected	Not relevant
Weerijsbeeb – Grote Aa	Selected	Yes	Aa of Weerijs	Not selected	Not relevant
Warmbeek	Selected	Yes	Tongelreep	Not selected	Not relevant
De Aa	Selected	Yes	Rovertsche Leij/ De Aa	Not selected	Not relevant
Leyloop	Selected	Yes	Poppelsche Leij	Not selected	Not relevant
Kleine Aa – Wildertse Beek	Selected	Yes	Watermolenbeek	Not selected	Not relevant

Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD	Name of the watercourse	Result of the selection at the borders according to Art. 5 of the FRD	Updating of the mapping of the 1st management cycle according to Art.6 of the FRD
GERMANY			**NETHERLANDS**		
Wurm	Selected	Yes	Worm	Selected	Yes
Rodebach	Selected	Yes	Roode Beek/Geleenbeek	Selected	Yes
Kitschbach	Selected	Yes	Kitschbach	Selected	Yes
Rur	Selected	Yes	Roer	Selected	Yes
Niers	Selected	Yes	Niers	Selected	Yes
Nierskanal	Not selected. The risk zone on the German side has been reduced and no longer extends to the Dutch border	Not relevant	Geldernsch Nieskanaal	Not selected, there is no risk on the Dutch section	Not relevant

Annex 2: Overview of the exchange of information: Comparison table of flow assumptions associated with the flood scenarios provided for in Article 6(3)

	State-Regions/ Hydrological station/ Reference point		**High probability flood** *HQ10/ HQ30/ other*		**Medium probability flood (probable return period ≥ 100 years)** *HQ100/ HQ 200/ other*		**Low probability flood or extreme event scenarios** *HQ1000/ other*		**Comments on the exchange of information**
Name of the watercourse	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	**Upstream**	**Downstream**	
La Chiers	**WL**	**FR**/ Longwy	?	71 m^3/s (Q_{10}) or (Q_{30})	?	128 m^3/s (Q_{100})	?	166 m^3/s (Q_{100})+30%	Data for the Chiers at Longwy coming from the Chiers flood hazard atlas (BCEOM, 2007)
La Meuse	**FR**/ Chooz-Graviat station	**WL**/ Border France-Belgium	(Q_{10}) or (Q_{30})	1356 m^3/s (Q_{25})	1572 m^3/s (Q_{100})	1645 m^3/s (Q_{100})	2043 m^3/s (Q_{100} +30%)	2140 m^3/s (Q_{100}+30%)	Data on the Meuse at Chooz from the FRPP of 28/10/1999.
La Sambre	**FR**/ Station of Hautmont in Maubeuge	**WL**/ Solre	120 m^3/s (*) (Q_{10})	148 m^3/s (Q_{25})	180 m^3/s (*) (Q_{100})	172 m^3/s (Q_{100})	Not relevant (mapping based on hydromorphological method)	Not relevant (mapping based on recent alluvial deposits)	(*) Provisional data for the Sambre at Maubeuge
Geer/ Jeker (*)	**WL**/ Eben Emael or Kanne	**VL**	16,47 m^3/s (Q_{25})	T_{10}	17,54 m^3/s (Q_{100})	T_{100}		T_{1000}	a model used
Rigole d'Awans/ Ezelbeek	**WL**	**VL**		T10		T100		T1000	No flow monitoring station
Exhaure d'Ans/ Beek (*)	**WL**	**VL**		T_{10}		T_{100}		T_{1000}	No flow monitoring station
Berwinne/ Berwijn (*)	**WL**/ Dalhem	**VL**	60,05 m^3/s (Q_{25})	T_{10}	105,82 m^3/s (Q_{100})	T_{100}		T_{1000}	a model used
Le Biek (tribut. Voer)/ De Beek (tribut. Voer)	**WL**	**VL**		T_{10}		T_{100}		T_{1000}	No flow monitoring station
Gulp	**WL**	**VL**		T_{10}		T_{100}		T_{1000}	
Meuse/ Maas	**WL**/ Lixhe	**NL**	2726 m^3/s (Q_{25})	2302 m^3/s (Q_{10})	3115 m^3/s (Q_{100})	3224 m^3/s (Q_{100})	4060 m^3/s (Q_{100}+30%)	3862 m^3/s (Q_{1000})	
Gueule/ Geul	**WL**/ Sippenaeken	**NL**/ Cottessen	39,10 m^3/s (Q_{25})	39 m^3/s (Q_{10})	57,89 m^3/s (Q_{100})	62,30 m^3/s (Q_{100})	92,43 m^3/s (Q_{1000})	107,1 m^3/s (Q_{1000})	Separate models in NL and WL
Gulp	**VL**	**NL**	T_{10}	6 m3/s (Q10)	T_{100}	13 m3/s (Q100)	T_{1000}		No Q1000 model at the border
Gemeenschappelijke Maas/ Grensmaas	**VL**	**NL**/ Borgharen	2302 (Q_{10})	2302 (Q_{10})	3224 (Q_{100})	3224 (Q_{100})	3862 (Q_{1000})	3862 (Q_{1000})	Exchange of information within the Flemish Dutch Bilateral Meuse Commission A model used
Voer (*)	**VL**	**NL**	T_{10}	T_{10}	T_{100}	T_{100}	T_{1000}	T_{1000}	a model used

Jeker (*)	**VL**	**NL**	T_{10}	T_{10}	T_{100}	T_{100}	T_{1000}	T_{1000}	a model used
Itterbeek/ Thornerbeek (*)	**VL** WIT012B (boundary node from the model)	**NL**	1,27 m^3/s (Q_{10})	1,27 m^3/s (Q_{10})	1,42 m^3/s (Q_{100})	1,42 m^3/s (Q_{100})	1,55 m^3/s (Q_{1000})	1,55 m^3/s (Q_{1000})	Coordination on the basis of flow data
Abeek - Grote Lossing/ Uffelsche beek	**VL**	**NL**	T10	5,5 m^3/s (Q_{10})	T100	7.9 m^3/s (Q_{100})	T1000	11,1 m^3/s (Q1000)	
Wurm/ Worm	Crossing the border **DE-NL**	Crossing the border **DE-NL**	HQ_{20}	T_{20}	HQ_{100}	Q_{100}	$HQ_{extreme}$	T_{1000}	A model is used and a common transboundary map is made For the second cycle a new model is used and therefore new data and maps will be made.
Rodebach/ Roode Beek	Crossing the border **DE-NL**	Crossing the border **DE-NL**	139,9 m^3/s (HQ_{20})	T_{10}	HQ_{100}	T_{100}	$HQ_{extreme}$	T_{1000}	A model was used and a common transboundary map was produced. The Netherlands made new calculations. This leads to small adjustments of the flood areas on the Dutch side. On the German side, the flood areas calculated in the first cycle were not adjusted. Germany has created new maps (new layout)
Kitschbach/ Molenbeek	Crossing the border **DE-NL**	Crossing the border **DE-NL**	H=12,16 m (bei HQ_{10})	T_{20}	HQ_{100}	T_{100}	$HQ_{extreme}$	$HQ_{extreme}$	A model was used and a common transboundary map was produced. No recalculations were made for the second cycle. Germany developed new maps (new layout).
Rur/ Roer	Crossing the border **DE-NL** (Stah)	Crossing the border **DE-NL** (Stah)	Q_{20}	125,5 m^3/s (T_{10})	HQ_{100}	180 m^3/s (T_{100})	$HQ_{extreme}$	290 m^3/s (T_{1000})	Dutch data were used and the initial conditions of the model were coordinated with those of the Dutch model for the development of the maps on the German side
Niers	Crossing the border **DE-NL** (Goch)	Crossing the border **DE-NL**	30	H=12,16 m (at T_{10})	H=13,13 m (at HQ_{100})	H=13,13 m (at T_{100})	H=13,79 m (at $HQ_{extreme}$)	H=13,79 (à T_{1250}))	The water level of the Meuse is decisive at the German-Dutch border. This water level is the downstream condition for Germany

(*) For some small streams, this was done differently because the reference points upstream and downstream of the border are not always on or near the border, so that the water levels are not comparable.

For this reason, the coordination was carried out as follows:

- Voer, Jeker, Berwinne: for these rivers, a cross-border model was developed in the first cycle within the framework of the Interreg project AQUADRA; this forms the basis for the flood hazard and flood risk maps. Coordination was therefore achieved through the development of a transboundary model.

- Wurm, Rodebach, Kitschbach: As these three rivers partially form the border, no flows at this level can be indicated. However, the maps for these rivers are based on a single model for each of them. Thus, the respective flows are identical on both sides of the border.

- Niers: the Niers on the German-Dutch side is located in the retention area of the Meuse. The water level of the Meuse was therefore taken into account as a decisive factor in the hydraulic calculation.

The table shows the return periods (Tx) or flows for a certain return period (HQx) for which the maps were produced.

Annex 3: Types of measures with a potential transboundary effect and expected form of coordination

Legend:

• green: measure or type of measure for which coordination or exchange of information exchange of information is not justified

• orange: measure or type of measure for which an exchange of information is necessary

• red: measure or type of measure for which multilateral coordination is required

either by virtue of the provisions of the FRD or because of the added value of such coordination.

	IMC
Aspects of flood risk management	
<u>1. Prevention</u>	
1.1. Avoidance	
Measure to prevent the location of new or additional receptors in flood prone areas	
a) planning policies	
b) land use regulation	
1.2. Removal or relocation	
a) remove receptors from flood prone areas	
b) relocate receptors to areas of lower probability of flooding and/or of lower hazard	
1.3. Reduction	
Measure to adapt receptors to reduce the adverse consequences in the event of a flood actions on buildings, public networks, etc...	
1.4. Other prevention	
Other measure to enhance flood risk prevention	
a) flood risk modelling and assessment	
b) flood vulnerability assessment	
c) maintenance programmes or policies	For transboundary watercourses
<u>2. Protection</u>	
2.1. Natural flood management / runoff and catchment management	
Measures to reduce the flow into natural or artificial drainage systems, such as overland flow interceptors and / or storage, enhancement of infiltration, etc and including in-channel, floodplain works and the reforestation of banks, that restore natural systems to help slow flow and store water.	
2.2. Water flow regulation	
Measures involving physical interventions to regulate flows which have a significant impact on the hydrological regime	

a) construction, modification or removal of water retaining structures (e.g., dams or other on-line storage areas)	
b) development of existing flow regulation rules	
2.3. Channel, Coastal and Floodplain Works	
Measures involving physical interventions in freshwater channels, mountain streams, estuaries, coastal waters and flood-prone areas of land, such as the construction, modification or removal of structures or the alteration of channels, sediment dynamics management, dykes, etc.	
2.4. Surface Water Management	
Measures involving physical interventions to reduce surface water flooding, typically, but not exclusively, in an urban environment, such as enhancing artificial drainage capacities or though sustainable drainage systems (SuDS)	
2.5. Other Protection	
Other measure to enhance protection against flooding, which may include flood defence asset maintenance programmes or policies	
3. Preparedness	
3.1. Flood Forecasting and Warning	
Measure to establish or enhance a flood forecasting or warning system	
3.2. Emergency Event Response Planning / Contingency planning	
Measure to establish or enhance flood event institutional emergency response planning	
3.3. Public Awareness and Preparedness	
Measure to establish or enhance the public awareness or preparedness for flood events	
3.4. Other preparedness	
Other measure to establish or enhance preparedness for flood events to reduce adverse consequences	
4. Recovery & Review	
4.1. Individual and societal recovery	
Clean-up and restoration activities (buildings, infrastructure, etc)	
Health and mental health supporting actions, incl. managing stress	
Disaster financial assistance (grants, tax), incl. disaster legal assistance, disaster unemployment assistance	
Temporary or permanent relocation	
Other	
4.2. Environmental recovery	

Clean-up and restoration activities (with several sub-topics as mould protection, well-water safety and securing hazardous materials containers)	
4.3. Other recovery and review	
Lessons learnt from flood events	
Insurance policies	
Other	

Annex 4: Potential synergy between the types of FRD measures and the environmental objectives of the WFD

Legend:

\+ = types of FRD measures supporting the environmental objectives of the WFD

0 = types of FRD measures not relevant to WFD environmental objectives

! = types of FRD measures that may conflict with the environmental objectives of the WFD and require a case-by-case examination.

	FR	WL	NRW	VL	NL	CIM
Aspects of flood risk management						
1. <u>Prevention</u>						
1.1. Avoidance						
Measure to prevent the location of new or additional receptors in flood prone areas	+	+	+	+	+	+
a) planning policies	+	+	+	+	+	+
b) land use planning policies or regulation	+	+	+	+	+	+
1.2. Removal or relocation						
a) remove receptors from flood prone areas	+	+	+	+	+	+
b) relocate receptors to areas of lower probability of flooding and/or of lower hazard	+	+	+	+	+	+
1.3. Reduction						
Measure to adapt receptors to reduce the adverse consequences in the event of a flood actions on buildings, public networks, etc...	+	+ / ! / 0	+ / ! / 0	+ / ! / 0	0 / +	
1.4. Other prevention						
Other measure to enhance flood risk prevention						
a) flood risk modelling and assessment	0	0	0	0	0	0
b) flood vulnerability assessment	0	0	0	0	0	0
c) maintenance programmes or policies	+ / !	+ / !	0	+ / !	+ / !	+ / !
2. <u>Protection</u>						
2.1. Natural flood management / runoff and catchment management						
Measures to reduce the flow into natural or artificial drainage systems, such as overland flow interceptors and / or storage, enhancement of infiltration, etc and including in-channel, floodplain works and the reforestation of banks, that restore natural systems to help slow flow and store water.	+	+	+	+	+	+
2.2. Water flow regulation						
Measures involving physical interventions to regulate flows and which have a significant impact on the hydrological regime						

a) construction, modification or removal of water retaining structures (e.g., dams or other on-line storage areas)	+ / !	+ / !	!	+ / !	+ / !	+ / !
b) development of existing flow regulation rules	+ / !	+ / !	!	+ / !	+ / !	+ / !
2.3. Channel, Coastal and Floodplain Works						
Measures involving physical interventions in freshwater channels, mountain streams, estuaries, coastal waters and flood-prone areas of land, such as the construction, modification or removal of structures or the alteration of channels, sediment dynamics management, dykes, etc.	+ / !	+ / !	!	+ / !	+ / !	+ / !
2.4. Surface Water Management						
Measures involving physical interventions to reduce surface water flooding, typically, but not exclusively, in an urban environment, such as enhancing artificial drainage capacities or though sustainable drainage systems (SuDS)	+	+	! / 0	+	+	+
2.5. Other Protection						
Other measure to enhance protection against flooding, which may include flood defence asset maintenance programmes or policies	+ / !	+ / !	0	+ / !	+ / !	+ / !
3. Preparedness						
3.1. Flood Forecasting and Warning						
Measure to establish or enhance a flood forecasting or warning system	0 / +	0 / +	0 / +	0 / +	0 / +	0 / +
3.2. Emergency Event Response Planning / Contingency planning						
Measure to establish or enhance flood event institutional emergency response planning	0 / +	0 / +	0	0 / +	0 / +	0 / +
3.3. Public Awareness and Preparedness						
Measure to establish or enhance the public awareness or preparedness for flood events	0 / +	0 / +	0	0 / +	0 / +	0 / +
3.4. Other preparedness						
Other measure to establish or enhance preparedness for flood events to reduce adverse consequences	0	0	0	0	0	0
4. Recovery & Review						
4.1. Individual and societal recovery						
Clean-up and restoration activities (buildings, infrastructure, etc.)	0	0	0	0	0	0
Health and mental health supporting actions, incl. managing stress	0	0	0	0	0	0
Disaster financial assistance (grants, tax), incl. disaster legal assistance, disaster unemployment assistance,	0	0	0	0	0	0
Temporary or permanent relocation	0	0	0	0	0	0
Other	0	0	0	0	0	0
4.2. Environmental recovery						

Clean-up and restoration activities (with several sub-topics as mould protection, well-water safety and securing hazardous materials containers)	0 / +	0 / +	0	0 / +	0 / +	0 / +
4.3. Other recovery and review						
Lessons learnt from flood events	0 / +	0 / +	0 / +	0 / +	0 / +	0 / +
Insurance policies	0	0	0	0	0	0
Other	0	0	0	0	0	0

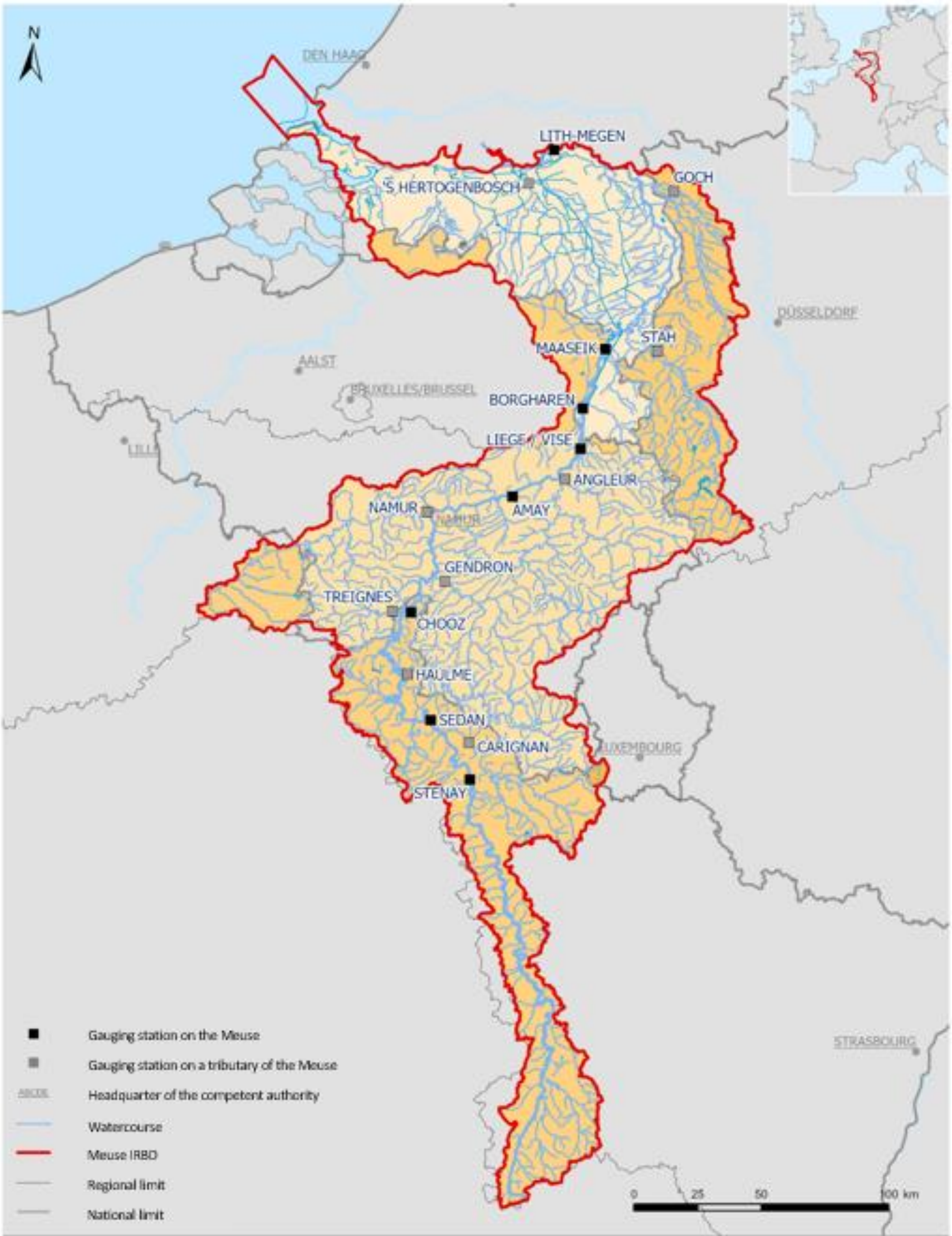
Annex 5: Retrospective analysis of the floods in the Meuse IRBD

Station / Pegel	Gestionnaire / Operator / Betreiber	Cours d'eau / waterloop / Gewässer	BV /SG /EZG (km²)	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
STENAY	DREAL Grand-Est	MEUSE / MAAS	3904	-	-	-	188	121	321	352	290	377	156	392	146	263	130	220	188	146	330	345	353	424	404					283	247	384	146
CARIGNAN	DREAL Grand-Est	CHIERS	1967	-	-	-	-	-	-	-	73	208	62,5	90,8	83	82,3	78,5	82,3	86	57,5	87	83	99,5	89,6	102	103	217	117	82,5	93,3	92	117	93,3
SEDAN	DREAL Grand-Est	MEUSE / MAAS	6492	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HAULME	DREAL Grand-Est	SEMOIS / SEMOY	1336	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	238	226	291	178	403	99,5	300	285	228	222
TREIGNES	SPW	VIROIN	548,2	-	-	-	-	-	-	-	-	-	33,7	72,9	48,7	60,7	59,4	74,5	62,2	55,8	76,5	68,8	89,4	171	99,5	88,6	70,1	122	54,8	94,5	98	110	62,3
CHOOZ	DREAL Grand-Est	MEUSE / MAAS	10120	690	730	640	895	540	1050	906	835	775	763	901	541	457	472	616	615	295	763	616	648	705	295	836	607	1150	496	740	713	751	568
GENDRON	SPW	LESSE	1286	-	-	-	-	-	-	-	-	122	84,3	178	101	120	91,6	126	105	58,1	131	116	121	377	130	124	157	228	94,7	159	156	210	143
NAMUR	SPW	SAMBRE	2843	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AMAY	SPW	MEUSE / MAAS	16416	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ANGLEUR	SPW	OURTHE	3607	413	501	456	331	331	480	607	403	343	280	621	170	315	259	415	204	183	254	284	446	748	505	399	509	822	231	472	485	711	332
LIEGE / VISE	SPW	MEUSE / MAAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BORGHAREN	RWS	MEUSE / MAAS		1576	2114	1621	1506	1124	1881	1935	1565	1349	714	2154	924	976	793	1241	1014	619	1186	1031	1420	1989	1246	1317	1057	2461	850	1665	1530	1810	1125
MAASEIK		MEUSE / MAAS		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1018	1382	1970	1271	1306	1095	2187	858	1535	1463	1825	1103
STAH	LANUV	RUR / ROER		84,4	114	95,8	43,2	46,6	109	129	112	99,6	55,7	103	42	54,5	51,6	89,5	86,9	39	49	50,3	76	111	104	86,7	129	116	69,9	82,1	117	126	93,6
GOCH	LANUV	NIERS / NIERSE		42,4	25,6	23,5	19,7	10,1	29,4	33,7	27,7	26,8	18,8	29,9	14,7	10,1	9,1	22,4	18,9	10,8	10,4	12,6	22,1	30,3	27,5	23,3	25,3	30,0	21,7	28,2	24,9	24,8	18,0
LITH-MEGEN	RWS	MEUSE / MAAS		1603	1782	1538	1311	953	1883	1998	1508	1432	903	1975	1001	960	876	1201	1039	736	1112	1079	1252	1531	1264	1322	1121	2231	980	1335	1381	1738	1103
'S HERTOGENBOSCH	WDD	DOMMEL	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37,5	57,5	79,4	73,3	61,7	57,2	71,1	62	76,1	17,7	61,5	52,2

Station / Pegel	Gestionnaire / Operator / Betreiber	Cours d'eau / waterloop / Gewässer	BV /SG /EZG (km²)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
STENAY	DREAL Grand-Est	MEUSE / MAAS	3904	463	432	193	415	399	533	222	368	247	392	313	254	437	262	268	116	248	336	245	188	268	291	260	340	157	164	243	179	410	194
CARIGNAN	DREAL Grand-Est	CHIERS	1967	109	122	104	191	113	197	96,4	113	1400	144	113	144	133	138	134	109	139	144	109	124	142	148	144	144	81,8	75,1	183	148	150	139
SEDAN	DREAL Grand-Est	MEUSE / MAAS	6492	-	-	-	-	572	875	285	440	413	318	244	501	583	420	383	211	285	421	291	271	328	393	367	411	215	234	320	391	552	277
HAULME	DREAL Grand-Est	SEMOIS / SEMOY	1336	235	383	200	641	293	465	131	237	288	303	142	329	241	457	153	113	141	321	159	166	215	364	266	164	111	122	130	169	231	169
TREIGNES	SPW	VIROIN	548,2	104	78,8	79,4	273	98,2	147	56,5	69	105	126	60,2	145	133	189	62,0	57,5	59,1	117	117	110	177	237	91,2	192	88,9	60,4	83,6	64	55,5	89,9
CHOOZ	DREAL Grand-Est	MEUSE / MAAS	10120	736	1114	655	1450	978	1570	480	623	852	996	560	1020	1060	####	604	490	523	809	579	713	790	1030	787	620	451	468	592	605	784	674
GENDRON	SPW	LESSE	1286	201	188	150	391	167	328	78,5	133	160	234	120	290	274	346	130	89,6	94,3	186	179	153	133	339	169	253	124	90,8	151	114	129	152
NAMUR	SPW	SAMBRE	2843	207	217	208	424	216	337	263	228	264	295	203	321	418	385	172	162	173	202	226	199	302	314	217	229	234	217	232	160	161	241
AMAY	SPW	MEUSE / MAAS	16416	-	-	-	-	-	-	667	897	1142	1521	852	1511	1549	####	1036	843	816	1181	1009	1089	1419	1826	1279	1282	983	841	1017	996	1155	1127
ANGLEUR	SPW	OURTHE	3607	342	770	329	829	402	654	193	226	602	480	338	351	686	599	408	372	302	389	296	345	490	647	409	342	329	321	314	260	345	537
LIEGE / VISE	SPW	MEUSE / MAAS	-	-	-	-	-	-	-	846	1038	1634	1996	1333	1835	2186	####	1325	1134	1139	1530	1378	1168	1636	2244	1619	1414	1166	1091	1151	####	1335	1476
BORGHAREN	RWS	MEUSE / MAAS		1420	1767	1191	2954	1592	2697	737	1055	1619	1977	1153	1758	2128	####	1218	1105	1072	1430	1252	1087	1613	2214	1506	1236	1031	895	1204	####	1359	1540
MAASEIK		MEUSE / MAAS		1353	1715	1200	2811	1609	2736	758	1064	1621	1913	1186	1766	2180	####	1337	1166	1120	-	1286	1194	1659	2177	1503	1284	1036	994	1219	####	1406	1593
STAH	LANUV	RUR / ROER		82,1	109	68	119	73	105	51	61	96	74	73	88	123	109	92	96	56	89	70	56	96	129	97	54	115	69	67	36	77	123
GOCH	LANUV	NIERS / NIERSE		17,6	15,5	12,5	18,6	31,0	39,0	16,0	14,3	36,7	29,1	21,8	18,9	30,1	35,0	18,9	27,6	17,1	21,4	18,1	17,3	29,2	28,1	22,3	17,6	18,5	20,0	29,3	18,7	21,0	13,2
LITH-MEGEN	RWS	MEUSE / MAAS		1219	1578	1160	2752	1705	2865	805	1031	1481	1560	1338	1768	2004	####	1241	1199	1069	1501	1233	1034	1443	2069	1496	1291	1003	1101	1233	####	1438	1493
'S HERTOGENBOSCH	WDD	DOMMEL	1800	42,2	50,2	43,8	87,3	83,5	99,6	40,1	43,6	100	86	66,6	53,6	98,3	104	48	76,6	50,9	59,3	55,3	52,9	82	82,5	65,7	52,6	40,2	45,6	33	65	53,5	51,5

Return period	T > 2 years	T > 10 years	T > 20 years	T > 50 years	T > 100 years
Flood	Seasonal Flood	Small Flood	Medium Flood	Large Flood	Very Large Flood
Frequency	Very Common	Common	Less Common	Rare	Very Rare
Potential damage	Localized overflows	Flooding of agricultural land and isolated dwellings, localized road cuts	Flooding of agricultural land and urbanized areas, interurban traffic cuts	Generalized overflows with localized evacuation of the population due to power or drinking water supply cuts	Generalized evacuation of the population for health or safety reasons, submersion or even breakage of dikes possible

Station	T = 2 years	T = 10 years	T = 20 years	T = 50 years	T = 100 years
STENAY	**260**	**440**	**500**	**590**	**650**
CARIGNAN	**110**	**170**	**190**	**210**	**230**
SEDAN	**330**	**490**	**550**	**650**	**700**
HAULME	**210**	**400**	**460**	**540**	**600**
TREIGNES	**74**	**128,9**	**149,8**	**176,9**	**197,3**
CHOOZ	**690**	**940**	**1100**	**1300**	**1500**
GENDRON	**133**	**229,9**	**267**	**314,9**	**350,9**
NAMUR	**190,3**	**300,2**	**342,2**	**396,6**	**437,4**
AMAY	**1008,2**	**1476,6**	**1655,8**	**1887,6**	**2061,3**
ANGLEUR	**365,2**	**576,3**	**657**	**761,4**	**839,7**
LIEGE / VISE	**1240**	**1907,6**	**2162,8**	**2493,2**	**2740,8**
BORGHAREN	**1410**	**2260**	**2560**	**2930**	**3190**
MAASEIK	**1562**	**2284**	**2600**	**3005**	**3316**
STAH	**87**	**122**	**136**	**155**	**160**
GOCH	**23,7**	**32,8**	**36,3**	**40,6**	**43,6**
LITH-MEGEN	**1409**	**2177**	**2448**	**2785**	**3014**
'S HERTOGENBOSCH	**62**	**82**	**90**	**102**	**111**



Location of the stations of the retrospective analysis of the floods in the Meuse IRBD

Annex 6: Methodology used in the available studies on the potential effects of climate change on the evolution of flood flows

1 – AMICE

The purpose of this sub-chapter is to summarise the method and results presented in the report "Analysis of climate change, high-flows and low-flows scenarios on the Meuse basin" of 30 June 2010 of Action 3 of Work Package 1 of the Interreg AMICE project (Adaptation of the Meuse to the Impacts of Climate Evolutions).

Carried out between 2009 and 2010 within the framework of the European Union's Interreg IV-B programme, the aim of this action was to identify possible impacts of climate change on the hydrological regime of rivers in the Meuse basin in the near future (2021-2050) and in the distant future (2071-2100).

A synthesis of the literature was carried out on climate change.

The studies analysed all give fairly clear trends for the Mediterranean region (very strong temperature increase and precipitation decrease) and the Scandinavian region (strong temperature increase and precipitation increase). As the Meuse basin lies between these two regions, and depending on the models used, the Meuse basin becomes drier or experiences an increase in precipitation.

The AMICE partners decided to divide the results of the climate models into future climates in order to study the two possible evolutions of the climate of the basin: a wet climate and a dry climate. This pragmatic approach was adopted because of: (1) limited time to use what was available (2) the uncertainty of some climate models indicating a drier climate and others indicating a wetter future.

It can be mentioned here that, within the framework of the European PRUDENCE project, Blenkinsop and Fowler (2007) tested several regional climate models, in particular over the Meuse basin. The regional climate models revealed a wide range of anomalies: from 0% change to 60% change in a single month. It is therefore not surprising that the AMICE partners are confronted with very different results from their national climate simulations. The same authors also mention that several models demonstrate the spatial variability of climate change.

The scenarios proposed by the AMICE partners are plausible scenarios: they are not very different from the trends used in other climate impact studies. However, this does not mean that the wet or dry climate scenario will actually happen. Water managers and decision-makers should be very aware that the results represent only two possible future climate trends, with no absolute certainty about which climate will occur.

A synthesis of the literature was carried out on the impacts of climate change on the hydrology of the Meuse.

The main conclusion was that the simplest solution is to create new climate and hydrological scenarios. To this end, the optimal solution was to apply the delta change approach to the existing national scenarios in order to create a wet and a dry scenario for the periods 2021-2050 and 2071-2100 for each national sub-basin (see Table 1).

Table 1: climate models used in the different parts of the basin to define the dry and wet scenarios

	SRES scenarios	Climate experiment or model	Data provider and contact person	Downscaling method	Source of data	Type of simulation	Time period for the control run
French part of the basin	A2/A1B	ARPEGE-climat v4.6	Météo-France (L. Labbé)	Bias correction (Q-Q plot)	Météo France	Transient simulation	1961-1990
Walloon part of the basin	A1B/ A2/B1/B2	CCI-HYDR Perturbation Tool	KULeuven (P. Willems)	statistical	Royal Institute Belgium		1961-1990
German part of the basin	A1B	WETTREG (wet scenario) CLM (dry scenario)	DWD (T. Deutschländer)	dynamical (CLM) & statistical (WETTREG)	WETTREG: Meteo Research pp Umweltbundesamt CLM: MPI-M-M/MaD pp BMBF	Transient simulation	1971-2000
Dutch and Flemish parts of the basin	A2/B1	PRUDENCE	KNMI	dynamical & statistical	KNMI	Transient	1961-1990

The meteorological variables for the future time periods were calculated using data from the E-OBS 2.0 climatological database transformed according to the "delta change" method (see Figure 1).

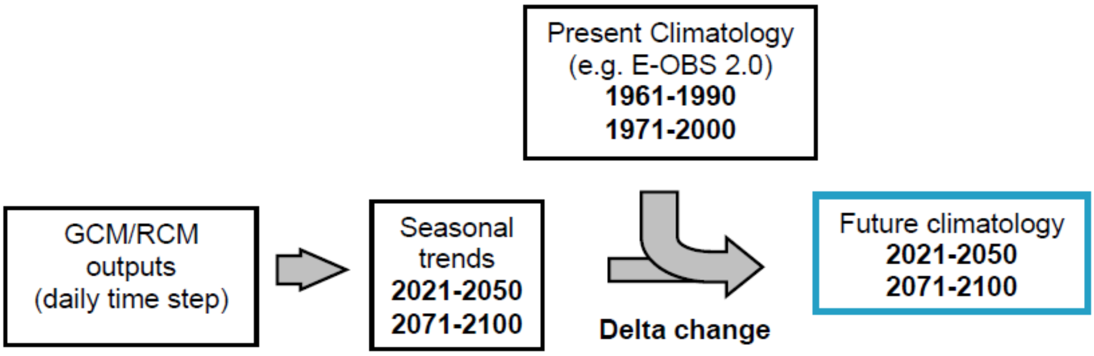


Figure 1: method for producing future weather data used in AMICE

The delta change method consists of deducing the daily weather data from the present time by applying the following transformations for each calendar day:

- for temperatures: $T_{future} = T_{obs\ present} + (\langle T_{mod\ future}\rangle - \langle T_{mod\ present}\rangle)$
- for precipitations: $P_{future} = P_{obs\ present} \times \langle P_{mod\ future}\rangle / \langle P_{mod\ present}\rangle$

where:

- T_{future} and P_{future} are the daily values calculated in the future time
- $T_{obs\ present}$ and $P_{obs\ present}$ are the daily values in the present time (E-OBS 2.0 database)
- $\langle T_{mod\ present}\rangle$ and $\langle P_{mod\ present}\rangle$ are the interannual averages of daily values calculated by global climate models (GCM) or regional climate models (RCM) for the present time (see Table 1)
- $\langle T_{mod\ future}\rangle$ and $\langle P_{mod\ future}\rangle$ are the interannual averages of daily values calculated by climate models (GCM or RCM) for future time (see Table 1)

The AMICE partners observed clear heterogeneities between the climate scenarios from the four national parts of the basin. In order to maintain downstream consistency of discharges, especially at boundaries, a transnational scenario was established. For this purpose, the national trends were weighted according to the area of each sub-basin (Table 2).

Table 2: weighting coefficients used to create the transnational seasonal trends

	Drainage area (km²)	Weighting coefficient
France	10.120	0,31
Walloon	10.880	0,33
Flanders & Netherlands	8.662	0,26
Germany	3.338	0,10
Transnational Meuse	**33.000**	**1,0**

For floods, it makes a big difference if it rains 20% harder or 20% longer. The climate scenarios currently available do not allow this point to be made. However, most climate-related projects change the intensity of rainfall but not its duration. The AMICE project followed this approach. This decision was taken mainly because our interest is in the maximum or minimum flows, and less in the volume of flood. The maximum flow is related to the height of the water and determines the flooded area. The volume is related to the duration of the flood itself and is important to calculate how long the area will be flooded. In the AMICE project, the partners have assumed that the flooded area can be changed, but that the duration of the flooding will remain the same as the current duration.

One of the main gaps in the AMICE project is the study of extreme rainfall in small basins.

Extreme rainfall concentrated in small areas can create devastating mudslides. The impact is very limited on the water level of the main rivers but the damage is very costly locally. In contrast to major floods which occur mainly in winter, extreme rainfall events can occur at any time of the year. Such events occurred, for example, in the eastern part of Liege in May 2008.

Climate scenarios predict that these extreme events will occur more frequently. But this phenomenon is hardly known in the Meuse basin. There is no monitoring or detailed analysis of their frequency and causes. It is also very difficult to predict the location and intensity of these events, and even more difficult to model them. Therefore, the AMICE project partners have only mentioned that extreme precipitation events may become more frequent in the coming century (Christensen & Christensen, 2003 – Intensification of extreme European summer precipitation in a warmer climate. Global and Planetary Change, 2004, 44, 107–117).

2 – New knowledge available since AMICE

a) KNMI'14 study:

Based on the new forecasts published by the Intergovernmental Panel on Climate Change (IPCC), the Royal Netherlands Meteorological Institute (KMNI) has drawn up four new climate scenarios for the Netherlands, known as KNMI'14, for the periods 2050 and 2085 (see figures 2 and 3 - source = "KNMI'14 climate scenarios for the Netherlands - Revised edition 2015"), which take into account both the evolution of temperature (G and W scenarios) and changes in air circulation (H and L indices).

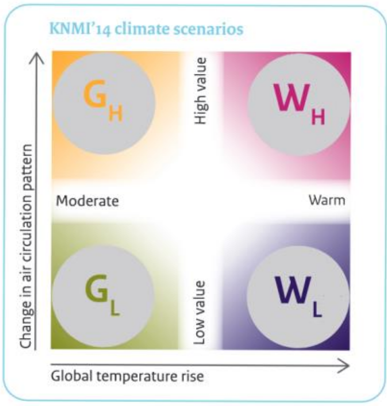


Figure 2: KNMI'14 scenarios (G stands for Gematigd, i.e. moderate in Dutch; W stands for Warm - H stands for High and L stands for Low)

The increase in global average temperature is the first classification criterion that distinguishes the scenarios. In the G scenarios, the increase in global average temperature is 1°C in 2050 and 1.5°C in 2085 compared to 1981-2010; in the W scenarios, it is 2°C in 2050 and 3.5°C in 2085 compared to 1981-2010 (see Figure 4). G stands for Gematigd, i.e. moderate in Dutch; W stands for Warm. These future warming ranges include about 80% of the latest climate model calculations.

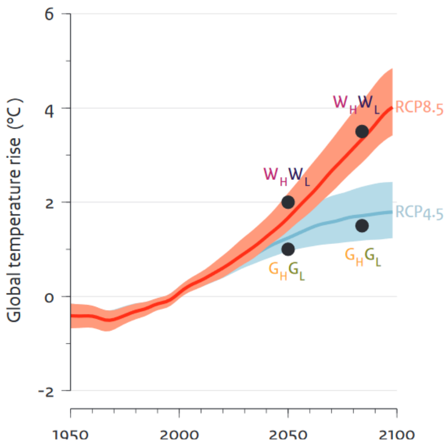


Figure 3: temperature increase by 2050 and 2085 compared to the period 1981-2010 in the KNMI'14 scenarios

In the H (High) scenarios, westerly winds are more frequent in winter. This results in milder and wetter weather than in the L (Low) scenarios. In summer, high pressure systems have a greater influence on the weather in the H scenarios. Compared to the L scenarios, these high pressure systems cause more easterly winds, which implies warmer and drier weather for the Netherlands.) They give the change towards 2050 and 2085 compared to the climate of the period 1981-2010.

A 5th meteorological scenario $W_{H,dry}$ was developed to identify possible impacts of climate change on the hydrological regime of the Meuse in 2050 and 2085 in the case of an extremely dry summer.

A new method called "advanced delta change" was used to calculate future daily rainfall in relation to current daily rainfall (see figure 4 from « KNMI'14 climate scenarios for the Netherlands – Revised edition 2015 »).

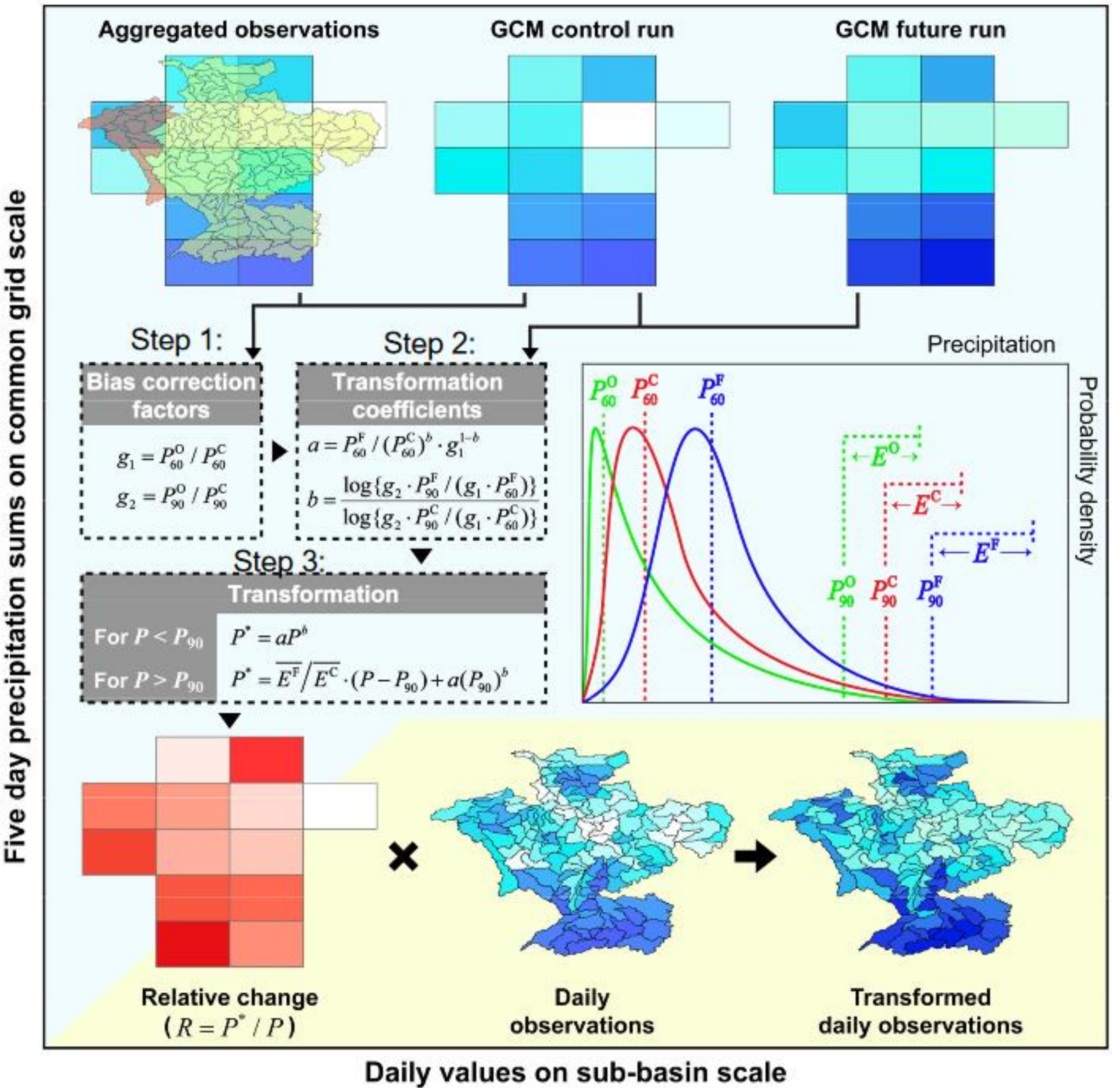


Figure 4: calculation steps in the "advanced delta change" method to transform daily precipitation in the present time from the variations observed in the RCM/GCM

The flows for the present and future time periods were calculated using the hydrological model HBV (Hydrologiska Byråns Vattenbalansavdelning)[12] coupled with the SOBEK hydraulic model to propagate the flood wave from Chooz (see figure 5).

12 *Bergström, S. (1976) Development and application of a conceptual runoff model for Scandinavian catchments. SMHI Reports RHO, No. 7, Norrköping.*
Bergström, S. (1976): Development and application of a conceptual runoff model for Scandinavian catchments. Ph.D. Thesis. SMHI Reports RHO No. 7, Norrköping.
Bergström, S. (1992) The HBV model - its structure and applications. SMHI Reports RH, No. 4, Norrköping.

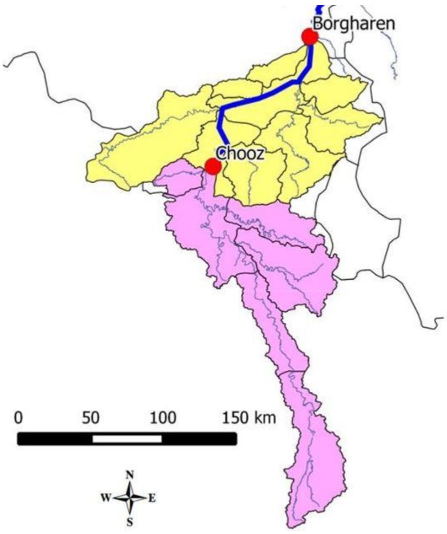


Figure 5: location of the hydrological station of Borgharen on the Meuse

b) Explore 2070

The study project called "Explore 2070 project" funded by the French Ministry of Ecology took place from June 2010 to October 2012 in order to assess the potential impacts of climate change on surface water resources over the future time period 2046-2065 in comparison with the present time reference period 1961-1990 based on the A1B scenario of the IPCC 4th assessment report.

To answer this question, a calculation chain involving two hydrological models (GR4 J and Isba-Modcou) was set up for 1522 catchment areas in mainland France (see figure 6 from the report "Explore 2070 - Hydrologie de surface A1 – Rapport de synthèse") and 35 catchment areas in the overseas departments (Guadeloupe, Guyana, Martinique and Reunion).

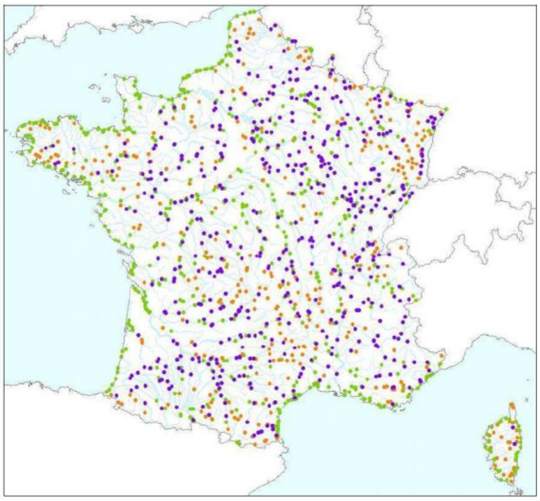


Figure 6: location of Explore 2070 calculation points (purple = points with GR4J and Modcou - orange = points with GR4J alone - green = points with Modcou alone).

7 climatological models were used to establish flow projections using the two hydrological models for the present time period 1961-1990 and the future time period 2046-2065 (see Table 3 from the report « Explore 2070 - Hydrologie de surface A1 – Rapport de synthèse »).

Table 3: climate models used in the Explore 2070 project

GHG Scenario	*Model name and nomenclature Explore 2070*		*Name of the simulation*	*Climate centre*	*Period provided (hydrological years between)*
A1B	CCCMA_CGCM3	**C1**	A1B_CCCMA-CGCM3	CCCMA (Canada)	1961-1991 2046-2065
A1B	ECHAM5/MPI	**C2**	A1B_ECHAM5-MPI	MPI (Allemagne)	1961-1991 2046-2065
A1B	ARPEGE V3+	**C3**	A1B-ARPV3	Météo-France	1961-1991 2046-2065
A1B	GFDL-CM2.0	**C4**	A1B_GFDL-CM2.0	GFDL (USA)	1961-1991 2046-2065
A1B	GFDL-CM2.1	**C5**	A1B_GFDL-CM2.1	GFDL (USA)	1961-1991 2046-2065
A1B	GISS_MODEL_ER	**C6**	A1B_GISS-MODEL-ER	GISS (USA)	1961-1991 2046-2065
A1B	MRI-CGCM2.3.2	**C7**	A1B_MRI-CGCM2.3.2	MRI (Japon)	1961-1991 2046-2065

To this end, a statistical downscaling method was used to move from the grid of the climatological models to a grid of 8 km x 8 km compatible with the hydrological models used.

This is a multivariate statistical downscaling based on the use of the concept of weather type and derived from the classical method of analogues (see figures 7 and 8 from the CERFACS report « DSCLIM: A software package to downscale climate scenarios at regional scale using a weather-typing based statistical methodology »).

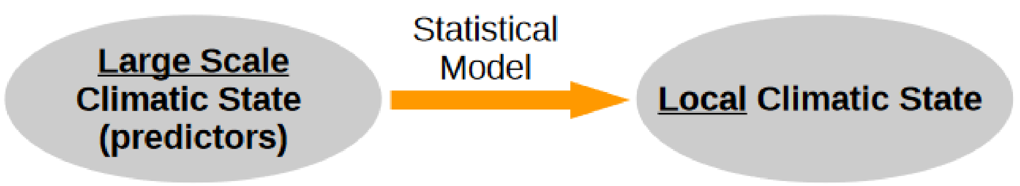


Figure 7: general outline of statistical downscaling methods

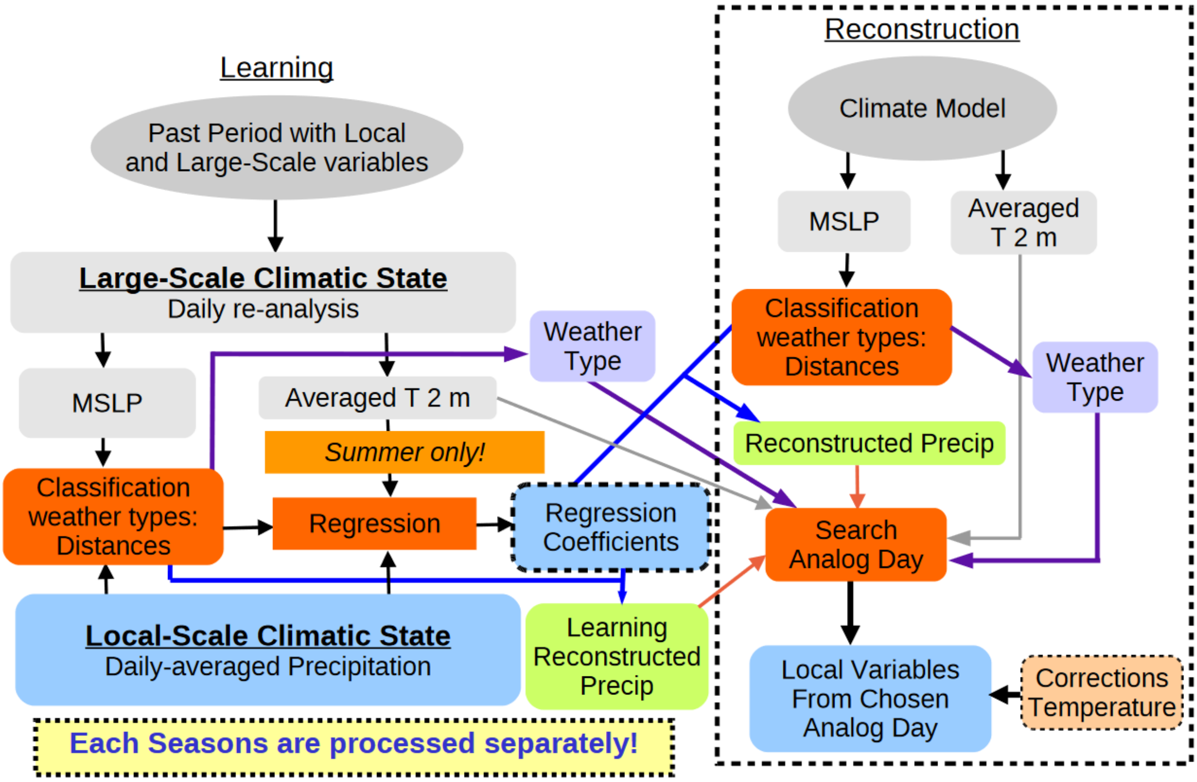


Figure 8: steps implemented in the DSCLIM downscaling method

Regional climate properties are used to establish discriminating weather types for a given local variable (precipitation). The main assumption is that each particular weather regime (represented by a large-scale atmospheric circulation variable, the predictor(s)) is associated with a specific distribution of local climate variables (e.g. temperature and small-scale precipitation, the predictant(s)). This association is represented by a transfer function which is statistically constructed from the available observations and/or reanalyses.

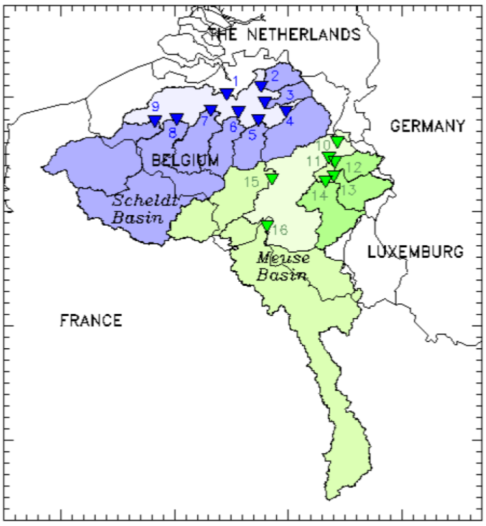
The datasets used to build the transfer function are, on the one hand, the SAFRAN mesoscale meteorological analysis developed at Météo-France (for the predictants) and, on the other hand, the meteorological reanalysis of the National Centre for Environmental Prediction NCEP (for the predictors).

A multi-variate classification of the geopotential field at 500 hPa and the precipitation (310 daily reference series), at daily time step, is performed in the space of the SAFRAN precipitation field principal components. 8 to 10 weather regimes are thus selected. These weather regimes are discriminating for the daily precipitation. Only the large-scale part (provided by the geopotential at 500 hPa, Z500) is then retained to define the weather types.

A regression between SAFRAN precipitation on an 8km grid and distance to weather types is calculated. Conditional resampling is used to determine analogues. A temperature index over Europe (DJ -Djmodel) is used to estimate the temperatures (uniform correction of the temperature with respect to that provided by the analogue). The downscaling is thus performed on the SAFRAN grid (8 km grid).

c) CCI-HYDR

The "CCI-HYDR" research project carried out by the Catholic University of Leuven and the Royal Meteorological Institute of Belgium from 2005 to 2010 aimed to study the impact of climate change on extreme events in rivers in the Belgian parts of the Meuse and Scheldt basins and on wastewater collection facilities (see figure 9 from the article « Climate change and hydrological extremes in Belgian catchments » from Baguis, P., Roulin, E., Willems, P., Ntegeka, V., published in 2010 in the journal Hydrology and Earth System Sciences Discussions).



	Watershed	Outlet	Area (km^2)
			Scheldt Basin
1	Scheldt	Antwerp	18801
2	Kleine Nete	Grobbendonk	590
3	Grote Nete	Hulshout	468
4	Demer	Diest	1908
5	Dijle	Wilsele	896
6	Zenne	Eppegem	1096
7	Dender	Confluence	1389
8	Bovenschelde	Asper	5810
9	Leie	St Baafs	3506
			Meuse Basin
10	Meuse	Visé	20588
11	Ourthe	Angleur	3627
12	Vesdre	Confluence	708
13	Amblève	Martinrive	1068
14	Ourthe	Tabreux	1616
15	Sambre	Namur	1964
16	Meuse	Chooz	10120

Figure 9: stations calculated in the framework of the CCI-HYDR project

The hydrological simulations carried out for the purpose of this study are based on the SCHEME (SCHEldt-MEuse) model, which is the distributed version of the IRM hydrological model (Bultot and Dupriez, 1976). This model has been successfully used for different catchments ranging from about 100 to 1600 km2 and representing different hydrological conditions in Belgium (Gellens and Roulin, 1998).

The structure of the SCHEME model includes 9 land use types with a snow accumulation and snow melt module for each type. Evapotranspiration is calculated on the basis of the water intercepted by vegetation and the water content of two soil layers, as well as potential evapotranspiration (PET) according to the Penman formula. Surface water is simulated with a unit hydrograph and groundwater is represented by two reservoirs. The flow produced on each cell of the network is routed to the outlet with a 1-D sub-model taking into account the river network (see figure 10 - from the article Climate change and hydrological extremes in Belgian catchments).

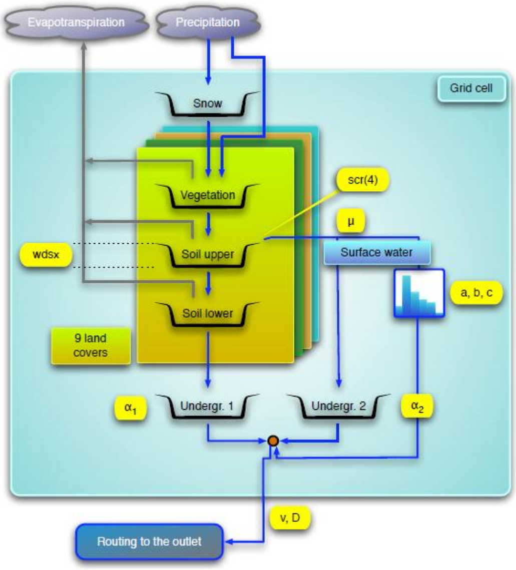


Figure 10: diagram of the mechanisms of the SCHEME model

The climatic data used in the CCI-HYDR project were obtained by transforming the observed meteorological data on the basis of a variant of the delta change method (see figure 11 from the final report « Climate change impact on hydrological extremes along rivers and urban drainage systems in Belgium »).

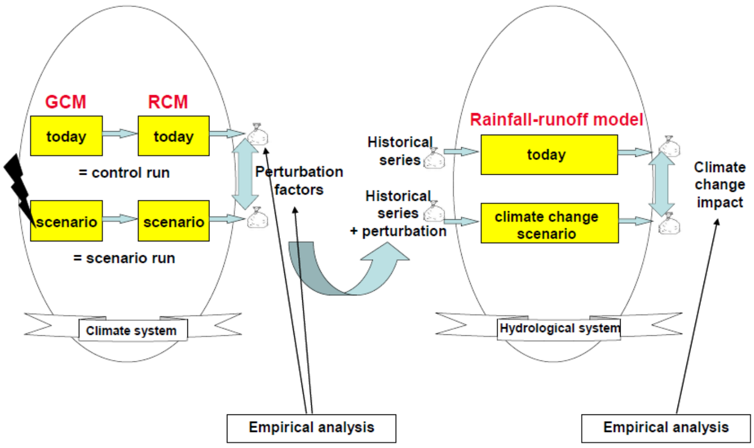


Figure 11: principle of production of the climate data used for the calculations with SCHEME

The transformation factors applied to the observed meteorological data were obtained from the results of the European project PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects - Christensen et al., 2007 - http://prudence.dmi.dk) where 11 RCMs were used to dynamically downscale the climate data produced by 4 different GCMs according to the A2 and B2 greenhouse gas emission scenarios (see table n°4 from the article Climate change and hydrological extremes in Belgian catchments).

Table 4: climatic data used for the hydrological calculations made with SCHEME

MEMBER	SCENARIO	RESOLUTION (Km)	SCENARIO	GCM	RCM
SMHI	SMHI-MPI-A2	49	A2	ECHAM4/OPYC	RCAO
	SMHI-MPI-B2	49	B2	ECHAM4/OPYC	
	SMHI-HC-22	24	A2	HadAM3H	
	SMHI-A2	49	A2	HadAM3H	
	SMHI-B2	49	B2	HadAM3H	
KNMI	KNMI	47	A2	HadAM3H	RACMO
METNO	METNO-A2	53	A2	HadAM3H	HIRHAM
	METNO-B2	53	B2	HadAM3H	
DMI	DMI-S25	25	A2	HadAM3H	HIRHAM
	DMI-ecsc-A2	50	A2	ECHAM4/OPYC	
	DMI-ecsc-B2	50	B2	ECHAM4/OPYC	
	DMI-HS1	50	A2	HadAM3H	
	DMI-HS2	50	A2	HadAM3H	
	DMI-HS3	50	A2	HadAM3H	
ETH	ETH	55	A2	HadAM3H	CHRM
HC	HC-adhfa	50	A2	HadAM3P	HadRM3P
	HC-adhfe	50	A2	HadAM3P	
	HC-adhff	50	A2	HadAM3P	
	HC-adhfd-B2	50	B2	HadAM3P	
MPI	MPI-3005	55	A2	HadAM3H	REMO
	MPI-3006	55	A2	HadAM3H	
CNRM	CNRM-DC9	59	A2	ARPEGE	ARPEGE
	CNRM-DE5	59	A2	ARPEGE	
	CNRM-DE6	59	A2	ARPEGE	
	CNRM-DE7	59	A2	ARPEGE	
GKSS	GKSS-SN	55	A2	HadAM3H	CLM
	GKSS	55	A2	HadAM3H	CLM
ICTP	ICTP-A2	52	A2	HadAM3H	RegCM
	ICTP-B2	52	B2	HadAM3H	RegCM
UCM	UCM-A2	52	A2	HadAM3H	PROMES
	UCM-A2	52	B2	HadAM3H	

d) CORDEX and HydroTrend

Since Belgium is small in terms of climate zones, it is important to first look at the trends in climate change at the European level. At the European scale, all IPCC models predict for all emission scenarios a significant global warming of temperature for the whole of Europe[13] as well as a significant increase in extreme events such as heat waves, droughts and intense precipitation events.

At the Belgian level, a number of studies conducted with the old emission scenarios from the IPCC Fourth Assessment Report attempt to predict the evolution of temperatures by 2100. All of them predict a global increase in temperature at this time horizon. Regardless of the emission scenario used by the various climate models, temperatures tend to increase during the 21st century, regardless of the season considered. However, this increase differs according to the emission scenario considered[14].
With regard to the evolution of precipitation in Belgium for the end of the century, the trends are less obvious and there are marked differences depending on the studies and models used. Despite the differences, the various studies agree on the fact that precipitation by 2100 will be both more numerous and more intense[15] [16].

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[13] Valentini, R., Bouwer, L. M., Georgopoulou, E., Jacob, D., Martin, E., Pounsevell, M., and Soussana, J.-F. (2014). Europe. In Climate Change 2014–Impacts, Adaptation and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pages 1267–1326. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[14] Marbaix, P. and Van Ypersele, J. (2004). Impacts des changements climatiques en Belgique. Greenpeace, Bruxelles.
[15] Baguis, P., Roulin, E., Willems, P., and Ntegeka, V. (2010b). Climate change scenarios for precipitation and potential evapotranspiration over central Belgium. Theoretical and Applied Climatology, 99 : 273
[16] Madsen, H., Lawrence, D., Lang, M., Martinkova, M., and Kjeldsen, T. (2014). Review of trend analysis and climate change projections of extreme precipitation and floods in Europe. Journal of Hydrology, 519 :3634–3650

In summary, the future evolution of precipitation seems much more uncertain than that of temperatures at the Belgian level. Indeed, for all greenhouse gas emission scenarios and regardless of the model used, temperatures tend to increase by the end of the century, whereas the evolution of precipitation seems to differ according to the seasons and the scenario considered. In the event that the predicted increase in temperature is combined with an increase in evapotranspiration and a decrease in precipitation, major problems in the availability of water resources can be expected[17].

More recently, the "COordinated Regional Climate Downscaling EXperiment and beyond" project for Belgium (CORDEX.be) seeks to further refine the results of the general circulation models that led to the IPCC Fifth Assessment Report at the regional scale. The overall aim of this local project is to bring together current Belgian research in the field of climate modelling in order to create a coherent scientific basis for future climate services in Belgium. More specifically, this project aims, among other things, to contribute to the European project Euro-CORDEX and to go beyond this project by carrying out, for Belgium, climate projections on a finer scale (4 km resolution) in order to be able, for example, to study the impact of climate change on agricultural production or on storm waves[18].

The data from this project are daily data that include values for maximum and minimum temperature, precipitation, relative humidity, solar radiation and wind speed. These data are available for a reference period from 1975 to 2005. They are also available between 2007 and 2100 for three emission scenarios from the latest IPCC report. These scenarios are the representative profile scenarios of concentration evolution.

The three scenarios considered by the CORDEX.be project are the two extreme scenarios (the RCP8.5 scenario, which predicts a forcing of +8.5 W/m2 by 2100, and the RCP2.6 scenario, which predicts a forcing of +2.6 W/m2 by the same date) and an intermediate scenario (the RCP4.5 scenario, which predicts a forcing of +4.5 W/m2 by 2100). The most optimistic scenario (RCP 2.6), only foresees a warming limited to less than 1°C. The most pessimistic scenario (RCP 8.5) predicts a warming of more than 3°C in Belgium (météo.be).

Besides these climate change projects, HydroTrend aims to detect and analyse trends in the amplitude and frequency of flood flows in Wallonia.

For this purpose, the annual maximums and values exceeding a certain threshold (POTs - peaks over threshold) were extracted from the data of 84 gauging stations. In order to analyse the evolution over time of the relationship between flood flows and return periods, frequency analyses were carried out for periods of 20 years. The significance of the trends was then checked using statistical tests.

Positive and negative trends were observed for just over half of the stations. Twelve percent of them are significant for the amplitude of the annual maximums and the frequency, and 6% are significant for the amplitude of the POTs. The trends are mostly positive in the Scheldt basin, but both positive and negative in the Meuse basin.

These results demonstrate that the instability of flood flows should be considered in hydrological analyses. This could have repercussions on flood management in Wallonia, since the results of the frequency analyses are used, among other things, in the sizing studies of flood control structures and for the flood hazard maps.

[17] Degré, A. and Bauwens, A. (2009). Amice : Interim activity report of the Walloon Support Committee.

[18] Van Schaeybroeck, B., Termonia, P., De Ridder, K., Fettweis, X., Gobin, A., Luyten, P., Marbaix, P., Pottiaux, E., Stavrakou, T., Van Lipzig, N., et al. (2017). The foundation for climate services in Belgium: Cordex. be. In EGU General Assembly Conference Abstracts, volume 19, page 6855.

e) Chimere 21

Methodology

A set of five pairs of global and regional climate models based on recent greenhouse gas emission scenarios, namely an intermediate scenario (RCP 4.5) and a more extreme scenario (RCP 8.5) were used in this project to produce climate projections. In order to obtain corrected projections for the Meuse catchment area, a debiasing method was used.

A multi-model approach (using four hydrological models and a set of parameters) was implemented. A flow naturalization strategy was implemented in order to neutralize the impact of the Chooz nuclear power plant and to identify the measured flows whose values appeared to be overly influenced by abstractions. The impacts of climate change were quantified based on various indicators relating to regimes, floods and low flows.

The evolution of climate and flows was analysed both on snapshots of the future compared to a historical reference period (1976-2005) and continuously in the 21st century.

Evolution of the climate

The analysis of climate projections indicates, unsurprisingly, a warmer future for the Meuse catchment area, especially in the distant future and in a future with more greenhouse gas emissions (RCP 8.5). Thus, for RCP 8.5, the various climate models agree on an increase in temperature of 3 to 4°C and an increase in the order of 10 to 30% in annual precipitation by 2100 (Figure 12). For RCP 4.5, the increase in precipitation and temperature is less marked.

The seasonal variation is contrasted for precipitation: there is a general trend towards wetter winters than in the present climate, but the trend for summers is more uncertain, with some projections indicating drier summers than in the present climate and others indicating wetter summers.

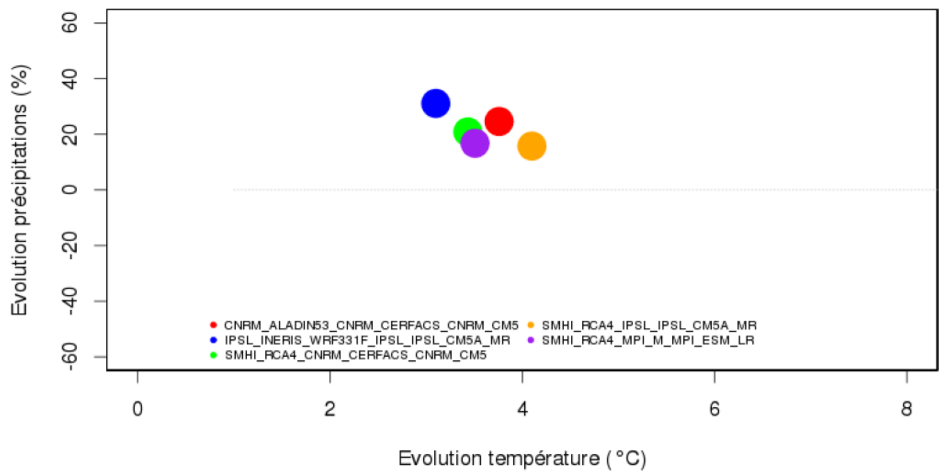


Figure 12: Precipitation and temperature trends for RCP 8.5 for the distant future (2071-2100) compared to the historical period (1976-2005) in the Meuse basin

Particular attention has been given to the quantification of uncertainties associated with the modelling chain. These uncertainties are increasingly large when looking at a long time horizon. Moreover, we have been able to show that the uncertainty associated with the hydrological models is negligible, and that the uncertainty associated with the RCPs is generally low, except for floods and average flows at the end of the 21st century. Finally, internal climate variability accounts for a major part of the uncertainty at the beginning of the century (2005-2020), while climate models account for the major part of this uncertainty from about 2020 onwards.

Consistencies and discrepancies with other work

Compared to an older but still leading project in France, Explore 2070, the climate projections used in the CHIMERE 21 project indicate a warmer, but also wetter future on an annual scale. Although the more recent DRIAS-2020 projections[19] could not be used in this project, a comparison carried out in the framework of CHIMERE 21 showed that the CHIMERE 21 and DRIAS-2020 climate projections were consistent, and both indicated a warmer and wetter future than Explore 2070. However, both sets of recent projections indicate high uncertainties in summer precipitation, as they include both increases and decreases.

Compared to Explore 2070, the flow projections are less pessimistic for low and average flows (smaller decrease in indicators), but more pessimistic for floods (larger increase). Indeed, Explore 2070 had shown strong pressure on low and average flows on the Meuse, which were decreasing, as well as an uncertain evolution of flood flows. This difference is largely based on the new climate projections used in this project, which now indicate an increase in precipitation, in contrast to Explore 2070. Thus, in CHIMERE 21, we were able to benefit from more recent climate projections, based on improved models, consistent with the larger set of projections called DRIAS-2020[20].

[19] http://www.drias-climat.fr/document/rapport-DRIAS-2020-red3-2.pdf
[20] Disponibles sur le site http://www.drias-climat.fr/.

Annex 7: Summary description of the organisation of flood forecasting and hydrometric services

1 – France

Two services are involved in the French part of the Meuse International River Basin District (IRBD) for hydrometry and flood forecasting:

- The Meuse-Moselle unit at the Direction Régionale de l'Environnement, de l'Aménagement et du Logement (DREAL) Grand-Est with the hydrometry unit (HU) and the flood forecasting unit (FFU) Meuse-Moselle;

- The flood forecasting and hydrometry unit of the DREAL Hauts-de-France for the Sambre river basin with the Hauts-de-France Hydrometric Unit and the Artois-Picardy Flood Forecasting Unit.

a) Organisation of hydrometry

- **The Meuse-Moselle monitoring network**

The Meuse-Moselle monitoring network comprises:

- **92** hydrometric stations;
- **20** hydro-meteorological stations;
- **12** meteorological stations.

It is monitored by **10** hydrometers and maintenance staff and a unit manager.

- **The Hauts-de-France monitoring network**

The Hauts-de-France monitoring network comprises:

- **135** hydrometric stations, including 14 in the Sambre basin;
- **20** meteorological stations, including 7 in the Sambre basin.

It is monitored by **13** hydrometers and maintenance staff and a unit manager.

The list of stations is available on the website: **www.vigicrues.gouv.fr**

- **Gauging equipment**

Several types of equipment are used for gauging depending on the flows and situations encountered. The main types are:

- ADCP current meters (M9 from Sontek, RiverPro from RDInstruments...);
- Mini current meters and associated rods;
- surface radars;
- electromagnetic current meters (e.g. EMC4 from Cometec).

- **Gauging strategies**

Gauging priorities are based on:

- gauging of flood to build the high parts of the rating curves;
- gauging in low water for the follow-up of the low water levels in particular the stations influenced by the vegetation;
- stations whose flows are used for the management of water uses;
- stations whose flows are used within the framework of the Water Framework Directive.

b) <u>Organisation of flood forecasting</u>

➢ Presentation of the Flood Forecasting Services (FFS)

The Meuse Moselle FFS consists of 7 forecasters.

Out of **112** hydrometric stations monitored:
- **34** stations are forecasting stations (from yellow vigilance: 24-hour water level forecasts);
- **13** stations are vigilance stations with thresholds (yellow / orange / red) defined according to the stakes.

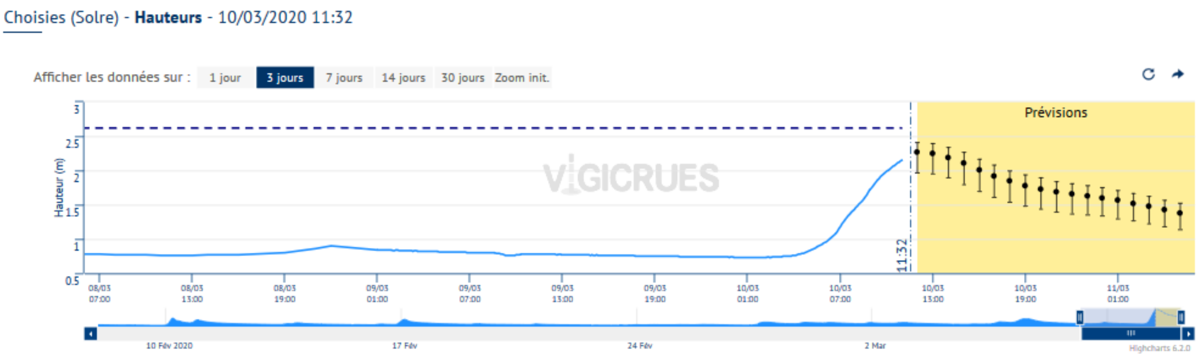
The Artois-Picardie FFS is made up of 5 forecasters and 1 IT referent.

Out of **68** hydrometric stations (including 11 in the Sambre basin) broadcast on Vigicrues:
- **13** stations are quantitative forecasting stations (from yellow vigilance: 24-hour water level forecasts);
- **22** stations are vigilance stations with thresholds (yellow / orange / red) defined according to the stakes.

For each FFS:
- A regulation for monitoring, forecasting and transmitting information on floods is available online.
- **2 flood vigilance bulletins are produced per day (10am and 4pm) with updates in flood situations.**

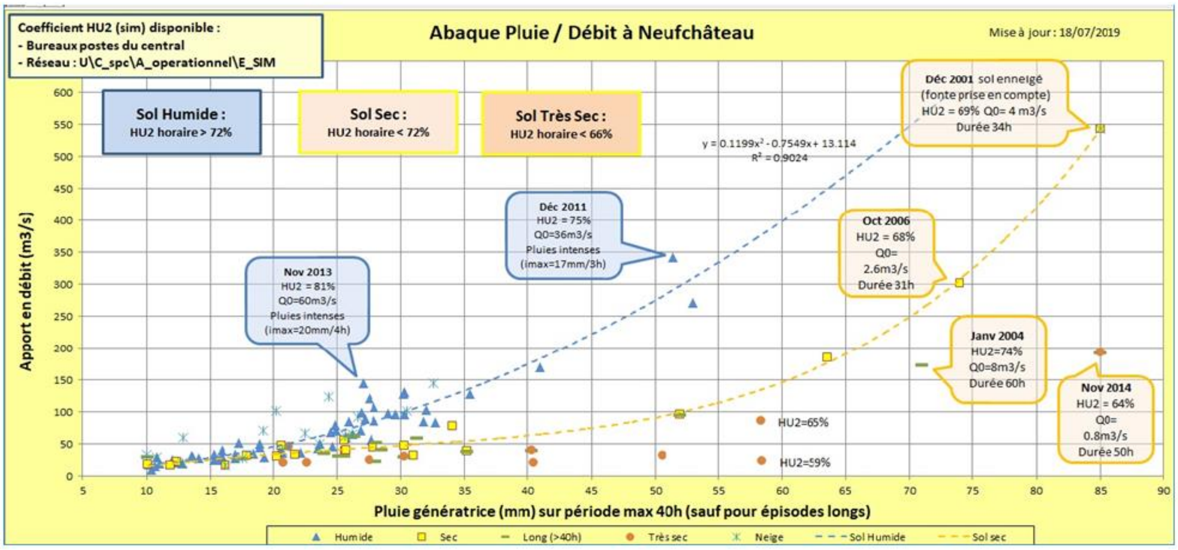
➢ Flood forecasting tools

To produce and display the 24-hour water level forecasts at the forecasting stations, various tools and models are used by the forecasters.
The following are available:
- **graphic forecasts**: available on Vigicrues for 10 stations for the Meuse Moselle FFS and 8 stations for the Artois-Picardie FFS. This number is still evolving;



Example of a graphic forecast for the Solre-sur-la-Sambre station – Source: Vigicrues

- **charts:**
    - Rainfall/flow chart, mainly at the upper part of the catchment area:



Example of a rainfall/flow chart for the Neufchâteau station according to the generating rainfall and soil moisture

- Chart of upstream/downstream flow or upstream/downstream water level relationship by means of observed correlations;

- **the so-called "GRP" forecasting models**

This type of model predicts future flows at a gauged point on a river based on measurements and rainfall forecasts for the corresponding catchment area.

- **hydraulic models (Mascaret – InfoWorks ICM)**

- **the LARSIM model**

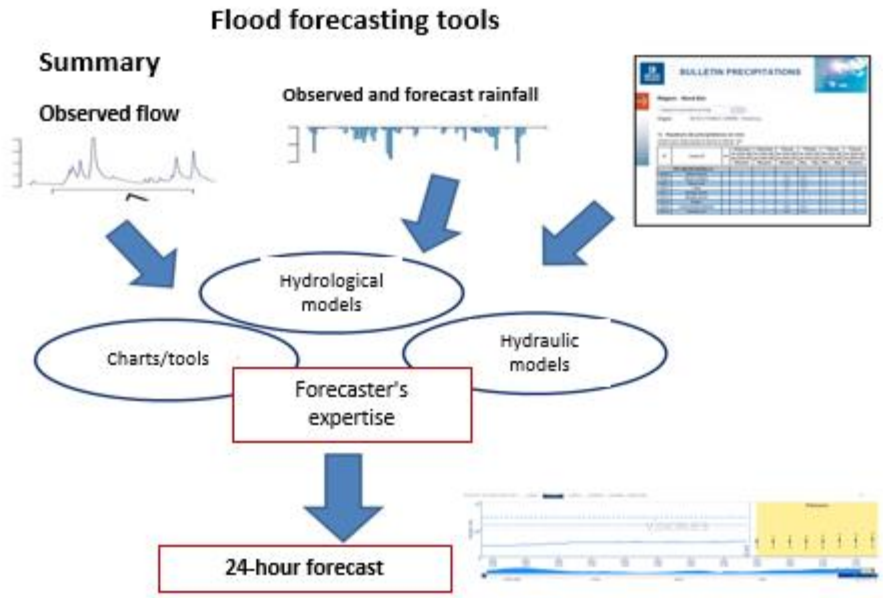
This is a global hydrological model developed for the international basins of the Meuse and Moselle rivers.

The input data for the model are:

- observed rainfall data (radar or from rain gauges).
- Short-term (AROME / ARPEGE / ICON models) or long term (CEP/ ICON EU) weather forecasts
- measured water level data.

The calibration data are: pedology, soil moisture, evapotranspiration, etc…

The model forecasts water level and flow at the stations.



Summary of tools used for flood forecasting

2- Luxembourg

a) Organisation of hydrometry

Monitoring network (from 01.01.2021):
- 41 permanently installed gauging stations:
  - ➢ Water level and temperature (currently 25 stations)
  - ➢ Direct flow measurement (currently 3 stations)
- 14 precipitation stations (rain gauges)
- 10 air temperature stations
- 4 meteorological stations (including precipitation)
- 15 groundwater monitoring stations (in alluvium)
  - ➢ Groundwater level and water temperature
  - ➢ Maintenance of station monitoring network and design of gauging stations (AGE & LIST network monitoring station)

Flow measurements (height-flow relationships and validation):
- Flow measurements AGE & external contractor (2020: approx. 290 measurements).
- Implementation of H/Q relationships and data validation (external contractor)

Creation of H/Q relationships and data validation (external contractor):
- Segmented H/Q relationships created, among others, using Origin Pro software.
- Flow measurements and information from 2D flood risk map models
- SVR100 (Prodis2) OTT: direct flow determination, separate water level transmitter required.
- RQ30 Sommer: direct water level and flow determination

Flow measurement:
- Current meter:
  - ➢ 2 ADC OTT (not used anymore)
  - ➢ 2 Nivus NivuFlowStick
- Acoustic Doppler Current Profiler (ADCP):
  - ➢ RDI Teledyne Rio Grande (1,2 MHz) on Trimaran

- RDI Teledyne Stream Pro (2 MHz) on Trimaran
- Sontek River Surveyor M9 (3.0 MHz; 1.0 MHz et 0.5 MHz)
  + rQPOD (propulsion) from september 2021 on Torrent Board

Evaluation of flow measurements:
- In principle, evaluations are carried out using the software provided by the manufacturer!

- ADCP measurement:
  - Initial evaluation with Winriver 2 or RiverSurveyor live
  - Further evaluation (correction) with AGILA (BfG) according to the gauging rules/gauging manual

Real-time measurement and remote data transmission:
- Measurement technology: OTT, Sommer, Sontek
  - Water level: PLS, RLS, Kalesto, CBS, Nimbus, OWK, SE200, Ecolog
  - Flow: 1 SVR100, 2 RQ30, 1 IQ
  - 1-, 5- or 15-minute measurement
  - Recovery server: SODA 5
  - HYDRAS & HYDRAS-NET (server)
  - Remote access (recovery also possible)
  - Database: WISKI 6 & WISKI 7
  - Transmission: IP station or push mode

Database storage:
- Currently WISKI 6 as operational database system
  - Provision of operational data
    Flood forecasting (LARSIM, inondations.lu)

- Upgrade to WISKI 7 planned (September 2021)
  - Database for data processing and data exports (periodic)

- KISTERS data validation application
  - Plausibility check of measurement data
  - 1 database for all departments!

Broadcasting to the public:
- Provision of measured water levels: https://www.inondations.lu/basins
  - Provision of currently measured water levels at 37 stations
  - 15 minutes of measured data (updated every 5 minutes if available)
  - 5 days of measured retrospective data
  - Main values, hydrological parameters
  - Historical water levels
  - Historical data on forecast flow

- Broadcasting to the public:
- Open data portal (similar to inondations.lu) :
  https://data.public.lu/en/datasets/measured-water-levels/
- Telephone announcement of measured water levels via the IVR server: 00352 24556-800
  https://www.inondations.lu/information/contact
- Measurement stations in the geoportal: https://map.geoportail.lu
- Measurement data as widget per station: https://www.inondations.lu/graph-widget/28

b) <u>Organisation of flood forecasting</u>

Provided by the Flood Forecasting Service of the Administration de la Gestion de l'Eau:
- Luxembourg part of the Sauer catchment area
- Luxembourg part of the Moselle catchment area (external)

Cooperation within ICPMS:
- Technical Committee
- Transboundary reporting service
- Joint work programme
- Data exchange
- Maintenance and development of LARSIM
- Joint training and exchanges

Flood forecasts are based on WHM LARSIM:
- WHM Sauer & WHM Mosel
- Model based on a grid (1km²) unlike WHM Meuse (sub-basin model)
- Measured data (8 days)
- Water level, flow (SPW), precipitation, air temperature, humidity, pressure, global radiation, wind speed.

Flood forecasts based on the WHM LARSIM model
- Weather/radar forecast products: Short term, medium term and long term (DWD, Météo France, ECMWF)
- Calculation of a forecast currently on 36 stations (25 in LU, 11 in DE and B)
- Output of additional parameters (soil moisture, water equivalent)

Publication of the forecasts: inondations.lu
- Current water levels at 37 stations
- Forecasts for 11 stations (24h)
- Flood report (https://www.inondations.lu/alerts)
- By mail to media and website subscribers

3 – Wallonia

a) Flood forecasting

In Wallonia and in accordance with the Water Code, the warning, monitoring and forecasting of floods for the entire territory is the responsibility of the manager of the waterways of the Wallonia Public Service Mobility and Infrastructures (SPW MI) and more precisely the Directorate of Hydrological Management (DGH).

This directorate has an operational permanence based on three components:

- continuous monitoring of weather forecasts, precipitation, water levels, flows and hydraulic structures (reservoirs, valve positions, etc.) using its own Wacondah observation network and partner networks such as Aqualim;

- interpretation of the hydrological data collected and the results of the forecasting models to determine the state of the main rivers in relation to the flood risk;

- alerting and rapidly disseminating information through various media to the authorities in charge of crisis management, to specific partners and to the general public.

➢ **Continuous monitoring of meteorological and hydrological data**

Thanks to a cooperation agreement, the DGH has privileged access to the meteorological forecasts and observations of the Royal Meteorological Institute (RMI), be it precipitation, storm cells or snow (accumulation and melting).

For observations of river levels and flows, the DGH relies on two observation networks, Wacondah (see b.1) and Aqualim (see b.2). As with rainfall observations, all these data are collected in real time with a 5-minute time step.

Hydrological data are also exchanged with the equivalent services of neighbouring regions and states.

Finally, a specific database collects the observations, with a time step of one minute, relating to hydraulic water regulation structures: reservoir dams, run-of-river valves, pumping stations, etc.

All these data collected provide a complete overview of the hydrological situation and water regulation infrastructures.

- **Flood forecasting and warning**

In order to anticipate and determine the risks and to trigger the alert phases, the duty operator can rely on a series of hydrological models that allow him to forecast the evolution of flows in the main Walloon basins.

More than 35 models are deployed in Wallonia and are all based on stochastic modelling. In short, these models compare hydrological measurements and meteorological forecasts in real time with previous floods in order to reproduce equivalent responses using a range of parameters (seasonality, presence of snow, etc.). They aim to determine flows at different strategic points in the network.

All the results of the Hydromax hydrological models are visualised in a specific interface called Augure, which facilitates the triggering of the flood warning phases in Wallonia thanks to a spatial and temporal view of the forecasts for the entire territory. A prioritization is made according to the size of the basins, knowing that some are very reactive (delay of a few hours between precipitation and overflow).

The thresholds are as follows and apply either at the river scale or at the sub-basin scale:

- Green level: the situation is normal in all basins. There is no flood risk in the short term. The flows and water levels are normal for the season. The river is in its minor bed and does not threaten to overflow.

- Green level but with warning: the observed and forecasted climatic conditions require increased vigilance (risk of thunderstorms, storms, rapid snowmelt...) with a reinforcement of the meteorological and hydrological surveillance and a warning to the Walloon Regional Crisis Centre.

- Yellow level (pre-alert): according to the forecasts and observations, one (or several) watercourses in a basin is (are) in a condition to overflow and cause localised and not serious floods.

- Red level (alert): according to forecasts and observations, one (or more) rivers in a basin is (are) in a condition to overflow and cause significant flooding with an impact on infrastructure and residents.

The crossing of the pre-alert and alert thresholds is communicated:

- as a priority to the Walloon Regional Crisis Centre, which triggers and coordinates the emergency plans with the provincial and municipal authorities.

- to the management services of the watercourse(s) in question for specific actions, notably in terms of hydraulic infrastructures or navigation management.

In the event of a flood alert, communication with the Regional Crisis Centre increases significantly with a sustained update of the forecasts.

In addition to the Crisis Centre and the managers, the forecasts and warnings are also transmitted to the hydrological services of neighbouring regions and states, to water resource managers and to the general public, via the dedicated website https://infocrue.wallonie.be.

b) Hydrometry

In Wallonia, two hydrometric networks complement each other and provide almost exhaustive coverage of flood risks:

- The Wacondah network of the Hydrological Management Directorate (DGH) of the Walloon Public Service Mobility and Infrastructures

- The Aqualim network of the Directorate for Non-Navigable Watercourses (DCENN) of the Walloon Public Service for Agriculture, Natural Resources and the Environment

The data from both networks are being integrated into a single database and disseminated, in particular via a single hydrological portal planned for 2021.

➢ **The WACONDAH network**

The WACONDAH system (Water CONtrol DAta system for Hydrology and water management) is managed and developed by the DGH, in particular for flood and low-water forecasting and the management of waterways and reservoirs. It mainly includes:

- About a hundred weighing rain gauges (i.e. about 1 per 150 km²);

- 150 water level measurement stations, of which about a hundred have a rating curve to establish the flows;

- 12 stations for measuring flows by cross chords (ADM) on waterways whose levels are regulated by run-of-river dams;

- 3 snow melt measurement stations (dynamic weighing and height measurement)

- Several hundred position sensors for hydraulic structures (reservoirs, locks, valves, pumps, spillways, etc.)

This data is available in real time with updates every 5 minutes or even every minute. Some stations in sensitive or strategic locations are doubled up to ensure that data is received at all times. Alarms are automatically transmitted to the operational headquarters or to external partners.

For flow measurements on unregulated rivers, gauging is carried out regularly throughout the network (1,200 measurements on average per year) either by ADCP (acoustic doppler current profiler) or current meters.

In order to optimise the measurements, a specific gauging planning tool prioritises the sites to be visited with regard to observations, forecasts, distances and measurements made in the past.

Quality control is a critical step in the measurement chain and is based on different pillars:

- Precipitation is validated in collaboration with the IRM on the basis of other rain gauges and radar data;

- The measured levels are validated by in situ checks, consistency controls between stations and a posteriori controls at several layers;

- The measured flows are validated by updating the rating curves as soon as new gauges are received.

- **The AQUALIM Network**

The DCENN manages the non-navigable watercourses of 1st category (parts of non-navigable watercourses downstream from the point where their catchment area reaches 5000 ha) and its "Limnimetry" unit operates the hydrological measurement network AQUALIM. This network is also implemented on the 2nd category rivers managed by the Walloon provinces.

The Aqualim measurement network is composed as follows:

- A bit more than 200 gauging stations along the rivers (height - flow),

- A bit more than 30 gauging stations on the temporary immersion zones to fight against floods in order to follow their filling (height).

The data are transmitted every 20 minutes or hour by GSM/GPRS and are stored in the AQUALIM database of the DCENN. Alarms are also sent automatically in the form of an SMS and/or email per watershed and according to 3 thresholds:

Threshold	Water level
Threshold 1	High without overflow
Threshold 2	Risk of localised overflows
Threshold 3	Observed overflows

The objective of these alarms is to help the river managers (regional and provincial), the Hydrological Management Directorate (DGH), the Regional Crisis Centre, etc. to take ad hoc measures. More specifically, within the DCENN, they are used to launch procedures for mobilising personnel, surveying flooded areas, controlling engineering structures, etc.

The quality control of the levels is ensured by:

- Automatic and manual controls of data consistency or anomaly detection;

- Regular on-site controls and corrective maintenance operations.

To convert water levels into flow, gauging must be carried out to enable the calculation of a rating curve. Gauging is carried out in-house (1700 per year), with a minimum of ten gauges per year per station, or even fifteen for the most unstable sections.

The rating curves are checked once a week during the implementation of the database with the gauging carried out. This control makes it possible to possibly intensify the measurements in the event of modification of the curves.

4 – Flanders

In Flanders, the Hydraulic Engineering Laboratory (Hydrological Information Centre-HIC) is responsible for carrying out water quantity measurements on the **navigable waterways**.
Within the Meuse basin in Flanders, these are the Meuse, bordering the Netherlands, and the canal system of Albert Canal and Kempen Canal. For the measurements on the **Grensmaas** (Meuse bordering Flanders and the Netherlands), there are agreements with the Netherlands to make the measurements as efficient as possible and to divide the work. All measurements are exchanged in real time between HIC and the Dutch RWS. In addition, HIC manages extra hydrological measurements on the **canals**.
The HIC performs hydrological measurements at 22 locations in the Flemish Meuse basin. On 5 of these locations not only the level is measured, but also the discharge. In addition, the HIC has 1 rain gauge (self-registering) in the Flemish Meuse basin. From all these measuring devices, the readings are measured continuously and transmitted with a frequency of 5 or 15

minutes.

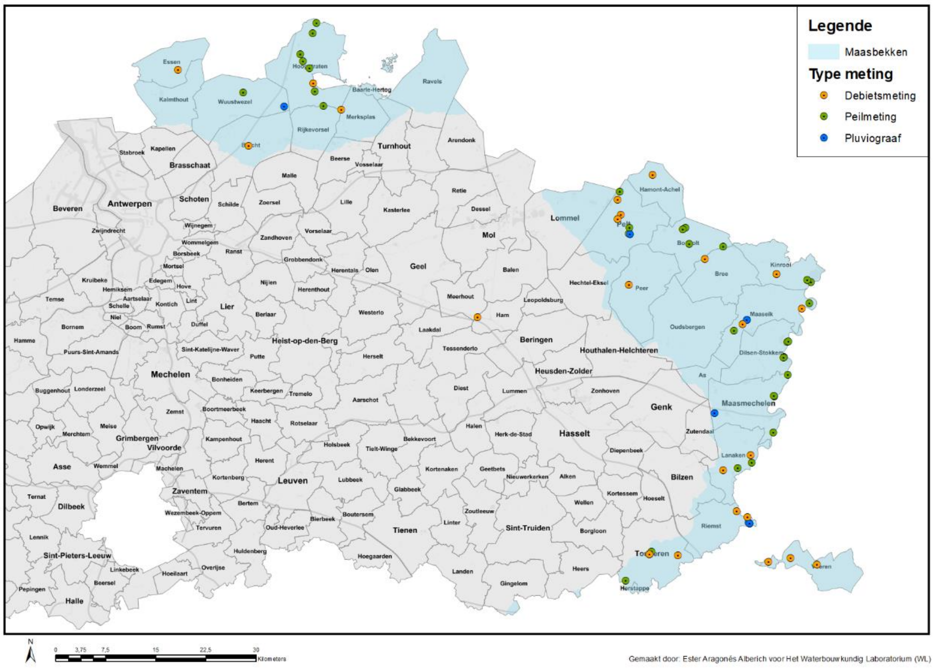
The VMM network for monitoring the surface water quantity of the **unnavigable watercourses** provides continuous measurement values with an interval of 1 or 15 minutes, depending on the type of measurement network. In the Flemish Meuse basin, water levels are measured at 62 locations, with flow determination also taking place at 23 of these locations. VMM also carries out precipitation measurements at 5 locations in the Flemish Meuse basin.

The data from the above monitoring networks are available in real time on the website www.waterinfo.be.

Due to the evolution of technology, it will be possible to significantly expand the monitoring network in the coming years with small, simple level gauges. In the near future, extra measuring points will be added on the smaller watercourses.

Below is an overview of the measurements in the Meuse basin.

	Total	HIC	VMM
WATER LEVEL MEASUREMENTS	39	17	22
FLOW MEASUREMENTS	23	5	18
RAINWATER MEASUREMENTS	6	1	5



FORECASTS IN THE FLEMISH MEUSE BASIN

Navigable waterways

Flanders does not run a separate forecasting model for the Border Meuse with the Netherlands and/or the Albert Canal and Kempen Canal. Floods from the canals due to precipitation are not possible because of the control. For forecasting the Meuse along the Flemish side, there is a cooperation agreement between Flanders and the Netherlands, whereby Flanders (HIC) participates annually in updating the models in the JAM-process (Yearly Actualisation Meuse Models). The forecast results are fully available to the HIC's permanent team and to citizens in Flanders via www.waterinfo.be.

Unnavigable waterways

VMM runs forecasting models for a number of unnavigable watercourses in the Flemish Meuse basin. They run several times a day with always recent input of measurements, measured precipitation and predicted precipitation from the KMI. These results are also available via www.waterinfo.be.

WWW.WATERINFO.BE PORTAL

The website www.waterinfo.be has been operational since January 2014. With this site, the Flemish water managers and knowledge institutes join forces and all measurements and forecasts are brought together. This way, water managers, crisis services and citizens can take the necessary measures in advance to minimise water damage. The water key maps, flood hazard and risk maps and the Flemish Hydrographic Atlas can also be viewed there. The Flemish water managers keep the portal www.waterinfo.be and the underlying forecasting systems permanently operational and up to date. In the autumn of 2020, an updated version of the website will be placed online.

5 – North Rhine-Westphalia

The following summary describes the organisation of the flood forecasting and hydrometry services.

The North Rhine-Westphalia State Agency for Nature, Environment and Consumer Protection (LANUV) is responsible, among other things, for flood forecasting and hydrometry in North Rhine-Westphalia (NRW).

The LANUV consists of eight departments. Department 5 is responsible for water management and water protection.

Department 5 itself comprises eight divisions, divided into Divisions 51 to 58, with Division 51 responsible for hydrology and monitoring network control and Division 53 responsible for flood protection, urban drainage, climate and water management. These two departments also include flood forecasting and hydrometry.

For flood forecasting, the LANUV uses the LARSIM (Large Area Runoff Simulation Model) and Delft-FEWS (Flood Early Warning System) forecasting models. In future, this will allow flood forecasts to be made at a total of 89 gauges in North Rhine-Westphalia. Some of the model technology and data required for this are already available, while others are still being developed. In the course of the new flood forecasting system, the next step will be the start of pre-operational test operations.

In addition to flood forecasting, there is a flood warning service in NRW. This is carried out by the district governments for the so-called flood-prone water bodies (including the Rur). The Cologne district government is responsible for the flood warning service for the Rur. The flood warning service is ensured at the district government of Cologne by a team of 4 persons who are on permanent standby duty.

The basic data required for this (water level and precipitation data) are collected by the LANUV and made available to the district governments via intranet. This ensures that the basic data for the flood service are always up to date. The basic data provided on the Internet are made available with a delay of about one hour and can therefore only be used for the flood service to a limited extent.

The flood service is carried out by the Cologne district government as follows: When a so-called pre-warning level (pre-set warning limit at the respective gauge) is reached at one of the 36 (warning) gauges in the area of the Cologne district government, the Cologne district government receives an automatic warning of the respective gauge. This is the beginning of the flood warning service. If the further warning limits 1, 2 or 3 are subsequently exceeded at a water level, a flood message is first sent by telephone and then a written flood message is sent by e-mail from the Cologne district government to the relevant disaster control centres and/or other relevant recipients.

These flood messages essentially contain the names of the gauges and water bodies, the current water level of the gauge and other gauges in the catchment area with date and time, the alarm limits (warning limits), the trend and forecasts of the expected development of the water levels at the gauges.

If the water levels at the gauges fall below the alarm or warning limits again, a final message is sent by the Cologne district government to those previously informed. This is the end of the flood warning service.

6 – Netherlands

- **Organisation**

All flood reports in the Netherlands are issued by the Water Management Centre of the Netherlands in Lelystad (WMCN). The flood reports are drawn up jointly by WMCN Rivers (part of Rijkswaterstaat Verkeer en Water Management) and the TEM (Team Expertise Maas, part of Rijkswaterstaat Zuid-Nederland).

- **Roles and responsibilities**

WMCN Rivieren is responsible for producing a water level and flow forecast for Eijsden and for drawing up a hydrological analysis of the upstream part of the Meuse catchment area. It is also responsible for the entire flood report process.

The Team Expertise Meuse provides the flow and water level forecasts for the Dutch part of the Meuse catchment area and supplies relevant regional information.

- **Cooperation process**

The cooperation takes place from the operational "RWSOS Rivieren" system. The expectations of both teams are brought together in this system and the mutual coordination leads to a coherent set of flow and water level forecasts for the entire Meuse catchment area.

- **Definition of floods on the Meuse**

Floods on the Meuse can be divided into increased discharge situations and high-water situations as defined in the National High Water and Flood Manual (LDHO). An increased discharge situation exists if the measured discharge at St. Pieter lies in the range 800 - 1500 m3/s. A high water situation exists if the measured discharge is 1500 m3/s or more.

- **Notification**

In case of an increased discharge situation, status messages are drafted and issued. A status report is the less detailed variant of a flood report. A status report contains a multi-day flow forecast for gauging station St. Pieter and a general description of the situation. Status messages are issued on average once a day.

In flood situations, a switch is made to flood reports. These messages contain multi-day water level forecasts for all gauging stations in the Dutch catchment, as well as predictions of where and when the top water level will pass, and water level forecasts per km of waterway. In addition, flood reports are provided with a detailed situation description.

The frequency of issuing flood reports depends on the height of the measured flow/water level. It lies between 1 and a maximum of 4 times a day.

Annex 8: Actions to develop international cooperation in flood forecasting and hydrometry of the Meuse IRBD

N°	Title	Deadline(s) - Frequency	Action(s) to be taken	Comments
1	Obtaining HBV hydrological forecasts from the RWS for the French sub-basins	January 2022	Sending the raw results from the RWS to the Meuse-Moselle FFS by email or ftp	The RWS forecasts are already provided to the SPW. -> Agreement in principle of the RWS (cf. mail of 29/09/21). The French and Dutch delegations will inform the secretariat of the beginning of the data transmission within the framework of the monitoring of the implementation of the FRMP.
2	Transmission of hydrological forecasts in Chooz to Flemish FFS	January 2022	Raw results sent by Meuse-Moselle FFS by email or ftp	The forecasts of the Meuse-Moselle FFS are already provided to SPW and RWS. -> Agreement in principle of the Meuse-Moselle FFS (cf. meeting of the WG H on 05/10/21). The French and Flemish delegations will inform the secretariat of the beginning of the data transmission in the framework of the monitoring of the implementation of the FRMP.
3	Directory of flood forecasting and hydrometric services of the Meuse IRBD	1st version: 1st quarter 2022 Annual update at the meeting of the flood forecasting and hydrometric services	Project: WG H chairman + IMC secretariat Complements: FFS Final version and broadcasting: IMC secretariat	Request the agreement of the IMC Heads of Delegation for the creation of a storage directory for documents dedicated to flood forecasting and hydrometric services (presentations, directory, minutes, etc.) on the restricted access part of the IMC website (cf. ICPR and ICPMS). In the meantime, the documents will be stored in the WG H directory.

N°	Title	Deadline(s) - Frequency	Action(s) to be taken	Comments
4	Update of the list of stations subject to data exchange	1st quarter 2022 Annual update at the Flood Forecasting and Hydrometric Services meeting	Sending the current available list to the GIS manager for the IMC Secretariat (Chair of the PG GIS) Definition of a list of associated metadata	The map developed for the data exchange agreement of July 2017 already indicates for each station the relevant parameters (Hmes, Qmes, Hprev, Qprev).
5	Annual meeting of the flood forecasting and hydrometric services of the Meuse/Scheldt IRBDs	Mid-September of each year	Poll for meeting date: IMC Secretariat Convocation and agenda: WG H chair + IMC secretariat Minutes: IMC Secretariat + WG H Chair	See if face-to-face or videoconference meeting Topics: - News in each FFS, - Feedback on the floods of the past year (*), - Review of data exchange (**), - Review of programmed actions, - Update of the FFS directory, - Technical exchange on a subject proposed by the FFSs (***)
6	WebGIS portal IMC/ISC	December 2022	Provision of URLs of hydrological stations: FFS Integration on WebGIS: secretariat via GIS means provided by SPW	The URL address will allow the Internet user to be redirected to the FFS's Internet page where the height and/or flow data measured for the selected hydrological station are made available to the general public. This action will also allow the list of stations and the parameters exchanged to be updated annually.

(*) Check with SPW and LANUV whether a return to the July 2021 floods is possible in view of the ongoing internal and external investigations

(**) Updating the GIS layer used by WebGIS

(***) For 2022: presentation of the IMC/ISC warning and alert system for accidental pollution to see if the tool could be used to send warnings between flood forecasting services in the event of floods on a (trans) boundary river and, if necessary, identify the adaptations to be made to meet this need

N°	Title	Deadline(s) - Frequency	Action(s) to be taken	Comments
7	Feasibility study for the connection of the main Meuse and Scheldt stations to the LHP internet portal (cf. ICPMS and ICPR) (*)	December 2022	Portal manager contact: WG H Chair + Secretariat Selection of stations and associated threshold values: FFS Data transmission methods to the portal managers to be specified	The RWS stations for the Meuse and Rhine are already represented on the LHP. In addition, the RWS has been receiving all the data measured by the other partners since the exchange agreement of July 2017. At the seminar on 16 and 17 September 21, it was proposed that the RWS should be used to transmit the data of the other partners to the LHP managers in the format required by this tool. The RWS proposes to study an alternative solution for direct transmission of their data to the LHP and will send an explanatory memorandum on this subject. See also consistency with thresholds displayed on national/regional sites
8	Joint gauging and comparisons of measuring instruments	From 2022	Send an invitation via the Commission secretariat(s) to the other delegations when a joint flow measurement is scheduled between two hydrometric services	Mailing list to be established according to common directory

(*) LHP = Länder-übergreifendes Hochwasser-portal - https://www.hochwasserzentralen.de/

N°	Title	Deadline(s) - Frequency	Action(s) to be taken	Comments
9	Technical visit of the FFS of the basin	From 2023	Find a volunteer FFS to organize: WG H Chair and IMC Secretariat Choice of date: organising FFS Convocation: IMC secretariat Report: secretariat	Usefulness of the visit: demonstration of the tools used in the visited FFS for flood forecasting and management of measured data See if it is possible to carry out the visit the day after the annual FFS meeting.
10	FR-LUX cooperation for flood forecasting at the Pétange station on the Chiers	Ongoing	Adaptation of the LARSIM Meuse model of the Meuse-Moselle FFS by the Administration de la Gestion de l'Eau du Luxembourg (2021) Modalities of use for operational flood forecasting to be specified (2022).	Discussions have already taken place in 2020 and 2021 within the ICPMS Technical Committee, which manages the maintenance and development of the LARSIM Meuse model, in order to realise a recalibration of the Pétange station in the LARSIM Meuse model in order to calculate the flows of nutrients produced in Luxembourg in the Meuse River Basin. Discussions on the practical details of using the LARSIM Meuse model for operational flood forecasting must be continued within this body. -> The French and Luxembourg delegations will inform the secretariat of the progress of the project as part of the monitoring of the implementation of the FRMP.