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REVIEW AND UPDATE OF THE PRELIMINARY FLOOD RISK ASSESSMENT IN THE 3rd PLANNING CYCLE

TASK 1. VERIFICATION AND UPDATE OF THE METHODOLOGY OF THE PRELIMINARY FLOOD RISK ASSESSMENT

WBS No. 3W.01 EN

METHODOLOGY FOR THE REVIEW AND UPDATE OF PRELIMINARY FLOOD RISK ASSESSMENT IN THE 3rd PLANNING CYCLE

CONTRACTOR: Consortium:

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LIST OF ABBREVIATIONS

APSFR	Areas of Potential Significant Flood Risk (Polish abbreviation "ONNP")
ARiMR	Agency for Restructuring and Modernisation of Agriculture
BDOT	Topographic Objects Database
CBDH	Central Hydrogeological Data Bank
CLC	Corine Land Cover
DTM	Digital Terrain Model
DWSM	Digital Water Surface Model
EU	European Union
FD	Floods Directive, Directive 2007/60/EC of the European Parliament and the Council of 23 October 2007 on the assessment and management of flood risks
FHM	Flood Hazard Maps (Polish abbreviation "MZP")
FHA	Flood Hazard Area (Polish abbreviation "OZP")
FRM	Flood Risk Maps (Polish abbreviation "MRP")
FRMP	Flood Risk Management Plan (Polish abbreviation "PZRP")
GDOŚ	General Directorate for Environmental Protection
GIOŚ	Chief Inspectorate of Environmental Protection
GIS	Geographic Information System
GUS	Central Statistical Office
HF	Historical Floods
ICPO	International Commission for the Protection of the Oder River against Pollution (Polish abbreviation "MKOOpZ)
IMGW-PIB	Institute of Meteorology and Water Management – National Research Institute
JST	Local Government Unit
KE	European Commission
KZGW	National Water Management Authority
MhP GUPW	Hydrogeological map of Poland (Main usable aquifer)
MhP PPW	Hydrogeological map of Poland. First aquifer
MHP PPW – WH	Hydrogeological map of Poland. First aquifer – occurrence and hydrodynamics
MPHP	Map of Hydrographic Division of Poland
MWP	Groundwater Monitoring

NID	National Heritage Institute
PGW WP	State Water Holding Polish Waters
PF	Probable Floods
PFRA	Preliminary Flood Risk Assessment (Polish abbreviation “WORP”)
PIG-PIB	Polish Geological Institute - Polish Research Institute
PSH	National Hydrogeological Service (from 1 January 2024, National Geological Service)
PSHM	National Hydrological and Meteorological Service
PSP	State Fire Service
RZGW	Regional Water Management Authorities
SEKOP	database of the Registration and Control System of Damming Structures
SMGP	Detailed Geological Map of Poland
UW	Voivodeship Offices

GLOSSARY

Damming structures - structures enabling permanent or periodic damming of surface water above the adjacent land or the natural water table (Water Law Act, Art. 16 point 2).

Flood risk management objectives - reducing the potential adverse consequences of floods on human life and health, the environment, cultural heritage and economic activity (Water Law Act, Art. 16 point 4).

River Basin Districts (RBD) - a land and sea area, made up of one or more neighbouring river basins together with their associated ground waters, internal marine waters, transitional waters, and coastal waters, being the main spatial unit of water management (Water Law Act, Art. 16 point 31).

Areas of potential significant flood risk (APSFR) - areas where a significant flood risk exists or is likely to occur (Water Law Act, Art. 16 point 33), i.e. areas of significant flood risk.

Areas of potential flood risk - these are areas for which analyses are carried out to identify APSFR; according to the PFRA scheme, they are determined based on the identification and assessment of historical floods and probable floods (considering significant adverse consequences of floods and forecasts of long-term developments) as the sum of areas of historical floods and probable floods (i.e. floods referred to in Art. 4.2 b, Art. 4.2 c, and Art. 4.2 d of the FD).

Special flood hazard areas (Water Law Act, Art. 16 point 34):

a) areas where the probability of flooding is medium (1%),

b) areas where the probability of flooding is high (10%),

c) areas between the shoreline and the flood embankment or a natural high bank with built-in flood embankments, as well as islands and alluvials, as referred to in Art. 224, which constitute cadastral parcels,

d) a technical belt.

Flood - a temporary coverage by water of land not normally covered by water, in particular, caused by water exceedance in natural watercourses, reservoirs, canals, and from the sea, excluding the coverage by water of land caused by water exceedance in sewerage systems (Water Law Act, Art. 16 point 43).

Historical (past) floods - floods that occurred in the past in a given area, including:

- **Floods, as referred to in Article 4.2b of the Floods Directive** - floods that have occurred in the past and which had **significant adverse consequences** for human health, the environment, cultural heritage, and economic activity, where similar events are likely to occur in the future;

– **Floods, as referred to in Article 4.2c of the Floods Directive** - floods that have occurred in the past and have not caused significant adverse consequences at that time but it can be predicted that similar phenomena **will have significant adverse consequences in the future** (considering e.g. land use changes or climate change).

Probable flood - a flood that may occur in a given area in the future and cause **potential adverse consequences** on human life and health, the environment, cultural heritage, and economic activity – **flood referred to in Art. 4.2d of the Floods Directive.**

Water region - a part of the river basin district separated based on hydrographical criteria for the needs of water resources management or a part of an international river basin area situated in the territory of the Republic of Poland (Water Law Act, Art. 16 point 46).

Residual flood risk – a flood risk remaining after the implementation of planned measures to achieve flood risk management objectives (taking into account both the reduction of flood risk and the vulnerability of the affected system), acceptable at a certain place and time due to external conditions (environmental - including flood magnitude, social, economic, etc.).

Flood risk – a combination of the probability of flood occurrence and potential adverse consequences of floods on human life and health, the environment, cultural heritage, and economic activity (Water Law Act, Art. 16 point 48).

Alert water level - a conventional water level that corresponds to the filling of the river bed, posing a threat to infrastructure and buildings, as well as to human life and health; usually placed near bank water [source: Thematic dictionary of terms used in hydrological forecasts, IMGW-PIB, 2014].

Significant adverse consequences of floods - negative consequences of floods (on human life and health, the environment, cultural heritage, and economic activity) of a supra-threshold nature (i.e. above certain threshold values resulting from the probability distribution of the values of adverse consequences of historical floods) on a local or regional scale, resulting from a specific flood hazard and the vulnerability of the system affected by that hazard.

Significant historical floods - floods that occurred in the past and had significant adverse consequences (on human life and health, the environment, cultural heritage, and economic activity) or constituted a flood hazard of a supra-threshold nature (i.e. above certain threshold values resulting from the probability distribution of values for historical floods).

1. INTRODUCTION

1.1. LEGAL BASIS

The review and update of the preliminary flood risk assessment (PFRA) is a task of the State Water Holding Polish Waters (PGW WP), resulting from Art. 168 points 1 and 10 of the Act of 20 July 2017 - Water Law (Journal of Laws 2023, item 1478), hereinafter referred to as the "Water Law Act" and Art. 14 point 1 of Directive 2007/60/EC of the European Parliament and the Council of 23 October 2007 on the assessment and management of flood risks, hereinafter referred to as the "Floods Directive (FD)".

According to Art. 315 point 5 of the Water Law Act, the PFRA is a planning document in water management.

The PFRA is reviewed every 6 years and updated if necessary. Performance of the review and update of the PFRA in the 3rd planning cycle of flood risk management (2022 - 2027) must take place by 22 December 2024.

The purpose of the PFRA is to estimate the flood risk in the river basin districts and to identify areas where this risk is significant, for which flood hazard maps (FHM) and flood risk maps (FRM)should be developed in further stages and measures should be planned in the flood risk management plan (FRMP).

The scope of the PFRA is defined in Art. 167 of the Water Law Act:

Art. 167. 1. A preliminary flood risk assessment shall be prepared for river basin districts based on available or easily accessible information, including the impact of climate change on floods.

2. The preliminary flood risk assessment shall include in particular:
   1) maps of the river basin districts including the borders of the river basins, and the border of the coastal area, showing the topography of the area, and its land use;
   2) a description of past floods:
      a) which have caused significant adverse consequences on human life and health, the environment, cultural heritage, and economic activity, including an assessment of those effects, the flood extent, and the conveyance routes;
      b) where similar flood events are likely to have significant adverse consequences on human life and health, the environment, cultural heritage, and economic activity;
   3) an assessment of the potential adverse consequences of floods that may occur in the future on human life and health, the environment, cultural heritage, and economic activity, taking into account:
      a) the topography,

   b) the location of watercourses and their general hydrological and geomorphological characteristics, including floodplains as natural retention areas,
   c) the effectiveness of existing water reservoirs and other flood protection and control structures,
   d) the location of inhabited areas,
   e) the location of areas where economic activity is conducted;
4) as far as possible, a forecast of long-term developments, in particular the impact of climate change on floods;
5) determination of areas of potential significant flood risk.

The principles of preparation, opinion, agreement, and approval of PFRA are specified in Article 168 of the Water Law Act:

Art. 168. 1. The draft preliminary flood risk assessment shall be prepared by State Water Holding Polish Waters.

2. The draft preliminary seawater flood risk assessment, including internal marine waters, shall be prepared by the minister in charge of maritime economy and submitted to State Water Holding Water Polish not later than six months before the date of preparation of the preliminary flood risk assessment. The draft preliminary seawater flood risk assessment, including internal marine waters, shall form an integral part of the draft preliminary flood risk assessment referred to in point 1.
3. State Water Holding Polish Waters shall submit the draft preliminary flood risk assessment to the voivodes for their opinion and to the minister in charge of inland waterway transport with regard to inland waterways for agreement.
4. The authorities referred to in point 3 shall give their opinion and agree within 45 days of receipt of the draft preliminary flood risk assessment. The absence of an opinion within the above time limit shall be considered as a favorable opinion of the project.
5. State Water Holding Polish Waters shall agree with the minister in charge of the maritime economy on the manner of examining the opinion for the draft preliminary seawater flood risk assessment, including internal marine waters.
6. State Water Holding Polish Waters shall notify the evaluating authorities of the manner in which their opinion is to be considered within 45 days of the date of receipt.
7. The preparation of the preliminary flood risk assessment for river basin districts, parts of which are located in the territory of other European Union Member States, shall be preceded by an exchange of information necessary to prepare this assessment with the competent authorities of those countries. The exchange of information shall be in the manner and scope specified in separate regulations.

8. State Water Holding Polish Waters shall submit the draft preliminary flood risk assessment to the minister in charge of water management for approval.
9. The minister in charge of water management shall approve the preliminary flood risk assessment and:
   1) forward it to the Director of the Government Security Centre;
   2) make the information public by placing it on the subjective website of the Public Information Bulletin of the office supporting the minister in charge of water management.
10. The preliminary flood risk assessment shall be reviewed every six years and updated if necessary.
11. A review of the preliminary flood risk assessment shall also take into account the possible impact of climate change on the occurrence of floods.
12. The provisions of points 1-9 shall apply accordingly to the update of the preliminary flood risk assessment.
13. The minister in charge of water management shall make the reviews and updates of the preliminary flood risk assessment available to the European Commission within 3 months from the date of their completion.

1.2. UNITS OF MANAGEMENT

According to Art. 12 of the Water Law Act, water resources management in Poland is carried out taking into account the division of the country into river basin districts, water regions, and river basins. **Flood risk management units in Poland within the meaning of the Floods Directive are the river basin districts.** The review and update of the PFRA should also be prepared for river basin districts, considering the division into water regions. The division of Poland into river basin districts and water regions is shown in Table 1 and Figure 1.

Table 1: River basin districts and water regions in Poland

No.	Water region	River basin district	Description
1	Little Vistula	Vistula	includes, in addition to the Vistula river basin located on Polish territory, the basins of the Slupia, Lupawa, Leba, Reda and other rivers flowing directly into the Baltic Sea east of the Slupia River estuary and into the Vistula Lagoon
	Upper West Vistula		
	Upper East Vistula		
	Narew		
	Bug		
	Central Vistula		
	Lower Vistula		
2	Upper Oder	Oder	includes, in addition to the Oder river basin located on Polish territory, the basins of the Rega, Parseta, Wieprza, Ücker and other rivers flowing directly into the Baltic Sea west of the Slupia River estuary and those flowing into the Szczecin Lagoon
	Central Oder		
	Lower Oder and Western Pomerania		
	Warta		
	Notec		
3	Dniester	Dniester	-
4	Czarna Orawa	Danube	-
	Czadeczka		
	Morawa		
5	Banowka	Banowka	-
6	Izera	Elbe	-
	Elbe and Ostroznica (Upa)		
	Metuje		
	Orlica		
7	Nemunas	Nemunas	-
8	Lyna and Wegorapa	Pregolya	-
9	Swieza	Swieza	-

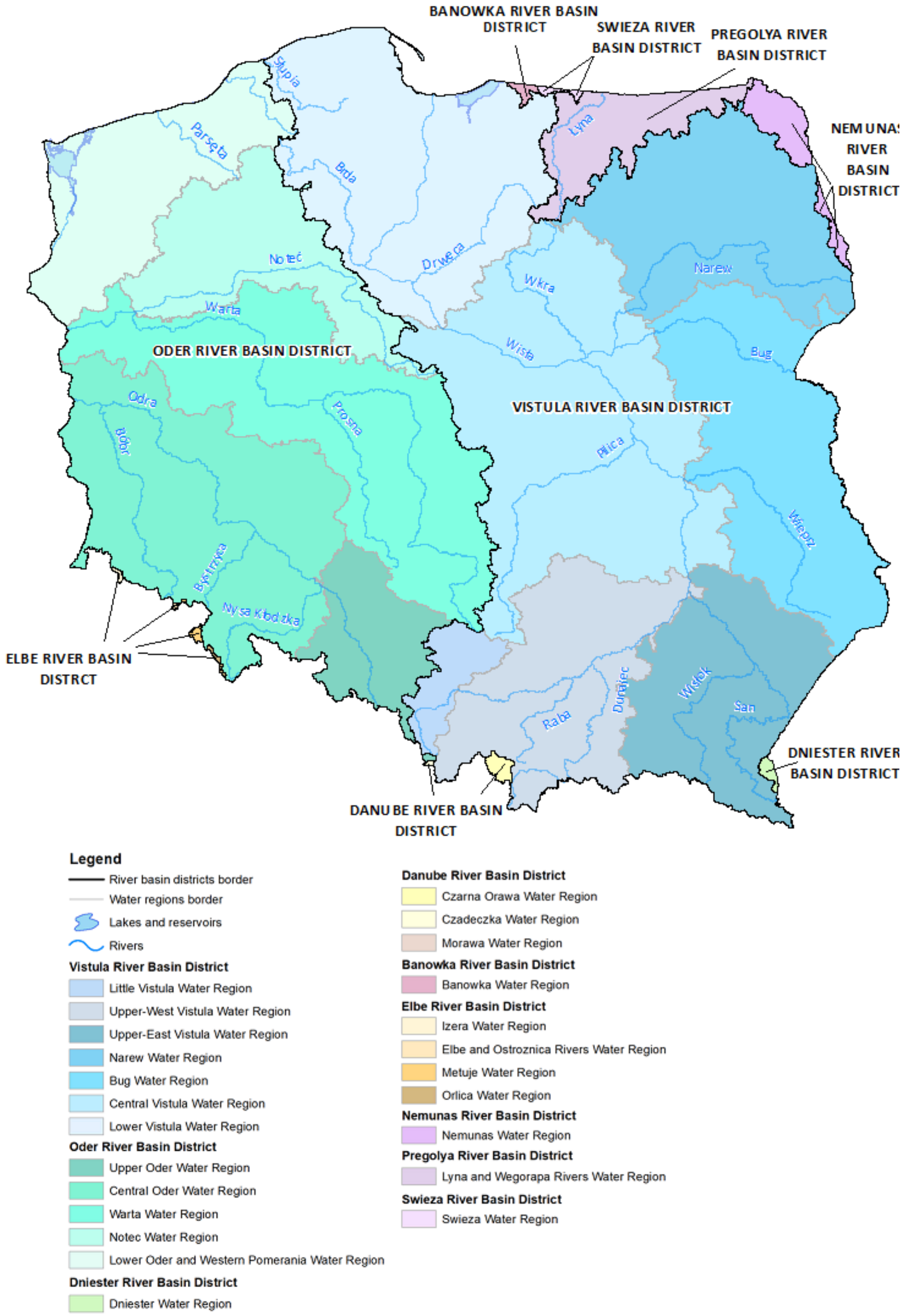

Figure 1: River basin districts and water regions in Poland

1.3. COMPETENT AUTHORITIES

The authorities responsible for flood risk management are those responsible for developing planning documents required by the Floods Directive or participate in the process of agreeing or giving opinions on them.

The leading authorities are the minister in charge of water management, the president of State Water Holding Polish Waters, the minister in charge of the maritime economy, and the directors of maritime offices.

The authorities responsible for flood risk management are listed below, with a description of their role in the implementation of the Floods Directive.

1) **Minister in charge of water management:**
   - approves the preliminary flood risk assessment and makes it available to the public by posting it on the Public Information Bulletin website;
   - approves the flood hazard maps and flood risk maps and makes them available to the public by posting them on the Public Information Bulletin website;
   - makes draft flood risk management plans available to the public for comments, ensuring active participation of all interested parties;
   - takes action to ensure coordination at the level of international river basin districts;
   - adopts, by regulation, flood risk management plans and their updates;
   - determines, by regulation, in consultation with the minister in charge of digital affairs and the minister in charge of maritime economy, the requirements for the development of flood hazard maps and flood risk maps and their scale;
   - provides the European Commission with reviews and updates of preliminary flood risk assessment, flood hazard maps and flood risk maps, and flood risk management plans;
   - monitors the implementation of measures included in flood risk management plans.
2) **Minister in charge of the maritime economy**:
   - prepares a draft preliminary seawater flood risk assessment, including internal marine waters, and forwards it to the Polish Waters;
   - prepares a draft seawater flood risk management plans including internal marine waters, and forwards them to the Polish Waters.
3) **Minister in charge of inland navigation:**
   - agrees on a draft preliminary flood risk assessment;
   - agrees flood risk management plans regarding inland waterways.
4) **Minister in charge of transport:**

- agrees on draft flood risk management plans regarding transport infrastructure.

5) **President of State Water Holding Polish Waters:**
   - prepares a draft preliminary flood risk assessment;
   - submits the draft preliminary flood risk assessment to the voivodes for their opinion and to the minister in charge of inland navigation in the area of inland waterways for agreement;
   - prepares draft flood hazard maps and flood risk maps in consultation with the competent voivodes;
   - prepares draft flood risk management plans (FRMPs) in consultation with the minister of transport regarding transport infrastructure, with the competent voivodes and after consultation with voivodeship marshals;
   - agrees on draft flood risk management plans regarding inland waterways with the minister of inland navigation.
6) **Directors of maritime offices - Director of the Maritime Office in Gdynia and Director of the Maritime Office in Szczecin:**
   - prepare draft seawater flood hazard maps and flood risk maps including internal maritime waters, and submit them to the Polish Waters.
7) **Voivodes:**
   - give opinions on preliminary flood risk assessment projects;
   - agree on draft flood hazard maps and flood risk maps;
   - agree on draft flood risk management plans.

2. CLASSIFICATION OF FLOODS

The basis for determining the types of floods to be included in the review and update of the PFRA is the classification used in the EU for the implementation of the Floods Directive (Flood Directive Reporting Guidance, 2019), which distinguishes between floods by source (origin), by the mechanism of their occurrence, and by their characteristics (such as the magnitude of the phenomenon).

Division of floods by source:

- Fluvial flood [A11];
- Pluvial flood [A12];
- Groundwater flood [A13];
- Seawater flood [A14];
- Flood from artificial water-bearing infrastructure [A15].

Division of floods according to the mechanism of their occurrence:

- Natural exceedance [A21];
- Defence exceedance [A22];
- Defence or infrastructural failure [A23];
- Blockage [A24].

Division of floods by characteristics:

- Flash flood [A31];
- Snow melt [A32];
- Other rapid onset [A33];
- Medium onset flood [A34];
- Slow onset flood [A35];
- Debris flood [A36];
- High velocity flow [A37];
- Deep flood [A38].

The above classification is shown in Tables 2-4, with reference to the types of floods used in Poland prior to the implementation of the Floods Directive.

Table 2: Classification of floods by source with reference to the flood classification used in Poland before the Floods Directive.

Type of floods by source		**Type of floods according to the classification used in Poland before the Floods Directive**	**UE codes***		
Name	**Definition**		**S**	**M**	**CH**
Fluvial flood [A11]	Floods associated with exceedance of river waters, streams, mountain streams, canals, and lakes, including snow melting floods.	Precipitation flood[1]	A11	A21	A39
		Flash flood[2]	A11	A21	A31
		Snow melt flood[3]	A11	A21	A32
		Winter flood[4]	A11	A24	A39
		Overflow of water through a flood embankment	A11	A22	A33
		Destruction or damage to a flood embankment	A11	A23	A33
Pluvial flood [A12]	Floods associated with flooding of land with waters directly deriving from rainfall or snow melting; it can include urban storm floods or excess water in non-urban areas.	Flash flood – if it is not related to a river	A12	A21	A31
		Urban flood - a flash flood in a city Inundations[5]	A12	A21	A31
Groundwater flood [A13]	Floods associated with flooding of land due to the rise of water levels above the ground level; it can include	Inundations[6]	A13	A21	A39

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[1] Precipitation floods (summer):
- torrential - local floods on mountain streams and small lowland watercourses (water catchment area A < 50 km^2) caused by local storms and heavy rainfall,
- frontal - wide range floods in mountainous, sub-mountainous and lowland areas,
- expansive - similar in its origin to the frontal ones, they are caused by precipitation, the productivity of which is influenced by orography (terrain); they occur in mountainous regions.

[2] *Flash flood* – it is a particular case of precipitation (torrential) flood, with a local range, very rapid course and short duration (usually less than 6 hours) caused by rainfall of high productivity, often of storm character; it may occur in any area, most often in mountain areas; favorable conditions for their occurrence also occur in urban areas (*urban flood*); it may also be caused by failure of hydrotechnical equipment.

[3] Snow melt flood - caused by rapid melting of the snow cover.

[4] Winter floods:
- blockage floods - created during ice flow as a result of the accumulation of ice floe, usually in narrowings of canals, river bends, bridge cross sections;
- slush floods - caused by rapid and abundant formation of slush and bottom ice, which clogs the cross-section of the river and causes damming of the water table.

[5]Inundations - temporary flooding of the land caused by local rains of high efficiency and intensity or by the rapid melting of snow of large thickness and density [Mikulski (1998) Systematics and definitions of water sciences: in historical terms. [In:] Zeszyty Terminologiczne/TNW. Earth Sciences; z. 1, "Retro-Art", Warsaw.

Type of floods by source		Type of floods according to the classification used in Poland before the Floods Directive	UE codes*		
Name	**Definition**		**S**	**M**	**CH**
	the rise of groundwater and underground water resulting from high surface water levels.				
Seawater flood [A14]	Floods associated with flooding of land by sea waters, estuaries, and coastal lakes.	Storm flood[7]	A14	A21	A39
		Destruction or damage to a flood/storm embankment	A14	A23	A33
Flood from artificial water-bearing infrastructure [A15]	Floods associated with flooding of land by waters from the water supply and sewerage infrastructure or resulting from failure of such infrastructure	Destruction or damage to a damming structure[8]	A15	A23	A33
Flood from another source [A16]	Application requires clarification and individual assignment of mechanism codes and characteristics		A16		
No data available [A17]	No data available on the source of the flood – only possible for floods by 2011				

**Legend:*

S: type of flood by source

M: type of flood by mechanism

CH: type of flood by characteristics

[6]Inundations - the appearance of groundwater close to the land surface due to: lowering of the land surface, damming of groundwater due to rising water table in surface watercourses and reservoirs, anthropogenic inhibition of groundwater flow [Dictionary of Hydrogeology (2002)].

[7]Storm flood - caused by stormy winds blowing towards the shores on the coasts of the sea, hindering the flow of rivers flowing into the sea, causing damming of states in river beds and on coastal floods, as well as the ingress of sea waters into river mouths.

[8]Damming structures are structures that allow surface water to accumulate permanently or periodically above an adjacent area or a natural water table.

Table 3: Types of floods by mechanism

Type of floods by mechanism	Definition
Natural exceedance [A21]	Flooding of land due to rising of water levels
Defence exceedance [A22]	Flooding of land due to overflowing water, e.g. through an embankment crown
Defence or infrastructural failure [A23]	Flooding of land due to destruction or damage to natural or artificial flood protection or technical infrastructure, including failure of retention facilities, flood protection gates
Blockage [A24]	Flooding of land due to natural or artificial blockage of a watercourse
Other mechanism [A25]	Flooding of land with water as a result of other mechanisms, e.g. strong wind (application needs to be clarified)
No data available [A26]	Lack of available data on the flood mechanism (applicable to floods that occurred by 2011; for floods after 2011 applicable in exceptional, justified cases

Table 4: Types of floods by characteristics

Type of floods by characteristics	Definition	Criterion of application
Flash Flood [A31]	Rapid flood caused by heavy rainfall in a relatively small area	Heavy rain: > 20 mm/d Rapid course: < 6 hours
Snow Melt Flood [A32]	Flood associated with melting of snow	Occurrence of snow cover rapid increase in air temperature > 0°C
Other rapid onset flood [A33]	Rapid flood, other than flash flood	Rapid course: < 12 godzin
Medium onset flood [A34]	Flood of average course	Course: 1 – 3 days
Slow onset flood [A35]	Flood of slow course	Course: > 3 days
Debris Flood [A36]	Flood accompanied by transport of a large amount of debris	Transport of a large amount of debris
High Velocity Flow [A37]	Flood of high speeds	Water velocity flow > 1 m/s (water has at least a strong ability to affect objects, is able to move objects of large size and mass and

Type of floods by characteristics	Definition	Criterion of application
		even breach the structure of static objects, and poses a serious threat to people)
Deep Flood [A38]	Flood of significant depths	Water depth > 2 m (the depth of the flood water poses at least a high risk to people and a very high risk of total property damage - not only the ground floor but also the first floors of buildings may be flooded)
Other characteristics [A39]	Flood with different characteristics or lack of specific characteristics (application needs to be clarified)	All other flood incidents
No data available [A40]	No data are available on the characteristics of the flood (only applicable to floods that occurred by 2011)	For floods by 2011, where no information is available to characterise them

A preliminary flood risk assessment is carried out for all types of floods, and as a result of the analyses, **significant types of floods** are identified, for which areas of potential significant flood risk will be identified.

A review and update of the PFRA should be carried out at least for the flood types identified in previous planning cycles, including:

1) Fluvial floods (A11) with the following mechanisms:
   - natural exceedance (A21),
   - defense exceedance (A22) or destruction of flood embankments (A23),
   - winter floods with blockage mechanism (A24),
   - flash flood (A31),
   - snow melt flood (A32).
2) Pluvial floods (A12);
3) Groundwater floods (A13);
4) Seawater floods (A14) with the following mechanisms:
   - natural exceedance (A21),
   - defense exceedance or destruction of flood embankments or storm embankments (A23),

5) Floods arising from the destruction or damage to damming structures (A15).

Where flood events of a flood type other than those indicated above are identified, they should be included.

The PFRA does not cover floods from sewerage systems, which is a consequence of Art. 16 point 43 of the Water Law Act, according to which a flood is defined as **the temporary covering by water of land that is not covered by water under normal conditions,** in particular, caused by water exceedance in natural watercourses, reservoirs, canals and from the seawater, **excluding the covering by water of land caused by water exceedance in sewerage systems.** As a result of the review and update of PFRA in 2018, the following **significant flood types were identified in Poland:**

1) fluvial flood – in two scenarios:
   - natural flood,
   - destruction of flood embankments;
2) seawater flood – in two scenarios:
   - natural flood,
   - destruction of flood embankments or storm embankments;
3) flood from artificial water bearing infrastructure – associated with flooding of land in the event of damage or destruction of damming structures.

As part of the review and update of the PFRA in the 3rd planning cycle, it should be verified whether the above list of significant types of floods in Poland remains valid at the stage of determining the APSFR (Section 7).

Detailed information on the analysis of flood types in the PFRA is presented in the following sections of the methodology.

3. SCOPE OF REVIEW AND UPDATE OF THE PRELIMINARY FLOOD RISK ASSESSMENT

The preliminary flood risk assessment in the 2nd planning cycle (2018) included areas of potential significant flood risk (APSFR) for 3 types of floods:

1) fluvial floods (A11) - a total of about 29,000 km of rivers, of which:
   - river sections indicated in the PFRA of 2011, for which FHMs and FRMs were developed in the 1st planning cycle - about 14,500 km,
   - river sections indicated in the PFRA of 2011, for which FHMs and FRMs were developed in the 2nd planning cycle - about 13,500 km,
   - river sections indicated in the review and update of PFRA from 2018, for which FHMs and FRMs were developed in the 2nd planning cycle - about 1.3 thousand km;
2) seawater floods, including internal marine waters (A14) - a total of about 1,200 km of rivers and coastal sections, of which:
   - estuary sections of rivers - approximately 450 km,
   - lagoons - 269 km,
   - coastal areas - 495 km;
3) floods from damage or destruction of damming structures (A15) - 26 dam reservoirs with a dam height of more than 10 m (10 in the Oder river basin district and 16 in the Vistula basin district).

APSFRs were designated in 6 river basin districts: Oder, Elbe, Vistula, Pregolya, Nemunas, and Danube.

Historical floods were identified in 6 river basin districts: Oder, Elbe, Vistula, Pregolya, Danube, and Dniester.

The main objective of the review and update of the PFRA in the 3rd planning cycle is to supplement the data on historical floods and to analyse and assess changes in flood risk that have occurred since the last update of the PFRA throughout the country, taking into account the division into river basin districts and, where appropriate, also into water regions.

The scheme of the PFRA review and update in the 3rd planning cycle is presented in Figure 2.

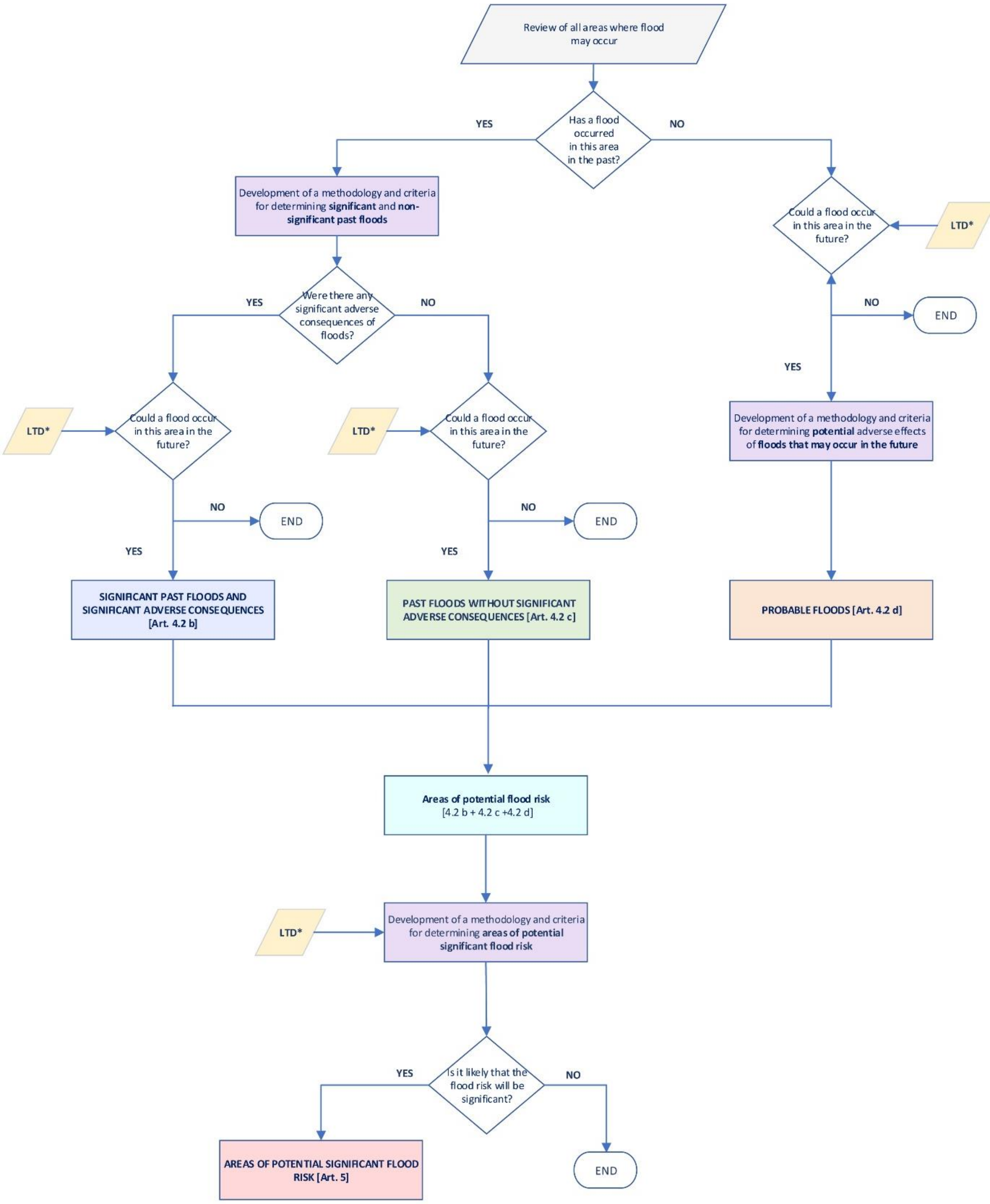

Figure 2: The scheme of the PFRA review and update

* LTD [long-term development] - taking into account the forecast of long-term developments, including climate change and land development.

The scope of the review and update of the PFRA includes the following stages:

1. Identification, description, and analysis of areas where flooding may occur.

   Areas where floods may occur should be understood as all places/areas where, based on available data (competent authorities, literature data and scientific sources, media information, hydraulic analyses, etc.) a flood problem has been identified or it is predicted that a flood may occur.

   1.1. Identification and description of historical floods;

      a) Verification and supplementation of flood data until 2017 (1st and 2nd cycles);

      b) Identification and description of floods between 2018 and 2023;

      c) Analysis of historical floods;

      After identifying all areas where floods occurred in the past, their analysis will be carried out in accordance with the PFRA scheme presented in Figure 2, including methodology and criteria for determining significant historical floods and assessing their consequences.

      d) Designation of floods referred to in Art. 4.2b and 4.2c FD;

      As a result of the analyses carried out , the following areas should be designated:

      - significant historical floods with significant adverse consequences (Article 4.2b FD);
      - significant historical floods without significant adverse consequences (Article 4.2c FD).

      The method of identifying, describing, and analyzing floods that have occurred in the past is described in Section 4.

      e) Preparation of reports on significant historical floods - in the scope described in Section 4.5.

   1.2. Identification and description of floods that may occur in the future;

      a) Updating data on areas where floods are likely to occur;

      b) Updating data on natural flood areas (floodplains);

      c) Determining the potential adverse consequences of floods;

      After identifying all areas where floods may occur in the future, an assessment will be carried out, taking into account the methodology and criteria for determining the potential adverse consequences of floods that may occur in the future.

d) Analysis of floods that may occur in the future in accordance with the PFRA scheme;

e) Designation of floods referred to in Art. 4.2d FD.

As a result of the analyses carried out, areas where floods may occur in the future should be designated (Art. 4.2d FD).

The method of identifying, describing, and analyzing floods that may occur in the future is described in Section 5.

1.3. Carrying out a forecast of long-term developments, including in particular land-use changes and the impact of climate change on floods - should be conducted at each stage, in accordance with the PFRA scheme is described in Section 6.

2. Designation of areas of potential significant flood risk is described in Section 7.1.
3. Analysis of changes and flood risk classification is described in Section 7.2.

An essential element of the PFRA scheme is the analysis of the adverse consequences of floods (on human life and health, the environment, cultural heritage, and economic activity). For historical floods, these consequences are assessed in relation to their significance (floods with significant adverse consequences and floods without significant adverse consequences). In the case of probable floods, the potential adverse consequences of floods that may occur in the future are assessed.

An essential aspect of PFRA is the consideration of the forecast of long-term developments on the occurrence of floods: the impact of climate change and the effect of changes in land development. The forecast of long-term developments is taken into account at every stage of the analysis of areas where floods may occur.

The PFRA procedure is carried out separately for each type of flood.

4. HISTORICAL FLOODS

4.1. VERIFICATION AND SUPPLEMENTATION OF FLOOD DATA BY 2017

The verification and supplementation of the flood data described in this section applies to events from 1946 to 2017. For floods before 1946, data can be aggregated based on the date of occurrence without in-depth analysis of the course of individual events.

One of the objectives of the preliminary flood risk assessment is to identify and describe historical floods and then designate significant floods for further analysis. In the 1st and 2nd cycles, the primary source of flood information was a survey of local government units and other state institutions, and obtaining information on historical floods focused on indicating the date of the phenomenon's occurrence, duration, and area coverage. Both in the 1st and 2nd cycles and at present, the fundamental problem with identifying sources of flood data is the lack of a structured approach in their collection and processing. Information is scattered among different institutions and there are no dedicated units collecting data in a comprehensive manner. Therefore, the results of the survey have only partially provided the information needed to identify and describe floods until 2017:

- out of 22,799 all objects in historical flood layers, 15,698 are point objects, i.e. with very limited information about their location,
- over 15% of all floods have no date of occurrence or the date is incomplete (no exact day or month),
- almost 86% have no information on the duration of the flood,
- very few floods have information on the frequency of the phenomenon,
- only 33.5% of objects have completed fields relating to the number of people at risk of flooding,
- for more than 71% of the data, information on flood losses is missing.

Due to the incompleteness of the data, the floods from the 1st and 2nd planning cycles require careful analysis and verification, in particular with regard to the following information:

- type of flood by source and mechanism,
- time range,
- spatial range (with continuity of the phenomenon),
- information on the magnitude and scale of floods,
- frequency,
- threat to the population,

– flood looses.

Verification of historical floods until 2017 should be carried out for all types of floods. All available data sources listed in Table 5 should be used for the description.

A detailed list of materials to be used is presented in Section 8 of the methodology.

Table 5: Data sources for verification of historical floods by 2017.

No.	Data source	Data usage	Type of flood
1	Publications - literature data	Description of historical floods, determination of the spatial range of historical floods	A11, A12, A13, A15
2	Data from the IMGW-PIB database - hydrological data (including statistical data) and meteorological data	Description of historical floods, flood aggregation	A11, A13, A15
3	Data from the UW - information submitted by JST (in particular years) including claims for compensation	Description of historical floods, determination of the spatial range of historical floods, assessment of the adverse consequences of floods	A11, A13, A15
4	Media information	Description of historical floods	A11, A12, A13, A15
5	Satellite data	Determination of the spatial range of the historical floods	A11, A13, A15
6	PSP data – PSP intervention data	Determination of the spatial range of the historical floods	A11, A12, A13
7	Data from the PIG-PIB databases - hydrogeological and geological data, data on the development of mineral deposits (including mining areas)	Description of historical floods	A13
8	ARiMR data	Description of historical floods	A13
9	DTM	Determination of the spatial range of the historical floods	A11, A12, A13
10	FHM and FRM	Determination of the spatial range of the historical floods	A11, A15
11	RZGW data	Description of historical floods, adverse consequences of floods	A11, A13, A15
12	GUS data on population	Description of historical floods	A11, A13, A15

4.1.1. VERIFICATION OF THE TYPE OF FLOOD

The flood type should be determined according to the classification of floods by source, mechanism and characteristics. For floods between 1946 and 2011, the source must be provided obligatorily, whereas the mechanism and characteristics should be indicated if data is available; in justified cases it is possible to indicate the lack of data.

The types of historical floods identified in the 1st and 2nd planning cycles were determined through a survey conducted by JST (local government units). Respondents answered questions about the causes of flooding of the land surface and independently identified the source and mechanism based on specific definitions. This information was not subsequently verified. Taking into account the previously applicable classification of floods in Poland, in which all floods, including fluvial ones, caused by precipitation were called pluvial floods (see Table No. 2, Section 2) in some cases, it was found possible to erroneously assign the type of floods identified in the 1st and 2nd cycles.

Therefore, for floods until 2017, information on the source, mechanism, and characteristics of the flood should be verified and supplemented. Additional data sources, not considered in the 1st and 2nd planning cycles will be used for this purpose.

Verification of fluvial floods will be carried out based on hydrological data at water gauges. Detailed information is included in Section 4.1.2.

Verification of pluvial floods will be carried out based on additional analyses, the results of which will be compared with data on National Fire Service interventions. Detailed information is included in Section 4.1.3.

The method of verification of groundwater floods is described in Section 4.1.4.

Historical floods for which such information has been updated or supplemented are highlighted in the table: Summary of flood data until 2017.

4.1.2. FLUVIAL FLOODS

4.1.2.1. FLOOD TIME RANGE

For each flood, the start and end date and duration of the flood, as well as the culmination date, should be determined.

In order to verify the time range, fluvial floods from the 1st and 2nd planning cycles should be aggregated according to the date of occurrence (separately for each watercourse or watercourse and its tributaries). In cases where the full flood date or year and month are given, aggregation involves grouping historical data with the same or similar date (tolerance +/- 1 month). This is due to the following assumptions:

- survey data may be inaccurate,
- the same flood may have a shifted culmination date along the watercourse.

Whereas, in the case of historical floods, for which only the year of occurrence is given, aggregation can be performed if a single flood occurred on a given watercourse in a given year (however, such aggregation may be subject to error).

The next step is to carefully verify the time range in terms of:

- confirmation of the occurrence of flood,
- the duration of the flood and the start and end dates of the flood,
- the date of the culmination of the flood.

The exception are floods before 1946 for which the data should also be aggregated, but this can only be based on the date of occurrence (YYYY-MM or YYYY), without the need for a deeper analysis of the flood course.

Depending on whether the flood occurred in a controlled or uncontrolled catchment, data from different sources are considered. For controlled rivers, the primary source of information on the flood time range is hydrological data from the IMGW-PIB database. However, other resources are analysed for rivers in uncontrolled catchments: literature, media information, data from voivodeship offices (conclusions from local government units), and high water marks. No exact time verification is foreseen for floods for which only the year of occurrence is available and which have not been aggregated with floods of known date.

4.1.2.2. SPATIAL RANGE OF THE FLOOD

The next stage is the spatial verification of identified (confirmed in terms of type and time range) historical floods from the 1st and 2nd planning cycles and supplementation of the continuity of flood ranges.

The geometry is verified or supplemented according to the following assumptions:

1) First, satellite images are analysed (if images from a given time interval are available);
2) Information from literature, media reports and, other materials may also be a source of data for determining the range of floods;
3) If there is no information from the data sources mentioned in points 1) and 2), the water table elevations are determined (verified) for historical floods in controlled catchments based on hydrological data from water gauge stations (where available), described in detail in Section 4.1.2.3; then, the PHA from the FHM are used to supplement/verify the range of the historical flood, taking into account the established tolerance range of +/- 30 cm for the maximum water table elevation recorded during the historical flood to the most similar scenario (10%, 1% or 0.2%);
4) Where the maximum water table elevations recorded during the historical flood differ significantly from the water table elevations in the scenarios with specified probability on the FHM and in the case of uncontrolled catchments (if hydrological

data from other sources - e.g. high water marks - are available for these catchments), hypothetical flood ranges based on DTM are entered into the database.

5) To obtain additional water table elevations for analysis based on DTM, it is possible to use elevation values estimated at the border of the known flood range below and above the analysed river section;
6) For uncontrolled rivers for which information on the range or elevations of the water table is unavailable, adjustments are made to the existing flood ranges from the 1st and 2nd planning cycles based on DTM only.
7) For previous floods, where information about the range is not available, a buffer along the watercourse (whole or part) is taken as a symbolic representation of the flood.

SCOPE AND WAY OF USE OF DATA SOURCES

SATELLITE DATA – are used to verify the spatial range of historical floods based on available data from the Sat4Envi service.

The range of flood hazard can be determined based on available satellite images from two types of satellites: optical Sentinel-2 and radar Sentinel-1. Sentinel-2 has been operating in Earth orbit since 2015, and Sentinel-1 since 2014.

Sentinel-2 is an optical sensor operating in both the visible light band (Figure 3) and the near- and short-wave infrared. Its advantage is that the image is more intuitive to interpret for the untrained user, but its disadvantage is dependence on atmospheric conditions (mainly cloud cover), which significantly hinders terrain observations.

Sentinel-2 is an Earth observation mission that acquires optical images with high spatial resolution (from 10 m to 60 m) and serves a wide range of applications related to land and coastal waters, including monitoring flood extents. The optical sensor mounted on the Sentinel-2 mission satellites is the Multi-Spectral Instrument (MSI). Its spatial resolution is different for different spectral channels. For the Red, Green, Blue and NIR channels it is 10 m; for the other spectral channels it is higher, and is 20 m or 60 m. The temporal resolution of these data is 5 days.

To determine the water mask from Sentinel-2 image, the Normalized Difference Water Index (NDWI) is used (Figure 4). This index allows you to separate the surface covered with water from other areas of the terrain. The resulting raster mask is vectorised using GIS software.

Sentinel-1 is a radar sensor that records images in the microwave radiation range and is independent of solar illumination and cloud cover (the satellite itself is a source of radiation that it sends towards the earth and then receives it), which makes the image of the land surface more often visible than in case of Sentinel-2. The spatial resolution obtained from these sensors is also theoretically 10 m, but the image is contaminated (measurement noise), significantly lowering the sharpness of the obtained images. The return period of the Sentinel-1 mission is 6 days.

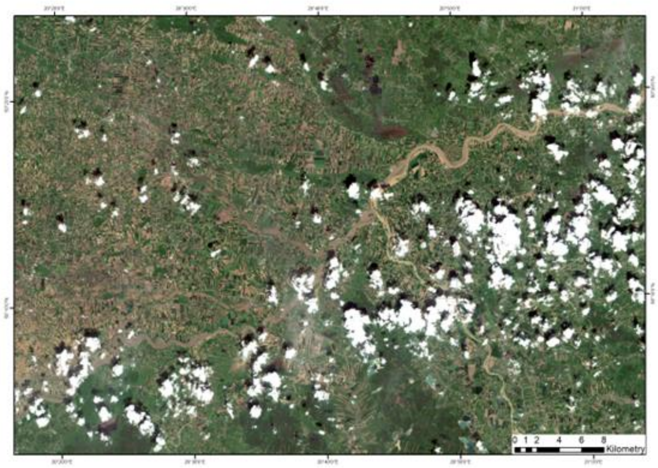

Figure 3: Composite of RGB channels for an example of exceedance on 25 May 2019, Vistula River, surroundings of Cracow

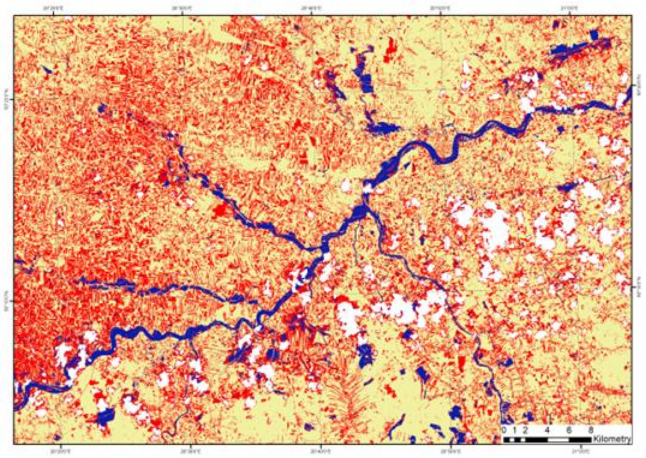

Figure 4: Visualisation of NDWI calculation for an example of exceedance on 25 May 2019, Vistula River, surroundings of Cracow

In order to determine the water mask from the Sentinel-1 radar image, through the SNAP software, it is possible to calibrate and geometrically correct the image (the Sentinel-1 radar image is taken at an angle and not perpendicularly down as in Sentinel-2) and to filter the image to remove speckle effects (salt and pepper). Due to the large spread of pixel values, switching to a logarithmic scale in decibels (dB) is also advisable. After performing these procedures, a threshold can be adopted so that an approximate classification of the image into the flooded area or non-flooded area can be made.

Figure 5 shows a scheme of the NDWI calculation process based on Sentinel-2 imagery.

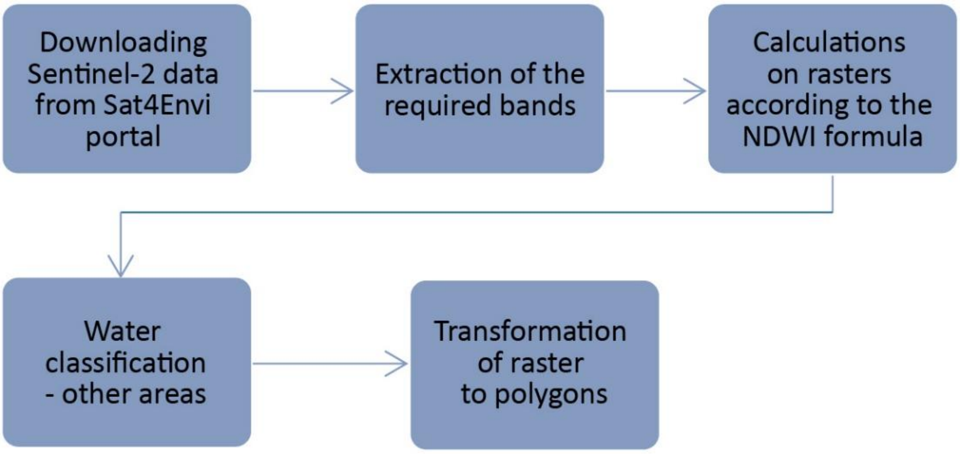

Figure 5: NDWI calculation process based on Sentinel-2 imagery

INFORMATION FROM LITERATURE, MEDIA REPORTS AND OTHER MATERIALS

As part of the work to verify historical floods, all available literature and press reports (articles and multimedia files) are analysed. Where these sources contain accurate and reliable information on the spatial range of the floods (maps, photos, precise description), this data is included in the historical flood layer.

In cases where a precise description of the flood range is not available, but information about the event should be included in the historical floods database, a buffer along the watercourse (whole or part) is taken as a symbolic representation of the flood. This situation applies in particular to literature data describing events for which DTM analysis is not possible (no data from water gauge stations) or the expected results will not reliably reflect the range of the flood at the time of its occurrence.

FHM AND FRM - FHA FOR THE 0.2%, 1% AND 10% SCENARIOS

In the case of rivers for which FHMs have been developed, it is possible to use flood hazard areas to supplement information on historical floods in justified situations. If, as a result of an analysis of historical hydrological data from the IMGW-PIB database, water gauges are identified for which the maximum elevation of the water table recorded during a flood is similar to one of the scenarios from the FHMs. Then, the FHAs will be used as a source of geometry for historical floods.

DIGITAL TERRAIN MODEL – is used for supplementing the spatial range of historical floods.

The analysis using DTM is used to supplement the data and as a subsidiary measure in special cases where satellite images are not available or the use of FHA range from the FHM is not advisable, e.g. when the elevations from historical flood do not match the FHM scenario, where the FHMs have not been developed, on uncontrolled rivers where information is given about the maximum flood elevation from other sources (e.g. high water marks). The analysis is carried out using suitably adapted GIS tools.

As part of the analysis, the discontinuity of the aggregated historical flood areas is supplemented by generating a hypothetical range based on the estimated water table elevations (based on the data collected to date) and elevation data from the DTM. The main assumptions of the proposed procedure are outlined below:

- The analysis is carried out in sections bounded by the location where information about the occurrence of historical floods and the estuary of the watercourse is available.
- The known values of the water table are the limits of the interpolation, while the course of the water table system coincides with the longitudinal profile read from the DTM. The interpolation interval depends on the decline of the water table and the physiographic conditions.
- Point layers of historical fluvial floods from the 1st and 2nd planning cycles are used to supplement the information on the areas of historical floods and their course. The points serve as supporting information at the verification stage of the developed hypothetical historical flood ranges but do not condition the analysis.

The analysis procedure using DTM consists of the following steps:

1) Preparation of layers for interpolation (Fig. 6A):
    a) Determination of the course of the river section, considering the course of the main riverbed based on the DTM.
    b) Determination of evenly distributed points along the axis of the watercourse and assignment of an ordinate read from the DTM to these points. The location and distances between points depend on the decline of the water table profile and the physiographic conditions of the watercourse. In exceptional cases, the location of points is modified accordingly to reflect the course of the flood event best.
    c) In place of the points, lines perpendicular to the axis of the watercourse on the analysed section of the river will be generated. The width of the lines depends on the width of the watercourse valley.
2) Determination of historical water table elevations:
    a) Water table elevations at cross sections enclosing the area are read from water gauge stations or derived from other data sources - these may be high water marks or elevations estimated from the known flood range above or below the analysed section.
    b) For other lines located along the watercourse, the value to be added to the elevation read from the DTM is determined. For this purpose, the difference between the known elevations of the water table in the water gauge profiles closing the analysed area and the DTM is calculated. Then, based on linear

interpolation, values are determined and added to the elevations read from the DTM at the previously determined points, thus indicating an estimated historical water table elevation along the entire section.

3) Resulting rasters:

   a) Interpolation of the digital water surface model (DWSM) raster based on lines perpendicular to the watercourse axis with assigned water table elevations values (Fig. 6B).

   b) Generation of a depth raster by subtracting the digital terrain model from the DWSM (Fig. 6C).

4) Resulting polygons (Fig. 6D):

   a) Conversion of depth raster to vector version.

   b) Development of polygons representing hypothetical historical flood areas - generalisation, removal of areas not hydraulically connected to the river, elimination of small objects and holes.

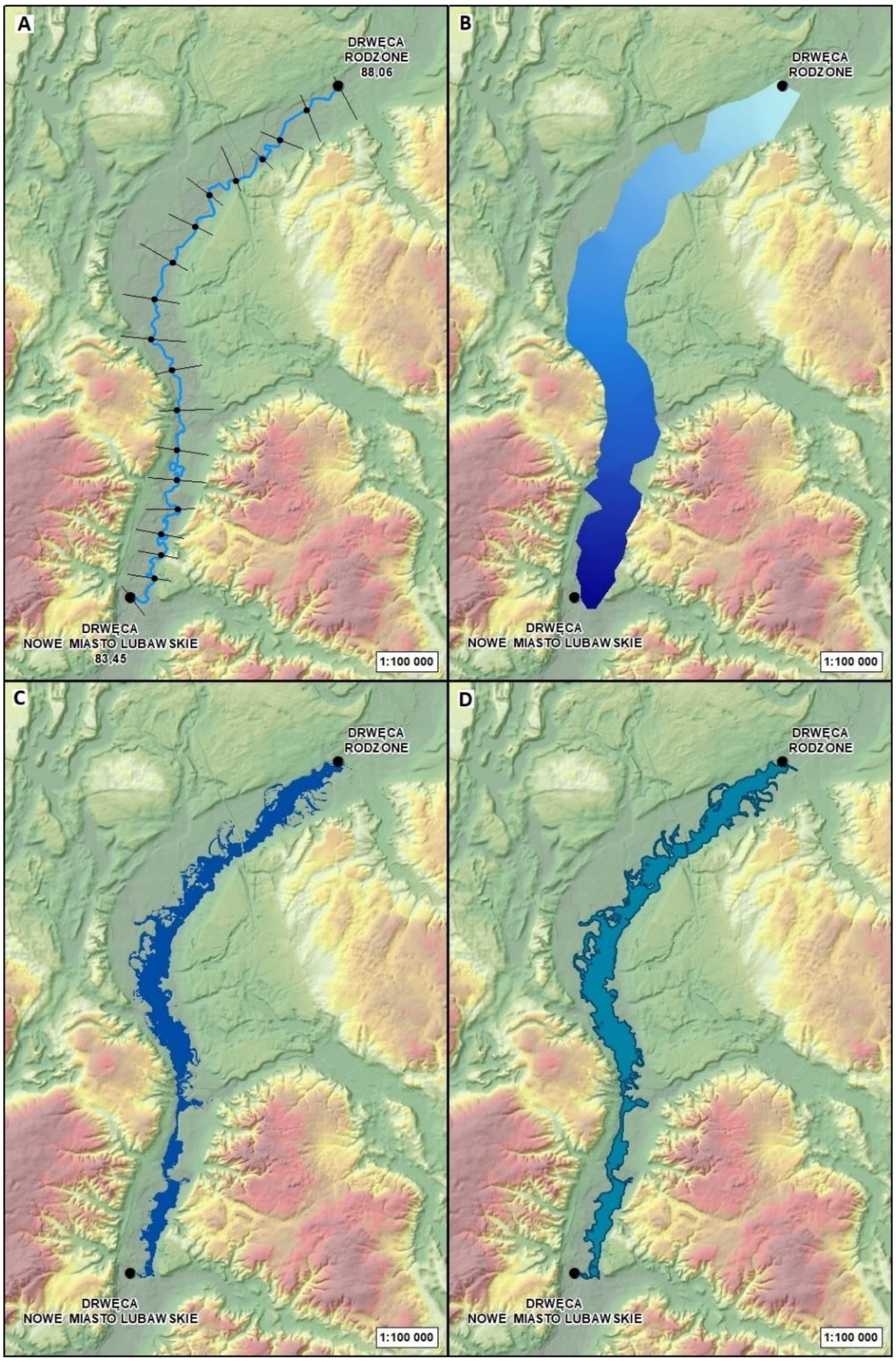

Figure 6: Stages of analysis of the spatial range of historical floods using DTM on sample data for the Drwęca River.

The analyses are based on a digital terrain model with a spatial resolution of 1 m from the resources of the Central Office of Geodesy and Cartography. Where DTMs with different validity are available, the data with the date of acquisition closest to the verified historical flood is used. The average height error of the collected data does not exceed 15cm.

In exceptional cases, i.e., in areas where a historical flood occurred and where there was subsequently a significant change in the topography (e.g., as a result of the construction of a retention reservoir canopy), it is possible to use topography data based on publicly available topographic maps and information on the year of putting the retention reservoirs into operation according to the data contained in the Register and Control System of Damming Structures RCSDS of IMGW-PIB is envisaged as an auxiliary measure.

4.1.2.3. HYDROLOGICAL AND METEOROLOGICAL DATA

A significant data source to organise and supplement flood data until 2017 is hydrological data that was not used in the 1st and 2nd cycles.

Hydrological and meteorological data from the IMGW-PIB database (where available) are used to supplement the data for floods in terms of:

- start, culmination, and end dates of the flood and duration of the flood – in case of exceeding the alarm water levels;
- or only the date of the culmination – in the case where the alarm water levels were not exceeded, but the warning levels or the medium high water level were exceeded; the culmination flow rate (or the highest recorded) together with the date of occurrence and the corresponding water stage;
- zero ordinate of the water gauge in order to determine the absolute position of the water table (water table elevation) [m above sea level];
- determination of the Q/H zone characteristic for the water gauges where the flood occurred;
- precipitation – to the extent required in the flood reports, described in Section 4.4.

By comparing the elevation of the water table calculated for the culmination of the flood wave at a given water gauge station with the elevations of the water table calculated from the flood hazard maps, the recurrence period (frequency) of the historical flood (F) is determined using the following intervals:

- F < once every 10 years,
- Once every 10 years ≤ F < once every 100 years,
- Once every 100 years ≤ F < once every 500 years,
- F ≥ once every 500 years.

The use of historical hydrological data from IMGW-PIB and statistical data from the FHM and FRM database allows for efficient filling in the gaps in the PFRA database (start and end of flood - duration, flood date, maximum magnitude, and frequency). If, for the same flood event, the maximum ordinates from individual water gauges for the culmination of the flood wave are assigned to different frequency ranges, the polygon representing the flood range is assigned the lowest frequency value assigned to one of the water gauges.

Hydrological data from the IMGW-PIB database and the zeros ordinates of water gauges are available in the PL-KRON86-NH height system. The currently valid FHMs are also available in this system. When preparing data on historical floods, values should be provided in two height systems: PL-KRON86-NH and PL-EVRF2007-NH.

The data prepared at this phase, mainly the flood date and the maximum water table elevations for the flood wave, will then be used to aggregate, supplement, and verify the range of the historical floods.

A detailed description of the measures to complete the flood data in terms of frequency of occurrence, duration of flooding and maximum water table elevations during the culmination of the flood wave is provided in Section 4.2.2.3.

FLUVIAL FLOODS (A11) CAUSED BY DEFENCE EXCEEDANCE (A22) OR DESTRUCTION OF FLOOD EMBANKMENTS (A23)

The following information is used to verify flood events:

1) RZGW data on floods that occurred due to destruction or damage to the flood embankment or water exceedance over the flood embankment.
2) UW data - information on local government units that reported events bearing the characteristics of natural disasters and conclusions related to removing the consequences of floods.
3) Media information.
4) Satellite data.

FLUVIAL FLOODS (A11) WITH A BLOCKAGE MECHANISM (A24)

The following information is used to verify flood events:

1) Information from the measurement and observation network of IMGW-PIB (occurrence of frazil or ice blockage).
2) Information from RZGW (including navigation guide for the Lower Vistula inland waterway, communications about ice, and information on ice-breaking operations).
3) UW data – information on local government units that reported events bearing the characteristics of natural disasters and conclusions related to removing the consequences of floods.
4) Media information.
5) Satellite data.

4.1.3. PLUVIAL FLOODS

In the 2nd planning cycle, pluvial floods were mainly identified based on data on fire brigade interventions between 2010 and 2017 for 39 cities with a population over 100,000. As a result of data analysis on fire brigade interventions (PSP database), information was obtained about the interventions that were treated as significant historical pluvial floods in point form. The source of information on pluvial floods was also the local government units survey.

In the 3rd cycle, as part of supplementing the database of historical pluvial floods, a point catalog of sudden local floods (flash floods) and a database of floods developed by IMGW-PIB as part of the “KLIMAT”project: "The impact of climate change on the environment, economy and society (changes, effects and ways of limiting them, conclusions for science, engineering practice, and economic planning) will be included. The project database includes 2,104 events from 1971–2010, developed based on, among others, the archives of the Main Flood Prevention Committee, materials of the Association of Polish Counties, the study entitled: "Monografia katastrofalnych powodzi w Polsce w latach 1946-1998" (Monograph of catastrophic floods in Poland in 1946-1998), and media reports. The above-mentioned sources provided information about damage in catchment areas and flood-affected places, and often about the nature of precipitation causing the flood and its duration. Additionally, the database includes information on precipitation from the Central Hydrological and Meteorological Database of the IMGW-PIB (CBDHM).

Updating and revising the historical pluvial flood database will involve changing the presentation of events from a point form to a polygon form, verifying the relevance of the information, and verifying the type of flood.

Due to the lack of information on flood range in historical sources (for the areas indicated above, covering 39 cities and data from the “KLIMAT”project), it is proposed to use the ESRI tool "Model bluespots to map flood risk". This tool was developed for the analysis of catchments located in urbanised areas where heavy precipitation can cause periodic flooding of residential buildings and critical infrastructure.

The term Bluespot (Figure 7), which the Danish Road Directorate defined in its report on the impact of rainwater on infrastructure[6], refers to a depression or basin in the terrain. It is an area that, during rainfall, can fill to a considerable extent with water, or if the rainfall is heavy, overflow and endanger buildings located within or near it. A spatial analysis carried out for the city of Copenhagen in Denmark allowed us to identify areas where there is a risk of flooding caused by heavy rainfall, and thus present urbanised areas that can be or are flooded and areas where future development should be avoided.

The operation of the model is based on DTM analysis by locating land depressions from the highest to the lowest within a given catchment, their filling and overflowing during simulated storm rainfall, and the designation and aggregation of water runoff paths across the land surface. It should be noted that the duration and rate of rainwater infiltration into the ground are ignored. It is also possible to include buildings and linear infrastructure in the form of roads and railway lines in the calculations.

[9]https://www.klimatilpasning.dk/media/364640/the_blue_spot_model_report_183.pdf

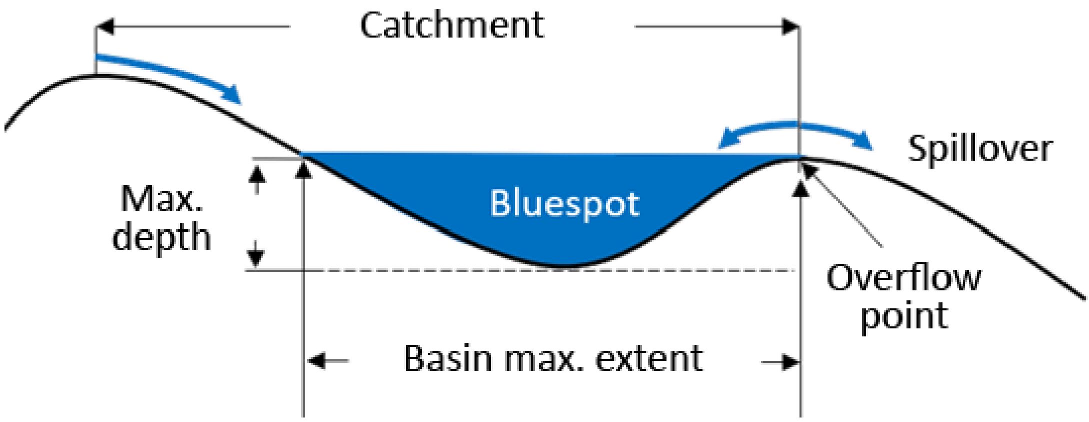

Figure 7: General scheme of the Bluespot local catchment area

Assumptions and measures related to the use of the Bluespot tool:

1) The DMT in raster format used for spatial analysis should be made using high resolution laser scanning technology;
2) The DTM along river beds and watercourses should be modified to ensure the natural flow of flood waters at culverts and bridges - they should be removed. Omitting this step will have a negative impact on free surface water runoff and the formation of artificial basins filled with rainwater;
3) The DTM should only represent the ground surface. The use of NMPT (numerical model of land cover), which presents, among others, vegetation, will result in significant errors in the results of the analyses, including errors in the modelling of surface water runoff paths, the location and volume of non-drainage areas, the catchment boundaries of individual land depressions and the location of their overflow points to subsequent, lower-lying catchments;
4) Including buildings from BDOT10k to guide spatial analysis by adding them to the DTM. Their impact on surface water runoff will then be shown: ponding of water, changing the flow direction, and flowing around. If the buildings have an internal courtyard, then it should be removed. This will avoid retaining water from precipitation within its area;
5) Use of BDOT10k elements, particularly the communication network, buildings, structures and facilities, and land utility networks.

6) The analysis does not take into account land development or the impact of rainwater or combined sewage systems.

The next step will be determining the amount of precipitation for a given point representation. Based on the measurement stations, a polygon layer will be created in the GIS software. This operation will make it possible to assign historical pluvial floods in point form to a specific meteorological station and determine the amount of precipitation that caused the flood.

Precipitation of 20 mm or more will be used for analysis because rainfall of this amount can cause various types of damage in the area.

In addition, a case study will be carried out according to the criterion of daily precipitation amounts. This criterion has been used in the "KLIMAT"project to assess precipitation posing an appropriate category of flood hazard in Poland:

- ≥30 mm/day – threatening precipitation (local flooding and flooding of areas and premises lower-lying),
- ≥50 mm/day – flood-threatening precipitation (rainwater forms concentrated linear runoff in both undeveloped and built-up areas, especially when terrain slopes down ; surface flooding of land and lower-lying premises),
- ≥70 mm/day – flood precipitation (limited absorption of water by the ground surface, reaching a critical point of storm and sewage infrastructure capacity of a large mass of water, streets become channels carrying excess water; In case of larger slopes of the terrain, rushing streams are formed, causing damage to the surface infrastructure,
- ≥100 mm/day – catastrophic precipitation (uncontrolled rainwater runoff into watercourses results in flooding of the areas around the watercourses and catastrophic damage to infrastructure.

If it is not possible to determine the amount of daily precipitation, the event is classified as local inundations and flooding of areas and lower levels when rainfall ≥20 mm/day.

Therefore, the following classification is adopted for the purposes of the PFRA:

- For precipitation <30 mm/d – the range corresponding to 20 mm of precipitation is assumed,
- 30-50 mm/d – the range corresponding to 30 mm of precipitation is assumed,
- 50-70 mm/d – the range corresponding to 50 mm of precipitation is assumed,
- 70-100 mm/d – the range corresponding to 70 mm of precipitation is assumed,
- ≥100 mm/d – the range corresponding to 100 mm of precipitation is assumed.

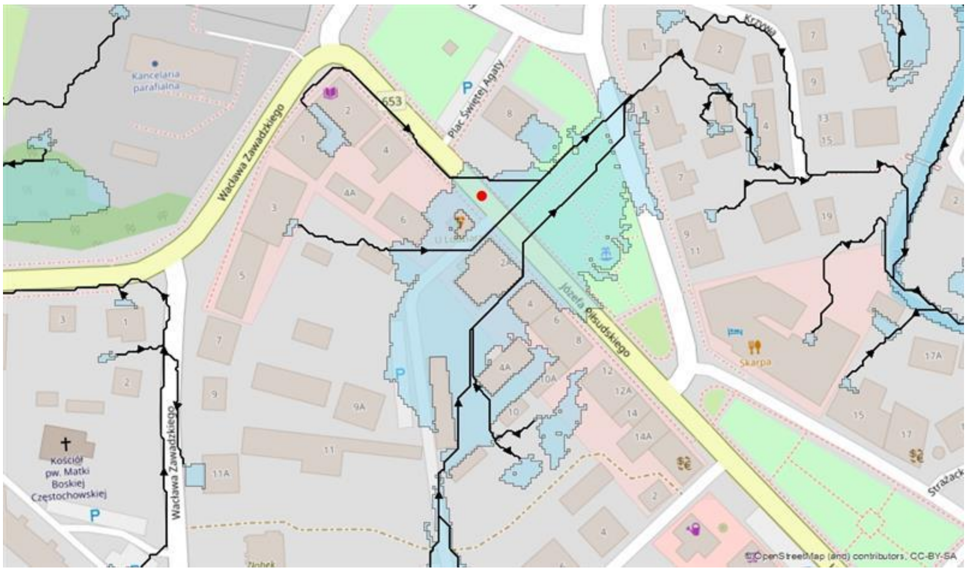

Figure 8: Presentation of land depressions flooded by the amount of precipitation

In addition to changing the type of spatial representation, the database of historical pluvial floods also requires verification of events in terms of their size and significance. The PFRA report in the 2nd planning cycle indicated that the vast majority of State Fire Service interventions concerned events that covered an area of several hundred square metres at most: depending on the city, between 28% and 87% of interventions concerned an area of up to 100 m2, and between 72% and 97% of interventions concerned areas up to 300 m2.

The strategic nature of the PFRA document requires constraints to be put in place to eliminate non-significant events, such as flooding of, e.g., individual properties or small area depressions.

In order to obtain significant events, only areas exceeding 10 000^{m2} and depths greater than 30 cm will be included.

Points representing events from the 2nd planning cycle and data from the "KLIMAT"project that fall outside the BLUESPOT areas (with the 10 m buffer) will be excluded from further analyses. Point data for which it is not possible to verify the amount of precipitation due to the lack or incomplete date of occurrence will also be excluded.

Polygon data from the 2nd planning cycle, for which the range was precisely determined through a survey conducted at that time and its area exceeds 10,000 m^2, will be subject to further analyses in an unchanged form (will not be replaced by an area from Bluespot). Other polygon data that do not have a date, have an area of less than 10,000 m^2, or include areas significantly different in the range from the designated Bluespot areas will be excluded from further analyses.

The result of the historical pluvial flood analyses carried out as part of the PFRA review and update in the 3rd planning cycle will be a surface layer representing the land depressions at risk of flooding in the event of precipitation of a certain amount (Figure 8).

The areas resulting from these analyses are of a general nature and represent only the approximate range of the flood.

4.1.4. GROUNDWATER FLOODS

In the database from the 1st and 2nd planning cycles, historical floods until 2017 include 96 locations that have assigned a groundwater flood type.

To verify this information, an analysis will be carried out using the available results of measurements of the location of the groundwater table at points of the PGI-PIB groundwater observation and research network. In-situ measurements provide the most reliable and direct information about the occurrence of groundwater tables above the ground surface. In the absence of locations of monitoring points representative for the areas of identified historical flood events, further analysis will be conducted using information from various sources as indirect information. First, an analysis of hydrogeological conditions (presence of aquifers with free water table occurring at a depth of up to 2 m below ground level, MhP PPW, MhP GUPW, CBDH) and geomorphological conditions (occurrence of flat or concave morphological forms - DTM and SMGP) will be carried out, and in case of negative results, analysis of information related to the impact of anthropopressure (location near mines/deposits - MIDAS Database, within depression funnels MhP GUPW).

The following works are carried out to supplement and update information on historical groundwater floods:

1) Data analysis in the Groundwater Monitoring Database, which collects measurement results from hydrogeological stations belonging to the PIG-PIB groundwater observation and research network. Points meeting the following criteria will be selected from the database:
   - aquifer with free water table,
   - the top of the aquifer at a depth of up to 2 m below ground level,
   - occurrence of groundwater table above the ground surface was found at the point along with the determination of the time range.

   The years where the maximum water stage was found should be correlated with data from IMGW-PIB on the amount of precipitation, and the so-called wet years (increased groundwater recharge) should be selected.
2) Analysis of data on the hydrogeological situation published in the PSH Guide *"Extremely high stages of groundwater in Poland between 1981 and 2015"* with regard to hydrogeological highs (sustained extremely high water stages for subsequent weekly measurements).

3) Analysis of data on hydrogeological hazards in terms of high groundwater stages based on warnings about dangerous phenomena occurring in groundwater supply or abstraction zones (Art. 380 of the Water Law Act).
4) Analysis of hydrological data regarding high surface water stages resulting in the damming of the drainage base causing flooding.
5) Analysis of areas reported by RZGW as part of PFRA *"Reporting an area for analysis in the preliminary flood risk assessment".*

The analysis of satellite images will also be used to verify the occurrence of a historical flood. Methods of supervised classification of satellite multispectral imagery will be based on the RGB composition and remote sensing spectral indices (including Modified Normalised Difference Water Index, Normalised Difference Pond Index and Normalised Difference Turbidity Index) will be used to identify past flooding. The classification will be made using Landsat-7-8 images and, from 2000 and later (from 2015), Sentinel-2. To limit the classification results to groundwater flooding, a mask will be applied to designate areas predisposed to their occurrence. The mask layer will be obtained by determining the range of areas of shallow groundwater table up to a depth of 2 m below ground level combined with the presence of permeable formations on the surface in concave or flat forms.

Data sources for verifying floods until 2017:

1) PFRA from the 2nd planning cycle - historical floods;
2) Publications – literature data;
3) IMGW-PIB data - meteorological data;
4) Data from UW, PSP, ARiMR;
5) PIG-PIB data (SMGP, MHP PPW WG, MIDAS MWP);
6) Cards of areas reported by RZGW under PFRA.
7) Satellite data;
8) DTM.

4.1.5. FLOODS FROM DAMMING STRUCTURES

The following information is used to verify flood events:

1) RZGW data on floods that occurred as a result of destruction or damage to damming structures.
2) UW data - information about local government units that reported events bearing the characteristics of natural disasters and conclusions related to removing the consequences of floods.
3) Media information.
4) Satellite photos

4.1.6. ADVERSE CONSEQUENCES OF FLOODS

For identified historical floods between 1946 and 2017, the adverse consequences of floods on human life and health, economic activity, the environment and cultural heritage are determined.

Information on the consequences of floods is determined based on information obtained on actual flood losses based on archival data (understood as: statistical data obtained from relevant institutions or data from the literature), including data collected in previous planning cycles. The verification and supplementation of data are mainly based on literature data or statistical data. Verification of data on the adverse consequences of floods applies only to significant historical floods, descriptions of which can be found in the literature or available statistical data.

Based on archival data, the adverse consequences of floods are described with the following information:

1) number of fatalities,
2) number of injured people,
3) total value of flood losses (PLN),
4) occurrence of adverse consequences of floods on human life and health (YES/NO),
5) occurrence of adverse consequences of floods on the environment (YES/NO),
6) occurrence of adverse consequences of floods on the cultural heritage (YES/NO),
7) occurrence of adverse consequences of floods on economic activities (YES/NO).

In addition, the adverse consequences of floods are described based on estimated data determined by spatial analyses:

1) estimated number of residents affected by flood - based on the number/area of residential buildings (BDOT10k - 2018) and information on the average usable area per person (BDL data from the Central Statistical Office); according to the FRM Methodology;
2) area of urban areas (cities) in the flood zone - based on CLC (classes 1.1.1. and 1.1.2.):
   for floods up to 1994: CLC 1990,
   for floods from 1995 to 2002: CLC 2000,
   for floods from 2003 to 2008: CLC 2006,
   for floods from 2009 to 2014: CLC 2012,
   for floods after 2015: CLC 2018;
3) area of industrial sites in the flood zone - based on the CLC (classes 1.2.1., 1.2.2., 1.2.3., 1.2.4.; assignment of the CLC version to individual floods as in the case of the area of urbanised sites).

Estimated data - as the name suggests - allow for the estimation of indicators illustrating the adverse consequences of floods. Such simplification is necessary because of the lack of homogeneous data from the entire period of the analysed floods, i.e. since 1946. The use of

CLC allows obtaining information over a longer period of time (starting in 1990), from the same data source - i.e. assuming continuity in how the data is processed.

For individual categories of adverse consequences of floods, a division into subcategories should also be taken into account:

1) **for the human life and health category:**
    a) **human health** (adverse consequences on human life and health, including fatalities, flooded buildings and adverse health effects resulting from pollution or interruptions of water supply and treatment services);
    b) **community** (adverse consequences on facilities of particular social importance, which may include, among others, facilities for public administration, emergency response, education, health care and social welfare;
2) **for the environment category:**
    c) **water bodies** (adverse consequences on the ecological or chemical condition of surface waters or groundwater covered by the Water Framework Directive. Such consequences may result from pollution from various point and diffuse sources or the hydromorphological consequences of floods;
    d) **protected areas** (adverse consequences on protected areas, including Natura2000 areas, bathing areas, and drinking water intakes);
    e) **sources of pollution** (sources of potential pollution in the event of a flood, such as IPPC and Seveso installations or point or diffuse sources);
    f) **other** (other adverse consequences on the environment, including soil, biodiversity, flora and fauna, etc.);

3) for the cultural heritage category:

    g) **culturally valuable objects** (adverse consequences on cultural heritage, which may include historic buildings and other culturally valuable sites);
    h) **landscape** (negative consequences on cultural landscapes (permanent or long-term), i.e., cultural spaces that represent combined works of nature and man, such as relics of traditional landscapes);
    i) **other**;
4) **for the economic activity category:**
    j) **property;**
    k) **infrastructure;**
    l) **land use in rural areas;**
    m) **economic activity;**
    n) **other.**

Subcategories should be defined for **significant floods from the 1st and 2nd cycles** - based on indicators, literature data, and archival data. However, for **other floods**:

1) **from the 1st cycle** - the general categories specified in the 1st cycle should be left;

2) **from the 2nd cycle** – leaving the subcategories specified in the 2nd cycle.

The following assumptions are made when determining the subcategories based on flood indicators until 2017:

1) the **human health** subcategory (B11) is defined when:

- the number of fatalities is greater than 0,
- the number of injured people is greater than 0,
- the estimated number of inhabitants affected by the flood is greater than 0,
- the number of flooded residential buildings is greater than 0;

2) the subcategory **protected areas** (B22) is defined when:

- the area of nature protection forms is greater than 0;

3) the subcategory **pollution sources** (B23) is defined when:

- the area of industrial sites in the flood zone is greater than 0;

4) the subcategory **cultural assets** (B31) is defined when:

- the number of flooded buildings and culturally valuable areas is greater than 0;

5) the subcategory **property** (B41) is defined when:

- the estimated number of inhabitants affected by the flood is greater than 0,
- the area of urban areas (cities) in the flood zone is greater than 0;

6) the subcategory **infrastructure** (B42) is defined when:

- the area of urban areas (cities) in the flood zone is greater than 0,
- the area of industrial sites in the flood zone is greater than 0;

7) the subcategory **economic activities** (B44) is defined when:

- the area of industrial sites in the flood zone is greater than 0.

If a given subcategory of flood consequences is associated with several indicators, it is assigned if the condition for at least one indicator is met.

All of the above information is used at the further stage of historical flood analyses – in the identification of significant historical floods.

4.2. IDENTIFICATION AND DESCRIPTION OF FLOODS BETWEEN 2018 AND 2023

The methodology used to identify flood events from 2018 to 2023 for each flood type and the methodology for obtaining and preparing data on these floods is intended to ensure the highest possible quality and completeness of the data.

The list of data sources for identification of historical floods between 2018 and 2023 is presented in Table 6.

Table 6: Data sources for identification of historical floods from 2018 to 2023.

No.	Data source	Data usage	Type of flood
1	Publications - literature data	Description of historical floods, determination of the spatial range of flood	A11, A12, A13, A15
2	Data from the IMGW-PIB database - hydrological data (including statistical data) and meteorological data	Description of historical floods, flood aggregation	A11, A13, A15,
3	UW data - information submitted by JST (in particular years) including claims for compensation	Description of historical floods, determination of the spatial range of historical floods, assessment of the adverse consequences of floods	A11, A13, A15,
4	Media information	Description of historical floods	A11, A12, A13, A15
5	Satellite data	Determination of the spatial range of the historical flood	A11, A13, A15
6	PSP data – PSP intervention data	Description of historical floods	A11, A12, A13
7	PIG-PIB monitoring data	Description of historical floods	A13
8	RZGW data	Description of historical floods	A11, A13, A15
9	ARiMR data	Description of historical floods	A13
10	DTM	Determination of the spatial range of the historical flood	A11, A12, A13
11	FHM and FRM	Determination of the spatial range of the historical flood	A11, A15
12	Request letters/conclusions to update the PFRA	Description of historical floods and the adverse consequences of floods	A11, A13, A15

4.2.1. DETERMINATION OF THE TYPE OF FLOOD

The numerical layer of historical flood (HF) will contain attributes defining the type of flood by source, mechanism and characteristics, according to the flood classification described in Section 2.

In the case of flood events reported by institutions, particular attention should be paid to whether the type of flood reported is consistent with the definitions (Section 2).

4.2.2. FLUVIAL FLOODS

4.2.2.1. FLOOD TIME RANGE

In the case of fluvial floods, the identified events are treated as a hydrological phenomenon that occurs along the river from the moment the flood wave originates until its end.

To determine the time of occurrence of fluvial flood events, it is necessary to:

1) Analyse the data included in the monthly Bulletins of the National Hydrological and Meteorological Service - a list of water gauge stations where exceedances of alarm water levels were observed (the situation of exceeding the alarm water levels is defined, among others, as a threat to infrastructure). An example of a table from the monthly bulletin is shown in Table 7.

Table 7: Water gauge stations where the alarm water levels were exceeded in July 2018 - Bulletin of the National Hydrological and Meteorological Service

Catchment area	River/ Receiver	Water gauge station	Exceedances in days	Maximum exceedance [cm]	Maximum exceedance date
Vistula	Skawinka	Radziszów	19 VII	9	19 VII
	Raba	Rabka	19 VII	0	19 VII
	Czarny Dunajec	Nowy Targ	19 VII	86	19 VII
	Dunajec	Nowy Targ-Kowaniec	19 VII	19	19 VII
		Sromowce Wyżne	19-20 VII	16	20 VII
		Krościenko	19 VII	5	19 VII
		Gołkowice	19 VII	16	19 VII
	Białka	Trybsz	19-21 VII	81	19 VII
	Niedziczanka	Niedzica	19 VII	22	19 VII
	Brda	Ciecholewy	19-25 VII	8	23 VII
Oder	Barycz	Odolanów	21 VII	0	21 VII
	Gwda	Piła	20-21 VII	12	21 VII

Water gauge stations coinciding with the location of the identified historical floods should be selected from the collected bulletin data based on the data described below. The list of water gauges will be updated continuously during the analysis of the obtained flood data.

In addition, flood events that result only from hydrological data from monthly bulletins should be verified. For situations where we do not have information from other data sources, sending a "targeted" survey should be considered.

2) Obtain information from the voivodeship offices (UW) about local government units (JST) that reported events bearing the characteristics of natural disasters and conclusions related to removing the consequences of floods. The types of documentation concerned are defined in detail in Section 8 of the methodology. Information from the UW should be used to supplement information on historical floods from 2018 within the scope presented in the table: Summary of flood data 2018-2023;
3) Analyse literature data and media information on the occurrence of flood events. Information from these two data sources obtained for specific historical flood events will be included in the table: Summary of flood data 2018-2023;

4) Analyse data from PGW WP: data from RZGW operational centres, comments submitted by RZGW on PFRA from the 2nd planning cycle, and other information provided on historical floods;
5) Other information and letters related to PFRA, e.g. reports from local government units.

The above data sources will allow the identification of historical floods on rivers:

– controlled: points 1 to 5,
– uncontrolled: points 2 to 5.

4.2.2.2. SPATIAL RANGE OF THE FLOOD

Flood events should have a specific spatial range. In order to determine the exact range of a historical flood, the following data should be taken into account:

– satellite data,
– media information, information from literature and other materials,
– hydrological data,
– the range of FHA from the applicable FHM,
– DTM.

The method and order of use of data sources, depending on availability for individual flood events are analogous to those in Section 4.1.2. in terms of supplementing the spatial range of historical floods from the 1st and 2nd planning cycles.

All acquired data from individual data sources will be included in dedicated tabular summaries, while the information on floods developed on their basis, which will supply the spatial layers of historical floods, will also constitute a separate set of data in an ordered structure depending on the form of the data source used.

Table 9 in Section 4.2.6 contains a list of data needed to identify and describe floods with assigned data sources, methods and dates of data acquisition.

4.2.2.3. HYDROLOGICAL AND METEOROLOGICAL DATA

A list of flood events assigned to the locations of the IMGW-PIB water gauges and identified historical floods are prepared in the form of an xlsx file and a spatial layer of flood events assigned to the locations of the IMGW-PIB water gauges. The summaries will contain information that will supply the attributes of the spatial layer of historical floods. They will allow for the verification of information, among others, about the maximum elevation of the water table during a flood, the start and end time of the event, and flood frequency.

1) GUIDELINES FOR DETERMINATION OF THE FLOOD FREQUENCY

The historical flood frequency (F) is determined using the following intervals:

– F < once every 10 years,

- once every 10 years ≤ F < once every 100 years,
- once every 100 years ≤ F < once every 500 years,
- F ≥ once every 500 years.

In the case of controlled rivers for which FHMs are available, to assign a historical flood to the appropriate frequency range, a comparison should be made (MAX_RZ_KRON) of the maximum water table elevation of the historical flood (the water table elevation during the culmination of the flood wave) on the water gauge profile closest to the given flood range, to the water table elevation, also in a controlled cross-section, determined on the FHM. On this basis, the entire polygon (aggregated) of the flood range on a given river should be assigned to the appropriate range. If, for the same flood event, the maximum elevations of individual water gauges for the culmination of the flood wave are assigned to different ranges, the entire (aggregated) polygon will be assigned the attribute value of the lowest frequency that was assigned to one of the water gauges.

In the case of controlled rivers without developed FHM, floods in the same catchment for which we have FHM should be verified, and the dates of occurrence should be compared. If the dates are consistent, the frequency should be assumed as for the river with the developed FHM. When the dates do not match, the frequency can be determined using readily available statistical data.

Determining the frequency of floods on uncontrolled rivers can be defined based on information from the administrator of a given watercourse or a local government unit that constantly monitors the occurrence of floods in their area of interest or from literature and media data. Based on the obtained data, it is possible to assign which of the above-mentioned frequency intervals a given flood event includes. Due to the lack of measurement data, no calculations can be made.

The definition of the MAX_RZ_KRON attribute is the value of the water table elevation (in the PL-KRON86-NH geodetic elevation system) during the culmination of the flood wave, i.e. the maximum water table elevation in the water gauge cross-section calculated based on the zero ordinate of the water gauge and the recorded water stage. The maximum water stages during the culmination of the flood wave (maximum values) are measured values. A separate layer with water gauges will be developed, which should include, among others, values of the maximum elevation of the water table recorded during the culmination of the flood wave. As described above, the MAX_RZ_KRON attribute can only apply to controlled rivers at the measurement station location.

2) GUIDELINES FOR DETERMINING THE TIME RANGE OF AGGREGATED FLOOD

The time range of the aggregate flood will be determined based on data for water gauges (located within the aggregate flood area) as follows:

- flood start date based on the water gauge from the upper course of the river,

– flood end date based on the water gauge from the lower course of the river.

Table 8 shows the method of determining the frequency, the maximum elevations of the water table for the culmination of the flood wave, and the duration of the flood. It also includes the characteristics of water gauge stations to supplement the flood attributes.

Table 8: Characteristics of water gauge stations to supplement attributes about the flood in 2005 - example for sections of the Drwęca and Wel rivers

Station characteristics (attribute)	**Data in the 1st and 2nd PFRA cycles**	**Data for the 3rd PFRA cycle**				**Data source**
River	-	Drwęca	Drwęca	Drwęca	Wel	IMGW-PIB database
Water gauge	-	Brodnica	Nowe Miasto Lubawskie	Rodzone	Kuligi	IMGW-PIB database
The zero ordinate of the water gauge in the system/ Kronstadt'86 [m n. Kr.]	-	67,36	79,79	84,8	94,76	IMGW-PIB database
Status of the water gauge station	-	operational	operational	operational	operational	IMGW-PIB database
Warning water level [cm]	-	230	330	280	150	IMGW-PIB database
Water table elevation for the warning level Kronstadt'86 [m above sea level]	-	69,66	83,09	87,6	96,26	IMGW-PIB database
Alert water level [cm]	-	260	340	320	180	IMGW-PIB database
Water table elevation for the alert level Kronsztad'86 [m above sea level]	-	69,96	83,19	88	96,56	IMGW-PIB database
Flood start date	-	2005-03-20	2005-03-18	2005-03-19	2005-03-17	IMGW-PIB database
Flood end date	-	2005-03-25	2005-03-21	2005-03-19	2005-03-19	IMGW-PIB database
Duration [days] (CZAS TRWAN)	No data available	5	3	1	2	Calculation: IMGW-PIB database
Flood culmination date (DATA KUL)	Supplemented from surveys	2005-03-22	2005-03-19	2005-03-19	2005-03-18	IMGW-PIB database
Maximum water stage WW_{2005} [cm] (MAX_STAN)	-	284	366	326	191	IMGW-PIB database
Maximum water table elevation for WW_{2005} Kronsztad'86 [m above sea level] (MAX_RZ_KRON)	No data available	70,2	83,45	88,06	96,67	IMGW-PIB database

Station characteristics (attribute)	Data in the 1st and 2nd PFRA cycles	Data for the 3rd PFRA cycle				Data source
Water table elevation corresponding to Q10% Kronsztad'86 [m above sea level]	-	70,15	83,23	87,68	96,36	FHM and FRM
Water table elevation corresponding to Q1% Kronsztad'86 [m above sea level]	-	70,45	83,5	87,84	96,52	FHM and FRM
Water table elevation corresponding to Q0,2% Kronsztad'86 [m above sea level]	-	70,61	83,66	87,91	96,57	FHM and FRM
FREQUENCY (recurrence period) (CZESTOSC)	No data available	Once every 10 years ≤ F < once every 100 years	Once every 10 years ≤ F < once every 100 years	F ≥ once every 500 years	F ≥ once every 500 years	Analysis: IMGW-PIB/FHM database

After collecting a complete database of flood events, an additional analysis should be carried out using the spatial layer with water gauge stations obtained from IMGW-PIB to check whether any water gauges located in the area of the historical flood have been omitted. Hydrological and statistical data from the identified water gauges will be supplemented using the IMGW-PIB database. They will be necessary for further work on completing the spatial range of the flood.

FLUVIAL FLOODS (A11) CAUSED BY DEFENCE EXCEEDANCE (A22) OR DESTRUCTION OF FLOOD EMBANKMENTS (A23)

The following information is used to verify flood events:

1) RZGW data on floods that occurred due to destruction or damage to the flood embankment or water exceedance over the flood embankment.
2) UW data - information on local government units that reported events bearing the characteristics of natural disasters and conclusions related to removing the consequences of floods.
3) Media information.
4) Satellite data.

FLUVIAL FLOODS (A11) WITH A BLOCKAGE MECHANISM (A24)

The following information is used to verify flood events:

1) Information from the measurement and observation network of IMGW-PIB (occurrence of frazil or ice blockage).

2) Information from RZGW (including navigation guide for the Lower Vistula inland waterway, ice messages, and information on ice-breaking operations).
3) UW data – information on local government units that reported events bearing the characteristics of natural disasters and conclusions related to removing the consequences of floods.
4) Media information.
5) Satellite data.

4.2.3. PLUVIAL FLOODS

The following source materials will be analysed in the review and update of PFRA in the 3rd planning cycle for floods in 2018 - 2023:

- database of PSP interventions for the whole of Poland for the years 2018 - 2023,
- precipitation measurement data (daily total) from the IMGW-PIB PSHM database.

Analysis of the PSP intervention database and the “KLIMAT”project database showed that precipitation is a phenomenon characterised by considerable variability in time and space. This feature makes aggregating this data over a larger area difficult and significantly limits determining the flood hazard area.

The PSP intervention database is the only data set kept structured and homogeneous for Poland, including the years 2018-2023. The use of this database is possible after verification which consists of, among others, the analysis of the quality of spatial data in terms of location errors, an analysis of correct coding and event descriptions in individual database fields. Spatial analyses of PSP interventions and atmospheric precipitation are expected to be carried out in the entire country in accordance with the Bluespot methodology and the criterion of daily precipitation amounts discussed in Section 4.1.3.

As part of the verification of pluvial floods from 2018, areas not exceeding 10,000 m2 and whose depth is less than 30 cm will be rejected.

The result of this analysis will be a surface layer representing land depressions at risk of flooding in the event of precipitation of a certain amount, corresponding to selected events identified in the PSP database.

The areas resulting from the precipitation analyses of historical floods carried out as part of the review and update of the PFRA in the 3rd planning cycle are of a general nature and represent only the approximate range of the flood.

4.2.4. GROUNDWATER FLOODS

Flood events caused by groundwater in 2018-2023 will be identified and characterised according to two complementary procedures. This approach aims to obtain as complete, detailed, and reliable information as possible. It is essential due to the specificity of these floods, which may occur scattered within the country, are usually characterised by a small area and result in relatively non-significant consequences, and are often incorrectly identified - confused with floods from rainwater or flooding of underground parts of buildings and structures that are not accompanied by flood phenomena consistent with its definition. The input data for further analysis will be hydrogeological data from the PIG-PIB Groundwater Monitoring database (first scheme) and archival data obtained from institutions collecting data on flood events (second scheme).

In the first procedure scheme, the initial stage of work (preparation of input data) will include:

- Analysis of information on the current hydrogeological situation published in Hydrogeological Messages on changes in the volume of resources, stage and hazards of groundwater – years 2018-2023;
- Analysis of information on the hydrogeological hazard in terms of high groundwater stages based on warnings about dangerous phenomena occurring in groundwater supply or abstraction zones;
- Selection of points of the PGI-PIB groundwater observation and research network where a periodic rise of the water table above ground level was observed;
- Analysis of the results of groundwater table location measurements at points of the PIG-PIB groundwater observation and research network to identify incidents of rising groundwater table location and its occurrence above the ground surface;
- A literature search of the subject and media publications.

After identifying phenomena whose characteristics indicate that rising groundwater levels may be the cause of their occurrence, verification of the type of flood source and the spatial extent of the phenomenon will be carried out. The following data will be used for this purpose:

- MHP PPW - WH - layer depth of occurrence of the first aquifer,
- hydrogeological profiles of boreholes collected in CBDH,
- DTM,
- SMGP – map of surface formations and geomorphological sketches,
- satellite images (subject to the availability of cloudless scenes from the period of the event).

In the second of the schemes to identify groundwater floods between 2018 and 2023, input data will be obtained from institutions that collect information on flood events and their consequences, including UW, PSP, and ARiMR.

Areas that have been reported by RZGW will also be analysed.

From the acquired data relating to all types of flood events, groundwater floods will be selected based on the assigned attribute or descriptive information (flood characteristics). Depending on the type of data obtained, it is also possible to classify floods based on other data, including spatial data.

The next step will be to verify the correctness of the assigned flood type (flood source) based on:

– hydrogeological data (MHP PPW-WH and MHP GUPW at a scale of 1:50,000, CBDH),
– geological data (SMGP, geomorphological sketches),
– data on mining activities (MIDAS PIG-PIB),
– geomorphology/terrain morphology (DTM analysis).

In the further step, the analysis of satellite images from the period of occurrence of the phenomenon (if available) will be used to verify the range of the flood event and/or obtain spatial data.

4.2.5. FLOODS FROM DAMMING STRUCTURES

The following information is used to verify flood events:

1) RZGW data on floods that occurred as a result of destruction or damage to dam structures.
2) UW data – information on local government units that reported events bearing the characteristics of natural disasters and conclusions related to removing the consequences of floods.
3) Satellite data.
4) Media information.

4.2.6. DATA ACQUISITION

In terms of data obtained from institutions collecting information on floods and from other sources, the data regarding the range of each registered flood event is of fundamental importance. Detailed characteristics of all data sources are provided in Table 9.

Table 9: Scope of data to be acquired, sources, format, data acquisition method, data owner, and date of acquisition

Scope of data	Data owner, data source	Form, method of data acquisition	Format
Type of flood by source, mechanism, nature	UW	Letters to UW	Digital copy of pdf documentation
	JST	Letters	List of letters in xlsx, own formats
	PGW WP	Data provided	Digital copy of pdf documentation

Scope of data	Data owner, data source	Form, method of data acquisition	Format
	IMGW-PIB	IMGW-PIB databases	xlsx, own formats
	IMGW-PIB	IMGW-PIB databases	xlsx, own formats
Losses to human life and health	UW	Letters to UW	Digital copy of pdf documentation
	JST	Letters	List of letters in xlsx, own formats
	PGW WP	Data provided	Digital copy of pdf documentation
	IMGW-PIB	Spatial analyses of IMGW-PIB	*shp
Losses for the environment	UW	Letters to UW	Digital copy of pdf documentation
	JST	Letters	List of letters in xlsx, own formats
	PGW WP	Data provided	Digital copy of pdf documentation
	IMGW-PIB	Spatial analyses of IMGW-PIB	*shp
	Literature data	Provided by PGW-WP or IMGW-PIB own resource	pdf or hard copy
	Internet data	Own recognition IMGW-PIB, Arcadis	
Losses to cultural heritage	UW	Letters to UW	Digital copy of pdf documentation
	JST	Letters	List of letters in xlsx, own formats
	PGW-WP	Data provided	Digital copy of pdf documentation
	IMGW-PIB	Spatial analyses of IMGW-PIB	*shp
	Literature data	Provided by PGW-WP or IMGW-PIB own resource	pdf or hard copy
	Internet data	Own recognition IMGW-PIB, Arcadis	

Scope of data	Data owner, data source	Form, method of data acquisition	Format
Losses to economic activities	UW	Letters to UW	Digital copy of pdf documentation
	JST	Letters	list of letters in xlsx, own formats
	PGW-WP	Data provided	Digital copy of pdf documentation
	IMGW-PIB	Spatial analyses of IMGW-PIB	*shp
Number of persons injured, number of fatalities, losses [PLN] (required for HF), losses [number of e.g. buildings] optional	UW	Letters to UW	Digital copy of pdf documentation
	JST	Letters	List of letters in xlsx, own formats
	Literature data	Provided by PGW-WP or IMGW-PIB own resource	pdf or hard copy
	Media data	Own recognition IMGW-PIB, Arcadis	
Flood date (flood culmination date)	IMGW-PIB	IMGW-PIB databases	xlsx, own formats
	PGW WP	Transfer of documentation	Digital copy of pdf documentation
	Request letter/conclusions to PGW-WP	Transfer of documentation	Digital copy of pdf documentation
	JST	Letters	List of letters in xlsx, own formats
Duration [days] (required for HF)	IMGW-PIB	IMGW-PIB databases	xlsx, own formats
	PGW WP	Transfer of documentation	Digital copy of pdf documentation
	Request letter/conclusions to PGW-WP	Transfer of documentation	Digital copy of pdf documentation
	JST	Letters	List of letters in xlsx, own formats
Name of the facility at risk (applies to	UW	Letters to UW	Digital copy of pdf documentation

Scope of data	Data owner, data source	Form, method of data acquisition	Format
pluvial floods) - optional	PSP	Provided by PSP	.xlsx files
Flood frequency (required for HF)	IMGW-PIB	IMGW-PIB databases	xlsx, own formats
	PGW WP, FHM and FRM	Data provided	spatial layers *shp
Probability	IMGW-PIB	IMGW-PIB databases	xlsx, own formats
	PGW-WP, FHM and FRM	Data provided	Spatial layers *shp
Area at risk of flooding	UW	Letters to UW	Digital copy of pdf documentation
	FHM and FRM	Data provided	Spatial layers *shp
	satellite data	Downloaded by the Contractor from Sat4envi/Copernicus	Rasters
	Letters/conclusions received by PGW WP	Transfer of documentation	Digital copy of pdf documentation
	RZGW conclusions	Transfer of documentation	Digital copy of pdf documentation
	IMGW-PIB	DTM analyses	*shp
Maximum elevation of the water table	IMGW-PIB	IMGW-PIB databases	xlsx, own formats

4.2.7. ADVERSE CONSEQUANCES OF FLOODS

For each identified historical flood from the years 2018-2023, the adverse consequences of floods on human life and health, economic activity, the environment and cultural heritage are determined.

Information on the consequences of floods is determined based on information obtained on actual flood losses from archival data, including data obtained from competent institutions.

In the absence of data on the adverse consequences of floods obtained from the competent institutions collecting such data, estimates will be determined based on spatial analyses carried out on pre-determined flood ranges, taking into account the methodology used for the preparation of flood risk maps and using, among others, BDOT10k:

for floods between 2018 and 2019: BDOT10k 2018
for floods between 2020 and 2021: BDOT10k 2020
for floods between 2022 and 2023: BDOT10k 2023

A detailed list of information required to obtain or determine the adverse consequences of floods is presented in Table 10.

Table 10: Summary of data on the adverse consequences of floods for the years 2018-2023

No.	Data type	Unit	Data source
1	Areas inundated by flooding	km^2	GIS analysis based on flood range
2	Total value of flood losses	PLN	Archival data
ADVERSE CONSEQUENCES ON HUMAN LIFE AND HEALTH			
3	Number of fatalities	people	Archival data
4	Number of people injured	people	Archival data
5	Estimated number of residents affected by the flooding	people	GIS analysis based on BDOT10k, according to the FRM Methodology
6	Number of flooded residential buildings	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
7	Number of flooded buildings of particular social importance, including hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, police units, fire protection units, border guard units, social welfare homes, facilities providing 24-hour care for disabled and chronically ill people or elderly people, hospices, prisons, correctional facilities, detention centres	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
8	Were there any adverse consequences of floods on human health and life?	YES/NO	Archival data
9	Adverse consequences of floods on human life and health - subcategories	EC codes	Analysis of the indicators corresponding to this subcategory: B11 - residential buildings B12 - buildings of particular social importance
ADVERSE CONSEQUENCES ON THE ENVIRONMENT			
10	Number of flooded surface and groundwater intakes	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology

No.	Data type	Unit	Data source
11	Area of nature protection: Natura 2000 areas, national parks, nature reserves	km^2	GIS analysis based on GDOŚ data, according to the FRM Methodology
12	Number of flooded industrial plants: – plants with a high risk of failure or an increased risk of failure; – installations which, in the event of a flood, may cause significant pollution of individual natural elements or the environment as a whole, for which an integrated permit is required; – other industrial plants	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
13	Number of flooded sewage treatment plants	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
14	Number of flooded sewage pumping stations	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
15	Number of flooded landfills	km^2	GIS analysis based on BDOT10k, according to the FRM Methodology
16	Number of flooded cemeteries	km^2	GIS analysis based on BDOT10k, according to the FRM Methodology
17	Were there any adverse consequences of floods on the environment?	YES/NO	Archival data
18	Adverse consequences of floods on the environment – subcategories	EC codes	Analysis of indicators corresponding to this subcategory: B22 - protected areas, water intakes, bathing areas B23 - industrial plants, cemeteries, landfills, sewage treatment plants, pumping stations
ADVERSE CONSEQUENCES ON CULTURAL HERITAGE			
19	Number of flooded culturally valuable objects and areas: immovable monuments, museums, open-air museums, libraries, archives, extermination monuments, UNESCO World Heritage Sites	quantity	GIS analysis based on NID data, according to the FRM Methodology
20	Were there any adverse consequences of floods on the cultural heritage?	YES/NO	Archival data
21	Adverse consequences of floods on the cultural heritage - subcategories	EC codes	Analysis of indicators corresponding to this subcategory: B31 – cultural assets
ADVERSE CONSEQUENCES ON ECONOMIC ACTIVITY			
22	Area of flooded urban areas (cities)	km^2	CLC2018

No.	Data type	Unit	Data source
23	Area of flooded industrial areas	km^2	CLC2018
24	Area of flooded areas in individual land use classes: residential areas, industrial areas, communication areas, forest areas, recreation and leisure areas, areas of arable land and permanent crops, grasslands, other areas	km^2	GIS analysis based on BDOT10k, according to the FRM Methodology
25	Number of km of flooded roads (including a category: public roads)	km	Archival data or analysis based on BDOT10k
26	Number of km of flooded railway tracks	km	Archival data or analysis based on BDOT10k
27	Number of km of destroyed flood embankments	km	Archival data
28	Were there any adverse consequences of floods on economic activity?	YES/NO	Archival data
29	Adverse consequences of floods on economic activity – subcategories	EC codes	Analysis of indicators corresponding to this subcategory: B41 – residential areas B42 – transport areas B43 – arable land, grassland, forests B44 – industrial areas B45 – recreation and leisure areas or other areas

Archival data may have different data sources depending on the type of flood (described below). In contrast, estimated data are determined uniformly for all types of floods based on spatial analyses. These analyses use available flood risk data (preferably uniform on a national scale - data source indicated in Table 10) in relation to a defined spatial range of a historical flood. For this range, the number, area, or length of objects relating to different categories of adverse flood consequences are determined.

Based on the data obtained, for each flood, the following is determined:

1) information on the occurrence of adverse consequences of the flood (YES/NO) for 4 categories: human life and health, economic activity, environment, and cultural heritage;
2) **division into subcategories, presented in Section 4.1.6.**

For **floods from the 3rd cycle (period 2018-2023),** subcategories are determined based on detailed assessment indicators.

The following assumptions are made when defining subcategories based on indicators:

1) the subcategory **human health** (B11) is defined when:

- the number of fatalities is greater than 0,
- the number of injured people is greater than 0,
- the estimated number of inhabitants affected by the flood is greater than 0,
- the number of flooded residential buildings is greater than 0;

2) the subcategory **community** (B12) is defined when:

- the number of flooded buildings of particular social importance is greater than 0;

3) the subcategory **protected areas** (B22) is defined when:

- the area of nature protection forms is greater than 0,
- the number of flooded surface and groundwater intakes is greater than 0;

4) the subcategory **pollution sources** (B23) is determined when:

- the area of industrial land in the flood zone is greater than 0,
- the number of flooded industrial plants is greater than 0,
- the number of flooded sewage treatment plants is greater than 0,
- the number of flooded sewage pumping stations is greater than 0,
- the area of flooded landfills is greater than 0,
- the area of flooded cemeteries is greater than 0;

5) the subcategory **cultural assets** (B31) is defined when:

- the number of flooded objects and culturally valuable areas is greater than 0;

6) the subcategory **property** (B41) is defined when:

- the number of flooded residential buildings is greater than 0,
- the area of urbanised areas (cities) in the flood area is greater than 0;

7) the subcategory **infrastructure** (B42) is defined when:

- the area of urbanised areas (cities) in the flood zone is greater than 0,
- the area of industrial sites in the flood zone is greater than 0,
- the area of flooded transport areas is greater than 0;

8) the subcategory **rural land use** (B43) is defined when:

- the area of flooded areas of arable land and permanent crops is greater than 0,
- the area of flooded grassland is greater than 0,
- the area of flooded forest areas is greater than 0;

9) the subcategory **economic activity** (B44) is defined when:

- the area of industrial sites in the flood zone is greater than 0.

If a given subcategory of flood consequences is associated with several indicators, it is assigned when the condition for at least one indicator is met.

FLUVIAL FLOODS

Archival data:

1) data from the UW regarding conclusions of JST (Section 8 of the Methodology),
2) PGW WP data (cards of areas reported by RZGW),
3) "targeted" surveys of JST (if necessary),
4) literature data and media information,
5) satellite data.

The above data sources are the same for all fluvial flood mechanisms.

PLUVIAL FLOODS

Archival data:

1) data from the PSP interventions database,
2) data from the UW regarding conclusions of JST (Section 8 of the Methodology),
3) literature data and media information.

GROUNDWATER FLOODS

Data on losses resulting from groundwater floods will be obtained directly from materials acquired from units where information on floods is collected or from surveys.

FLOODS FROM DAMMING STRUCTURES

Archival data as for fluvial floods.

4.3. CRITERIA FOR DETERMINING SIGNIFICANT HISTORICAL FLOODS AND ASSESSING THEIR CONSEQUENCES

Once all floods that have occurred in the past have been identified and described, they are analysed according to the PFRA scheme (Fig. 2) to designate the areas:

1) **Significant historical floods with significant adverse consequences** - i.e. floods that have occurred in the past and have had significant adverse consequences on human health, the environment, cultural heritage, economic activities, and the probability of a similar event occurring in the future is still high (**Article 4.2b of the Floods Directive**).

   In the case of floods, as referred to in Article 4.2b DP - if there is no probability of such a flood occurring in the future, it means that it is not a significant flood as referred to in Article 4.2b DP.

Such a situation may occur when, after a flood has occurred in a given area, protection measures have been implemented to ensure that a flood with significant adverse consequences should not occur or the risk of such a flood is residual.

2) **Significant historical floods without significant adverse consequences** - i.e. floods that occurred in the past and did not cause significant adverse consequences at that time, but it can be predicted that a similar phenomenon in the future will have significant adverse consequences, taking into account, for example, changes in land development or climate change (**Article 4.2c of the Floods Directive**).

   In the case of floods referred to in Article 4.2c FD – this refers to a significant flood that occurred in the past but no adverse consequences were identified at that time or there is no information about them, but there is a probability of a future flood that may cause significant adverse consequences (Article 4.2c FD).

   Such a situation may occur when, as a result of changes in land use or climate change in a given area, the flood risk (with adverse consequences of floods) has increased and become significant. If there is no probability of a future flood with significant adverse consequences, it means that it is not a significant flood, as referred to in Article 4.2c FD.

In order to divide historical floods into floods referred to in Articles 4.2b and 4.2c, floods should be classified into significant and non-significant floods, taking into account the classification of the adverse consequences of floods into significant and non-significant floods.

Significant adverse consequences of historical floods are considered to be the adverse consequences of floods (on human life and health, the environment, cultural heritage, and economic activity) of a supra-threshold nature (i.e. above certain threshold values resulting from the probability distribution of the values of the adverse consequences of historical floods) as a result of a specific flood hazard and the vulnerability of the system affected by that hazard.

Flood classification is based on the use of all available data and information on historical floods, organized, and standardized as far as possible. However, two significantly different groups can be distinguished in terms of quality in the data set:

1) data for floods from the period 1946-2017 (prepared according to the description presented in Section 4.1.);
2) data for floods from the period 2018-2023 (prepared according to the description presented in Section 4.2.).

Due to significant differences in the quality of data from the entire analysis period, solutions were used to identify significant historical floods. These solutions enable, on the one hand, the most reliable reflection of flood conditions, taking into account archival data, and, on the other hand, the comparison of flood events occurring over a very long period of time (almost 80 years).

The identification scheme for significant historical floods is presented in Figure 9.

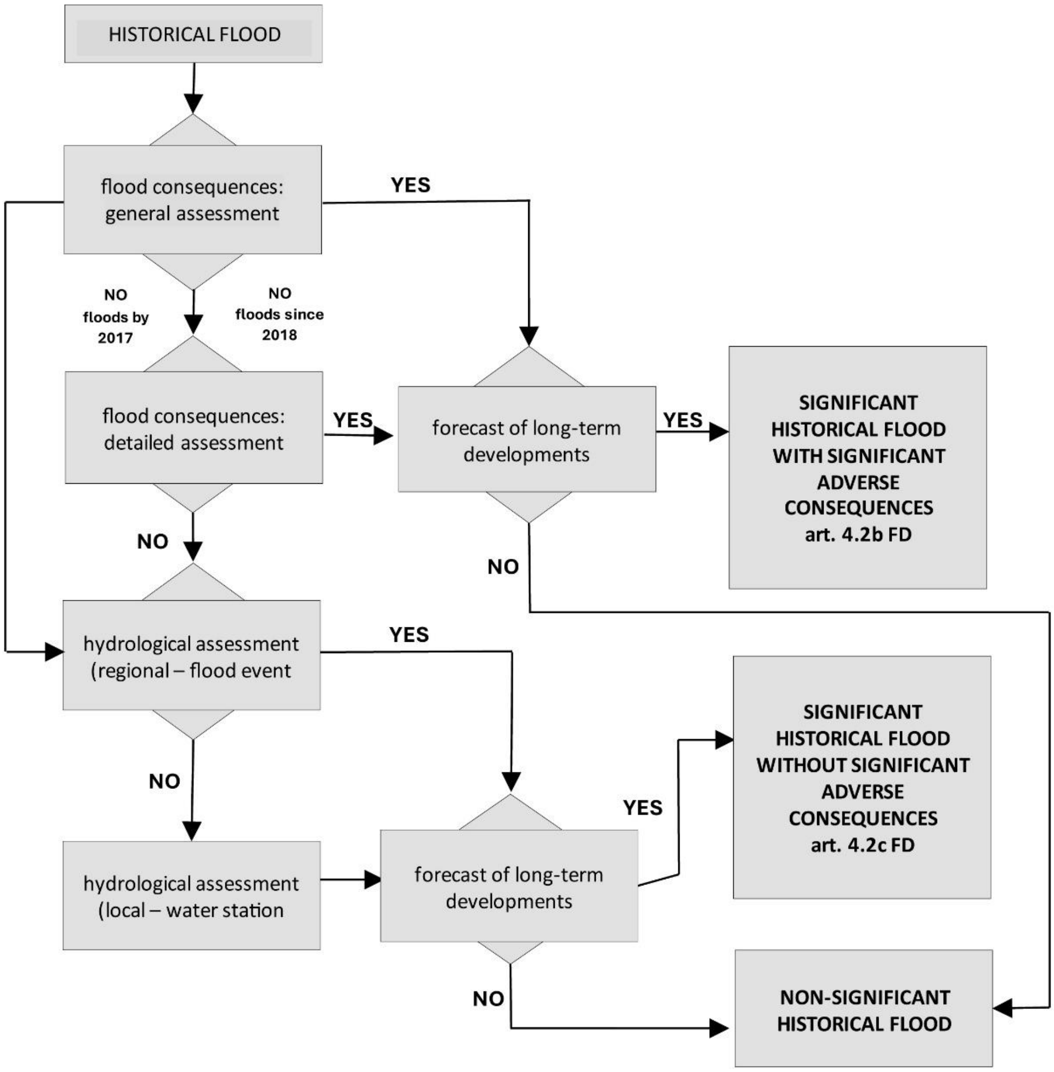

Figure 9: The scheme for identification of significant historical floods

The classification of historical floods is carried out, taking into account the type of flood. The presented scheme is described on the example of fluvial floods, but it can be used similarly for other types of floods (apart from hydrological assessment).

4.3.1. FLUVIAL FLOODS

The identification of significant historical floods is carried out in the following steps:

1) Assessment of the adverse consequences of floods:
    a) General assessment;
    b) Detailed assessment;
2) Hydrological assessment:

   a) on a regional scale, including characteristics of historical floods;
   b) on a local scale, including historical flood data for individual water gauges;
3) Consideration of the forecast of long-term developments;
4) Classification of historical floods.

The adopted course of action is based on the assumption that the basis for classifying historical floods as significant/non-significant is the assessment of flood consequences (i.e., the risk assessment). In the contrast, the hydrological assessment (i.e., the hazard assessment) is a supporting factor.

An essential element of identifying significant historical floods is to take into account a forecast of long-term developments - following an general/detailed assessment of the adverse consequences of floods or a hydrological assessment on a regional/local scale, depending on the assessment results. The assumptions of the long-term developments forecast are described in Section 6.

4.3.1.1. ASSESSMENT OF THE ADVERSE CONSEQUENCES OF THE FLOODS

General assessment

An general assessment is carried out for all identified historical floods. The general nature of the assessment is a consequence of the need to apply specific assumptions and simplifications resulting from the heterogeneity of the archival data set on historical floods.

In the general assessment, based on archival data, adverse flood consequences are simplified for 4 categories: human health and life, environment, cultural heritage and economic activities (Yes/No).

Moreover, additional criteria are taken into account that concern the following categories: human life and health and economic activity.

For the assessment, archival data on the number of fatalities and the number of people affected are used directly.

In addition, based on spatial analyses, the following are determined:

Estimated number of inhabitants affected by flood - based on the range of flooded areas and data on the estimated number of people living in these areas (based on data from the Central Statistical Office and BDOT10k);

Area of flooded urban areas (cities) - based on CLC data from the period closest to the historical flood;

Area of flooded industrial sites - based on CLC data from the period closest to the historical flood.

Given the incompleteness of archival data, the above indicators obtained from spatial analyses support the results of the adverse consequences assessment.

An essential criterion for the general assessment of the adverse consequences of floods is the expert assessment of the floods, aimed at deciding whether it is reasonable to classify the floods as significant (in terms of consequences). It considers any available knowledge of historical floods that cannot be included in a quantitative assessment (descriptions in the literature, etc.).

Other criteria are regarded as auxiliary elements of the analysis.

The criteria considered in the general assessment of adverse consequences of floods are shown in Table 11.

Table 11: Identification of significant historical floods - criteria for the general assessment of adverse consequences of floods

No.	Criterion	Unit	Method of determination
1	Occurrence of adverse consequences of floods on human health and life	YES/NO	Archival data
2	Occurrence of adverse consequences of floods on the economic activity	YES/NO	Archival data
3	Occurrence of adverse consequences of floods on the environment	YES/NO	Archival data
4	Occurrence of adverse consequences of floods on the cultural heritage	YES/NO	Archival data
5	**Number of fatalities**	**people**	**Archival data**
6	**Number of people injured**	**people**	**Archival data**
7	**Estimated number of people affected by the flood**	**people**	**GIS analysis (GUS, BDOT10k, FRM)**
8	Area of flooded urban areas (cities)	km^2	GIS analysis (CLC)
9	Area of flooded industrial sites	km^2	GIS analysis (CLC)
10	**Expert assessment of floods - whether it is reasonable to classify a flood as significant (in terms of consequences)**	**YES/NO**	**Analysis based on archival data**
11	Total flood losses	PLN	Archival data
12	Flooded areas	km^2	GIS analysis

The ranking of the obtained values for the selected criteria is a preliminary basis for identifying significant adverse consequences of historical floods.

This identification is based on the distribution of criteria values and the determination of limit values based on these. To identify significant adverse consequences of floods, the following limit values for the following criteria are considered relevant:

- Number of fatalities ≥ 1,
- Number of people injured ≥ 100,
- Estimated number of people affected by the flood ≥ 100.

If at least one criterion exceeds the adopted limit value, then the adverse consequences of floods can be considered significant.

The expert assessment uses literature data and additional criteria based on available data.

DETAILED ASSESSMENT

A detailed assessment of the adverse consequences of floods is carried out only for floods between 2018 and 2023, for which more information is available than in the case of floods until 2017. This assessment is based on criteria from the flood losses and flood risk elements.

The adverse consequences of floods are defined for 4 categories: human life and health, environment, economic activities, and cultural heritage. The subcategories of adverse consequences are determined as described in Section 4.2.7.

The criteria considered in the detailed assessment of the adverse consequences of floods are presented in Table 12.

Table 12: Identification of significant historical floods - criteria for detailed assessment of the adverse consequences of floods

No.	Criterion	Unit	Method of determination
1	Number of flooded residential buildings	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
2	Number of flooded buildings of particular social importance (hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, police units, fire protection units, border guard units, social welfare homes, facilities providing 24-hour care for the disabled, chronically ill or elderly people, hospices, prisons, correctional facilities, detention centres)	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
3	Number of flooded surface and groundwater intakes	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
4	Area of nature protection: Natura 2000 sites, national parks, nature reserves	km^2	GIS analysis based on BDOT10k, according to the FRM Methodology

No.	Criterion	Unit	Method of determination
5	Number of flooded industrial plants: - plants with a high risk of failure or an increased risk of failure (ZDR and ZZR); - installations that may, in the event of a flood, cause significant pollution of individual natural elements or the environment as a whole, for which an integrated permit (IPPC) is required; - other industrial plants	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
6	Number of flooded sewage treatment plants	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
7	Number of flooded sewage pumping stations	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
8	Area of flooded landfills	km^2	GIS analysis based on BDOT10k, according to the FRM Methodology
9	Area of flooded cemeteries	km^2	GIS analysis based on BDOT10k, according to the FRM Methodology
10	Number of flooded objects and culturally valuable areas (immovable monuments, museums, open-air museums, libraries, archives, extermination monuments, UNESCO World Heritage Sites)	quantity	GIS analysis based on BDOT10k, according to the FRM Methodology
11	Area of flooded land by use classes: residential areas, industrial sites, communication sites, forest areas, recreation and leisure areas, arable land and permanent crops, grasslands, other areas	km^2	GIS analysis based on BDOT10k, according to the FRM Methodology
12	Number of km of flooded roads (including the category of public roads)	Km	Archival data or analysis based on BDOT10k
13	Number of km of flooded railway tracks	Km	Archival data or analysis based on BDOT10k
14	Number of km of destroyed flood embankments	Km	Archival data

The ranking of values for the selected criteria is the basis for identifying significant adverse consequences of historical floods. This identification is based on the distribution of criteria values and the determination of limit values based on them.

To identify significant adverse consequences of floods, the following limit values for the criteria are considered relevant:

- Number of flooded residential buildings ≥ 20,
- Number of flooded buildings of particular social importance ≥ 3.

The limit value taken into account in the general assessment for the criterion of the estimated number of inhabitants affected by the flood ≥ 100 is also important.

If at least one criterion exceeds the limit value, then the adverse consequences of floods can be considered significant.

4.3.1.2. HYDROLOGICAL ASSESSMENT

REGIONAL SCALE

The use of hydrological assessment on a regional scale (i.e., including the characteristics of a historical flood) is intended to distinguish historical floods that are significant in terms of flood hazard.

The criteria considered in the hydrological assessment on a regional scale are presented in Table 13.

Table 13: Identification of significant historical floods - criteria for hydrological assessment on a regional scale

No.	Criterion	Unit	Method of determination
1	Flood range - comparison with 0.2% flood extent	km^2 (+/-)	GIS analysis
2	Flood range - comparison with 1% flood extent	km^2 (+/-)	GIS analysis
3	Flood range - comparison with 10% flood extent	km^2 (+/-)	GIS analysis
4	Flood frequency - is it within the range: F ≥ once every 500 years	YES/NO	Based on the FHM
5	Flood frequency - is it within the range: once every 100 years ≤ F < once every 500 years	YES/NO	Based on the FHM
6	Flood frequency - is it within the range: once every 10 years ≤ F < once every 100 years	YES/NO	Based on the FHM

The hydrological assessment on a regional scale is based on information on the range and frequency of floods - for floods with probabilities of 0.2%, 1%, and 10% (based on the FHM), which allows flood hazard assessment. The range and/or frequency F ≥ 10 years is taken as a significant hazard.

The expert assessment also uses information on exceedances of alert levels at water gauges.

In addition, it is assumed that all floods identified as significant in the generall assessment of the adverse consequences of floods based on the expert assessment can also be considered hydrologically significant.

It should be emphasised that the range of the historical floods often covers many rivers, resulting in significant variation in the flood characteristics of the different sections - it is assumed that the most unfavourable situation is taken into account in the assessment.

LOCAL SCALE

The hydrological assessment on a local scale, including historical flood data for individual water gauges, allows the use of detailed hydrological information for different watercourses where historical floods occurred, thus considering the heterogeneity of the phenomenon on different rivers.

The criteria considered in the hydrological assessment on a local scale for individual water gauges are presented in Table 14.

Table 14: Identification of significant historical floods - criteria for hydrological assessment on a local scale for individual water gauges

No.	Criterion	Unit	Method of determination
1	Flood range - comparison with 0.2% flood extent	km^2 (+/-)	GIS analysis
2	Flood range - comparison with 1% flood extent	km^2 (+/-)	GIS analysis
3	Flood range - comparison with 10% flood extent	km^2 (+/-)	GIS analysis
4	Flood frequency - is it within the range: F ≥ once every 500 years	YES/NO	Based on the FHM
5	Flood frequency - is it within the range: once every 100 years ≤ F < once every 500 years	YES/NO	Based on the FHM
6	Flood frequency - is it within the range: once every 10 years ≤ F < once every 100 years	YES/NO	Based on the FHM
7	Duration of flood	days	IMGW-PIB
8	Zone of characteristic levels - whether it is in the zone of high levels	YES/NO	IMGW-PIB
9	Zone of characteristic flows - whether it is located in the zone of high flows	YES/NO	IMGW-PIB
10	Maximum water stage	cm	IMGW-PIB
11	Maximum water flow	m^3/s	IMGW-PIB
12	Analysis of the frequency and magnitude of exceedances of alert water levels	quantity, cm	IMGW-PIB

The basis for the hydrological assessment on a local scale is, as in the case of hydrological assessment on a regional scale, information on the range and frequency of floods - for floods with a probability of occurrence of 0.2%, 1%, and 10% (based on the FHM).

In addition, information on water stages (maximum water stage, zone of characteristic stages/levels) and flows (maximum water flow, zone of characteristic flows), as well as the duration of the flood are taken into account. Important information may include an analysis of the frequency and magnitude of exceedances of alarm water levels.

The existence of water gauges that are significantly distinctive in terms of flood hazard is the basis for the possibility of classifying a historical flood as significant.

The expert assessment uses information on the exceedance of alarm levels at water gauges. It is assumed that if the exceedance of alarm levels at water gauges is ≥ 150 cm, the flood can be considered hydrologically significant.

4.3.1.3. FORECAST OF LONG-TERM DEVELOPMENTS

The purpose of the analysis for the forecast of long-term developments is to verify whether floods with significant adverse consequences are likely to occur in the future in a given area (as defined in Articles 4.2b and 4.2c of the FD).

Two cases are considered:

- whether the forecast of long-term developments concerning flood risk indicates that the probability of similar phenomena occurring in the future is still high,
- whether the forecast of the long-term developments concerning flood risk indicates that similar phenomena in the future will have significant adverse consequences.

With regard to the probability of similar phenomena occurring in the future (attribute PROGN_Praw = T), information on forecast changes in high flows is used. It is assumed that if ZK_QMAX_45 > 10 OR ZK_QMAX_85 > 10 (more unfavourable scenario), then: attribute PROGN_PRAW = T.

For the ranges of individual floods, when determining forecast changes in high flows, the basis is information for the main river, with particular emphasis on the increase in flows (the most unfavourable situation).

For ice dam floods, information on the forecast change in air temperature is additionally used (attribute ZK_TEMP_45 and attribute ZK_TEMP_85) - in the case of a temperature rise, the attribute PROGN_PRAW = N.

For significant future flood consequences (attribute PROGN_NEG = T), information on projected changes in population (ZP_LUDN) and land development (ZP_ZAGOSP) is used. It is assumed that if ZP_LUDN > 10, then: attribute PROGN_ NEG = T. Because of the minor impact of land development changes, the parameter ZP_ZAGOSP can be omitted.

The assumptions of the long-term developments forecast are described in Section 6.

4.3.1.4. CLASSIFICATION OF HISTORICAL FLOODS

The basis for classifying floods as floods referred to in Articles 4.2b and 4.2c of the FD is the assessment of the identified historical floods as significant or non-significant, with significant or non-significant adverse consequences of floods.

The classification of historical floods is based on the previous steps of the analysis. Table 15 presents individual elements of the historical flood classification procedure.

Table 15: Classification of historical floods - elements of the procedure

No.	Element of the historical flood classification procedure	Result
1	Expert assessment - can the flood be considered significant?	YES/NO
2	Does the general assessment indicate that there are significant adverse consequences of floods?	YES/NO
3	Does the detailed assessment indicate that there are significant adverse consequences of floods?	YES/NO
4	Does the hydrological assessment indicate a significant flood hazard?	YES/NO
5	Does the forecast of long-term developments concerning flood risk indicate that the probability of similar phenomena occurring in the future is still high?	YES/NO
6	Does the forecast of long-term developments concerning flood risk indicate that similar phenomena in the future may have significant adverse consequences?	YES/NO
7	**Are the conditions of Art. 4.2b of the FD fulfilled? (identification of significant historical flood according to Art. 4.2b FD)**	**YES/NO**
8	**Are the conditions of Art. 4.2c of the FD fulfilled? (identification of significant historical flood according to Art. 4.2c FD)**	**YES/NO**
9	**Is historical flood identified as significant? (identification of significant historical flood according to Art. 4.2b FD or 4.2c FD)**	**YES/NO**

The procedure results present the following **classification of historical floods:**

1) Significant historical floods with significant adverse consequences (Art. 4.2b of the FD)
2) Significant historical floods without significant adverse consequences (Art. 4.2c of the FD);
3) Non-significant historical floods.

The following assumptions are made to identify **flood 4.2.b**:

1) The flood was considered significant as a result of expert assessment.

When a quantitative assessment is not feasible, an expert assessment is performed. This assessment draws on all available knowledge about historical flood occurrences and their adverse consequences (including literature descriptions).

2) The adverse consequences of floods were identified as significant.
   The classification of the adverse consequences of floods as significant and insignificant is based on a ranking method - considering the criteria for the general assessment or the detailed assessment of the adverse consequences of floods. The distribution of values is the basis for determining the limit values that define the classification. The criteria and threshold values are described in Section 4.3.1.1.
3) The identified historical flood was considered significant (in terms of flood hazard), and future flooding is probable.
   The basis for the hydrological assessment is mainly information regarding the extent and frequency of floods, and the exceedance of alert levels. The hydrological assessment is described in Section 4.3.1.2.
4) The possibility of adverse impact of climate change or land use change has been identified, which may result in significant adverse consequences of floods in the future.

The following assumptions are made to identify **flood 4.2c**:

1) The historical flood was considered significant (hydrologically).
2) Adverse consequences of historical floods were considered non-significant.
3) There is the potential for significant adverse consequences in the future due to land use change since that flood or the predicted significant impact of climate change.

When identifying floods 4.2b and 4.2c, it is essential to consider information on the implementation of flood protection measures that reduce flood risk (e.g., resulting from the FRMP). This information is included in the expert assessment to assess the possibility of a similar phenomenon occurring in the future.

4.3.2. PLUVIAL FLOODS

In the case of pluvial floods, due to their specific nature, no assessment of consequences is carried out, and no historical floods are designated.

Pluvial floods are usually small-scale and short-term compared to fluvial floods.

In addition, the flood areas determined based on the Bluespot analysis are approximate and historical information on the extent and losses caused by heavy rainfall is incomplete.

4.3.3. GROUNDWATER FLOODS

In the case of groundwater floods, no assessment of consequences is carried out due to their specific nature, and no significant historical floods are designated.

This is related to the specificity of this type of flood, which differs significantly from other types of floods. Groundwater floods do not cause significant losses compared to the other types of floods due to their less rapid course, slight rise in water levels above the land surface, occurrence in limited areas and only under certain hydrogeological conditions (shallow, free groundwater table, permeable formations occurring in the aeration zone). At the same time, groundwater floods most often accompany or follow other types of floods, especially fluvial floods.

4.3.4. FLOODS FROM DAMMING STRUCTURES

Criteria for determining significant historical floods as in the case of fluvial floods.

4.3.5. RESIDUAL FLOOD RISK

An essential element of the assessment of the adverse consequences of floods is the residual flood risk, understood as the flood risk (taking into account the adverse consequences on human life and health, the environment, cultural heritage, and economic activity) remaining after the implementation of planned measures to achieve flood risk management objectives (considering both the reduction of flood risk and the vulnerability of the affected system), acceptable in a certain place and time due to external conditions (environmental - including flood magnitude, social, economic, etc.).

This definition refers directly to the extended definition of flood risk, which states that flood risk is a function of hazard, exposure, and vulnerability.

Residual flood risk is included in the concept of flood risk management, aimed at reducing the potential adverse consequences of floods - according to it, the aim should be to:

- flood risk reduction,
- where such a reduction is not possible - to stabilise the current flood risk (by preventing its increase).

The adoption of this stabilisation determines a priori the possibility that a certain level of flood risk exists and will continue to exist (in a given area) despite the implementation of specific measures aimed at achieving the objectives of flood risk management. This level can be identified as the residual risk.

The magnitude of residual risk depends on a number of factors, the main ones include:

- the specificity of the flood area (e.g. the method of catchment management - in relation to potential adverse consequences on the one hand and the possibility of flood formation on the other),
- the characteristics of floods occurring in a given area, with respect to individual flood phenomena (e.g. flood with a specific probability of occurrence),

- possibilities of implementing specific flood risk management measures - aspects: technical (e.g. technical feasibility related to local conditions), economic (e.g. financial costs), social (e.g. acceptability by the local community), political/planning (e.g. compliance with national, regional, local policies, strategies, programmes, etc.).

A schematic illustration of the magnitude of residual risk is presented in Figure 10.

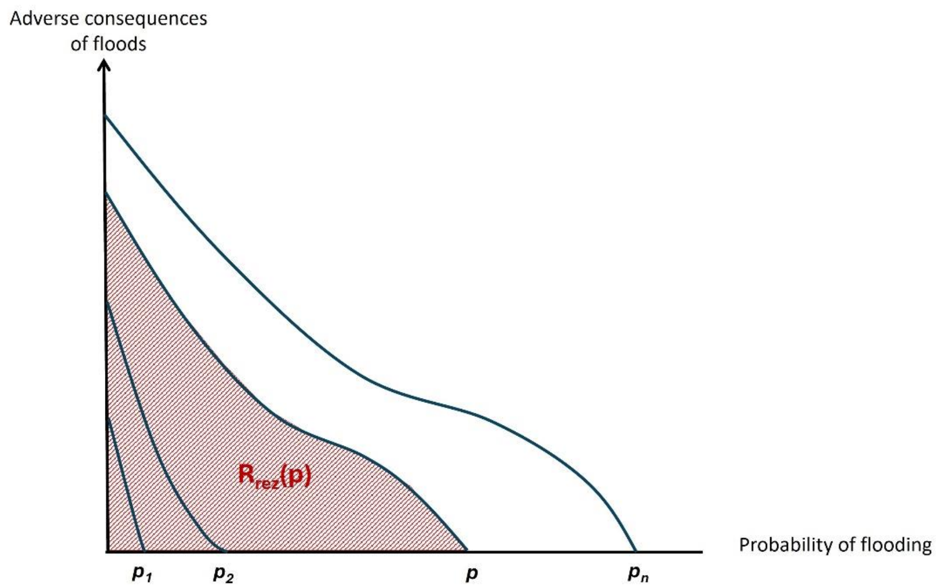

Figure 10: Schematic illustration of the magnitude of residual risk R_{rez} (Nguyen 2023)

The determination of residual risk should be regarded not so much as a calculation method but rather as a decision-making process that results in a decision as to the level of risk that can be "consent", as it were - taking into account a number of social, economic, natural, and the like conditions. Its acceptability is, therefore, essential. This level depends on the flood area and varies over time (i.e., a level acceptable today may not be acceptable in the long term).

The basis for determining the residual risk may be the identification and assessment of potential flood risk, based, for example, on detailed criteria for assessing adverse consequences of floods. These criteria are primarily related to objects within the flood range (exposure). They can be analysed each time for different floods (e.g. based on the probability of occurrence) with a view to the feasibility of counteracting the potential adverse consequences of a given flood. It should be remembered that measures to achieve the objectives of flood risk management are not only measures that reduce the flood extent but also the vulnerability of an area or facility to flood hazards and simultaneously increase its resistance.

These are primarily non-technical measures, which include:

1) Appropriate catchment area development aims to increase the retention capacity and slow down outflow in the catchment area by reducing sealed areas, appropriate agrarian treatments, etc.
2) Land use planning - taking into account FHAs (according to FHM) in spatial planning documents; e.g., the Water Law Act contains provisions regarding the need to include areas of particular flood hazard in the voivodeship's land use plan, voivodeship's development strategy, municipal's development strategy, supra-local development strategy, the study of conditions and directions of municipality's land use, local land use plan, municipal's revitalisation programme, decisions on the location of a public purpose investment and the decision on development conditions.
3) Forecast and warning system – related to meteorological/hydrological monitoring.
4) Building social awareness and education - in the context of responding to a flood event and the possibility of preparing for it, both for the broadly understood society and decision-making bodies influencing the development of flood risk management policy (at various levels).
5) Legal and financial instruments - e.g. legal regulations, insurance systems, financing the maintenance of technical measures (e.g. flood embankments), etc.
6) Emergency services - in relation to response (e.g. evacuation plans) and removal of flood consequences.

It is important to emphasise that the above measures will only be effective if they are integrated into one system - in line with a consistent and continuous response to the potential consequences of floods regardless of their occurrence at any given time.

Taking the above non-technical measures into consideration, one must be aware that while determining the residual risk, the values of the proposed detailed criteria for assessing the adverse consequences of floods will not change (the number of objects within the flood range will remain the same), the sensitivity and resilience of these objects will change - which can be reflected by adopting an appropriate reduction factor.

Determining such a coefficient is not easy, as it requires a detailed analysis of the vulnerability and resistance of both a specific facility and the entire system with regard to the direct and indirect consequences of floods. Nevertheless, exemplary estimates of the effectiveness of certain measures can be found in the literature. For example, it is estimated that the operation of the early warning system can reduce the potential adverse consequences of floods by 25% (EC JRC 2015), reducing the warning time of residents about an approaching flood reduces damage by approximately 10% (the amount of reduction depends on the depth of flooding), and preparing the lower floor of a single-family house for flooding reduces the damage by 5–30% (Sowiński 2008).

It should be stressed that the essence of residual risk is inherently incorporated into the concept of flood risk management. When defining measures in this area (e.g. within the framework of the FRMP), one should be aware of the residual risk and its origins, related, on the one hand, to the nature of flood as a natural phenomenon (it can and will occur - and may even intensify as a result of climate change) and, on the other hand, to the historical determinants of the location of urban and industrial centres (generating the most significant adverse consequences of floods) in the vicinity of rivers.

5. PROBABLE FLOODS

5.1. DEFINITION OF PROBABLE FLOODS

Probable flood - a flood that may occur in the future in a given area and cause potential adverse consequences on human life and health, the environment, cultural heritage and economic activity - flood referred to in **Art. 4.2d of the Floods Directive.**

In the case of probable floods, there are no "significant" adverse consequences, there are only "potential" adverse consequences of floods.

Probable flood areas are determined based on the following:

– areas where floods are likely to occur, as described in Section 5.2;

– natural floodplains as described in Section 5.3.

The identification of floods, as referred to in **Article 4.2d** of the Floods Directive, is done in two stages:

1) In the first stage, areas where there is a probability of flood occurrence are determined - PF (described in Sections 5.2 and 5.3);
2) In the second stage, the areas from point 1 are designated as areas where **potential adverse consequences of floods** may occur, i.e. the areas referred to in Art. 4.2.d of the Floods Directive – PF according to Art. 4.2.d FD (described in Section 5.4).

Information on the sources of data for probable floods is presented in Tables 5 and 6.

5.2. IDENTIFICATION OF AREAS WHERE FLOODING IS LIKEY TO OCCUR

Identification and analysis of probable floods should be carried out separately for each type of flood.

5.2.1. FLUVIAL FLOODS

The main data source on probable floods are FHMs developed for the following flood probabilities: 0.2%, 1%, and 10% (resulting from hydrodynamic modelling). The PFRA review and update use flood hazard areas (FHA) for floods with a probability of occurrence of 1% from the current FHMs.

In addition, consideration is given to areas that were designated by hydraulic modelling, developed as part of other projects, in particular the flood protection programmes implemented by individual Regional Water Management Authorities.

5.2.2. PLUVIAL FLOODS

In the case of pluvial floods, there is no simple quantitative relationship between information on the probability of heavy rainfall and the probability of a flood hazard to a certain extent. In addition, hazards caused by heavy rainfall are usually of a limited nature. They are also variable in time and space.

Moreover, obtaining detailed and accurate ranges of pluvial floods would require two-dimensional modelling with the identification of elements influencing rainwater flow and considering the impact of the operation of the existing rainwater and combined sewer system. It is not possible to perform such detailed analyses nationwide as part of the preliminary flood risk assessment. According to the Water Law Act, the preparation of PFRA is based on readily available information.

Taking the above into consideration, the PFRA conducts simplified analyses without determining the probability of such a phenomenon occurring. In order to identify areas where pluvial floods may occur, it is proposed to apply the ESRI tool "Model bluespots to map flood risk", the principles of which are described in Section 4.1.3.

The Bluespot model detects all land depressions, regardless of their depth and volume. A filter will be applied to eliminate the smallest, unimportant basins from further calculations. It is assumed that land depressions will be rejected if:

1) The volume does not allow the accumulation of more than 50 mm of precipitation;

2) The depth is less than 30 cm and the area is less than 10,000 m2;

3) The impervious area (determined from BDOT) does not exceed 40% of the total area.

The result of the analyses is a surface layer representing the land depressions at risk of flooding in the event of precipitation of a certain amount. The obtained areas are very general and represent only the approximate extent of flooding.

5.2.3. GROUNDWATER FLOODS

In the case of groundwater floods, analyses are carried out to identify natural or quasi-natural areas where there is a naturally conditioned vulnerability to groundwater floods.

The identification of areas where groundwater flood is likely to occur is based on spatial analysis of selected information from various sources (Table 16).

Table 16: Spatial data sources and scope of analysed information

Purpose of analysis	Analysed information	Source of data
Verification of the fulfillment of the assumed precondition for the occurrence of groundwater floods; identification of areas with a natural predisposition to groundwater floods	1) Location of areas where the top of the first aquifer occurs at a depth of not more than 2 m relative to the ground surface; 2) The nature of the water table of the first aquifer in the above areas.	The database of the Hydrogeological Map of Poland at a scale of 1:50,000 (MHP PPW-WH); additionally, in areas not yet covered by this study, it is necessary to use borehole data from the CBDH including in the analysis information on aquifers where the free groundwater table was drilled at a depth of not more than 2 meters.
Identification of areas with a natural predisposition to groundwater floods	Lithology of near-surface formations - (permeable soils) located 2 meters below ground level.	Detailed Geological Map of Poland (SMGP) or Lithogenetic Map of Poland on a scale of 1:50,000 or other geological maps of Poland
	Topography - location of concave or flat morphological forms	DTM or SMGP
	Location of wetlands	GIS-Wetlands 1:100 000,
		Distribution of natural habitats
	The proximity of natural reservoirs and surface watercourses that can cause groundwater damming during high surface water stages.	MPHP
Cumulative analysis	Discretisation grid	Grid created in GIS software

A necessary condition for the area to be classified as a probable flood area is the shallow location of the groundwater table and the free nature of the water table of the first aquifer. The probability of the phenomenon occurring is increased by the co-occurrence of other factors, such as the permeability of near-surface formations, the presence of concave or flat morphological forms, wetlands, and the proximity of surface watercourses, natural water reservoirs or retention reservoirs.

To identify areas of probable groundwater floods, a multi-criteria analysis is carried out consisting of the following partial analyses:

1) **Analysis of hydrogeological conditions** conducive to the occurrence of groundwater floods and verification of fulfillment of the necessary condition should be based on data on the depth of occurrence of the free groundwater table according to the Hydrogeological Map of Poland (MHP PPW - WH), which specifies the depth of occurrence of the first aquifer from the surface for individual sheets. Areas with a free groundwater table to a depth of 2 metres are areas that meet the adopted

necessary criterion for potential groundwater floods. In areas not yet covered by this study, it is necessary to use borehole data located in the CBDH including in the analysis information about aquifers where the free groundwater table occurs at a depth of 2.0 m. or less. Synthetic, continuous polygon information layers should be considered more beneficial for the PFRA analysis than point data resulting from the spatial distribution of boreholes. The analysis is carried out in hexagons of 100,000 m2 (10 ha) according to the adopted discretisation grid, with the necessary condition considered to be fulfilled when at least 70% of the hexagon area is covered.

2) **Analysis of geological conditions** conducive to groundwater floods should be based primarily on the categorisation of landforms from the SMGP map or lithogenetic map in terms of the lithology of the surface formations and their permeability, which determine the possible free flow of groundwater and rapid response to changes in water relations, and consequent rapid rise of the groundwater table. Areas are identified where the type of soil and rocks (geological structure) are characteristic of concave or flat non-positive (non-convex) landforms. The analysis is carried out in hexagons with an area of 100,000 m2 (10 ha) according to the adopted discretisation grid, and this favourable factor is considered to be met when permeable formations and lithology typical of concave or flat forms cover at least 70% hexagon area.

3) **Analysis of the occurrence of wetlands** - the analysis is based on data from the GIS "Wetlands" database. The analysis is based on the valoriation of wetlands on the basis of information on the type of water-dependent habitat. The analysis is carried out in hexagons of 100,000 m2 (10 ha) according to the adopted discretisation grid. It is verified whether there are areas adjacent to wetlands. The area is counted only from a 100 m wide buffer from the wetland boundary. Only wetlands with an area of at least 50,000 m2 are subject to analysis. The “proximity to wetlands” factor is considered to be met when it covers at least 20% of the hexagon area.

4) **Analysis of watercourses** - the proximity of natural watercourses that may cause damming of groundwater during high water stages is analysed. The analysis is performed in the adopted hexagonal grid. It is verified whether at least 40% of the hexagon area has land adjacent to rivers, and only rivers with a width of at least 4 m are considered. The area is counted only from the buffer (along the river) between 50 and 500 m wide. Buffer size adopted depending on the river flow: for rivers above 500 m3/s (Oder and Vistula) a 500 m buffer was assumed; for rivers with a flow rate between 100 and 500 m3/s – 300 m; for rivers with a flow between 50 m3/s and 100 m3/s – 200 m; for rivers with a flow between 10 m3/s and 50 m3/s – 100 m; other rivers with a section width of more than 4 m – 50 m buffer.

5) **Analysis of the proximity of water reservoirs** - the analysis identifies water reservoirs that may cause groundwater damming (raising the drainage base, blocking groundwater outflow) during high surface water stages. Prescribed buffers are

introduced around the selected objects, and areas predisposed to groundwater floods are designated. The analysis is conducted in the adopted hexagonal grid. It is verified whether there are areas adjacent to water reservoirs on min. 20% of the hexagon area. The area is counted only from a buffer of 100 m to 500 m width counting from the reservoir boundary. 100 m is when the reservoir has an area of less than 100,000 m2; 200 m is when the reservoir area is in the range [100,000; 400,000] m2; 500 m is when the reservoir has an area greater than 4,000,000 m2. Reservoirs smaller than 4,000 m2 are not included in the analysis.

Due to the use of spatial layers of different scales and an unagreed common topology in the analysis, spatial analyses are conducted in blocks (clusters) of the discretisation grid.

The following are considered clusters in which the necessary condition is met, i.e. shallow groundwater occurrence:

a) Blocks of the discretisation grid, covered by at least 70% of MHP PPW - WH sheets, where areas with water table depths of 0-1 and 1-2 m were separated (data source: MHP - first aquifer - occurrence and hydrodynamics (MHP PPW-WH) in the scale 1:50,000, PIG-PIB) and the water table of the first aquifer is free;
b) Blocks of the discretisation grid showing hydrogeological boreholes with a free groundwater table located between 0-2 m below ground level (data source: Hydrogeological boreholes from CBDH PIG-PIB);

Other blocks of the discretisation grid for which the MHP PPW - WH map was prepared but which do not meet the necessary condition, are not taken into account in further multi-criteria analyses. These clusters are defined as areas where the probability of groundwater floods is close to zero.

Determination of probable groundwater flood areas should be carried out in clusters that meet the necessary condition, i.e., the presence of areas with a shallow groundwater table and a free water table. In the clusters, the co-occurrence of factors (listed in Table 17) affecting the probability of groundwater flood is analysed.

The analysis of estimating the probability of groundwater floods was divided into stages:

1) Verifying that the necessary condition is met - whether the computational block of the discretisation grid (cluster) was included in the development of the MHP PPW - WH map or there are hydrogeological boreholes or dug wells with a groundwater table at a depth of not more than 2 m below ground level);
2) Verifying whether the cluster was included in the SMGP map development;
3) Determining whether the selected conditions (Table 17) are present in the discretisation grid calculation block;

4) Determining, in the discretisation grid calculation block, the number of fulfilled conductive factors (Table 17);

5) Assignment of a groundwater flood probability class based on the number of co-occurring factors (Table 17) within a single cluster (Table 18).

Table 17: Factors selected to estimate the class of probability of groundwater floods based on the predisposition of a given area to this phenomenon

Factors contributing to groundwater floods		**Factor presence**	
Description	**GIS layer**	**Yes**	**No**
Permeable soils associated with concave morphological forms	SMGP	1	0
Wetlands	GIS-WETLANDS	1	0
Proximity of natural watercourses which may cause groundwater damming during high surface water stages	MPHP	1	0
Proximity to facilities that may cause groundwater damming in the form of surface water reservoirs	MPHP	1	0

Table 18: Classes of probability of groundwater floods based on the predisposition of a given area to this phenomenon

Class of flood probability	**Number of factors present (total in cluster)**	**Class No.**	**Cluster colour**
VERY LOW	0	1	DARK GREEN
LOW	1	2	GREEN
MEDIUM	2	3	YELLOW
HIGH	3	4	ORANGE
VERY HIGH	4	5	RED
NO HAZARD	Not applicable (failure to meet a necessary condition)	-	WHITE

Based on the work carried out, it is assumed that all the component factors of the analysis (Table 16) are of equal importance. The flood probability class depends on the number of components present in the discretisation grid cluster (Table 17). According to the assumptions of the methodological study, the following discretisation grid blocks were identified in the analysis:

a) **Very low** probability - clusters within which the absence of any analysed factor was found (Table 16);

b) **Low probability** - clusters with shallow groundwater table, i.e. up to a depth of 2 m below ground level, and one factor from Table 16 is present;

c) **Medium probability** - clusters with shallow groundwater table, i.e. up to 2 m below ground level, and the coexisting of two factors from Table 16;

d) **High probability** - clusters with shallow groundwater table, i.e. up to a depth of 2 m below ground level, and the coexisting of three factors from Table 16;

e) **Very high probability** - clusters with shallow groundwater table, i.e. up to a depth of 2 m below ground level, and the coexisting of four factors from Table 16.

In addition, blocks of the discretisation grid are determined:

a) **No hazard** - probability close to zero - clusters where no groundwater table was found at a depth of up to 2 m below ground level with a free water table.

b) **No data available:**

   1) Clusters for which MHP PPW - WH maps have not been prepared and at the same time in which there are no hydrogeological holes or dug wells with an identified groundwater table no deeper than 2 m below ground level;

   2) Clusters for which SMGP maps were not prepared. This is due to the lack of information about the possible occurrence of lands conducive to groundwater flooding.

Areas of probable floods will be designated based on the classes with the highest probability of groundwater floods. The exact number of these classes will be determined after analysis of real data about the factors in the adopted discretisation grid.

5.2.4. FLOODS FROM DAMMING STRUCTURES

The source of the data on probable flood areas are the FHMs developed for this type of flood (for 26 reservoirs).

When developing the FHMs, it was assumed that they would present a scenario resulting in the maximum possible flooding of the areas below the reservoir. This scenario involves the destruction of the dam (in a certain section), which allows the reservoir to be completely drained. The most likely conditions for a disaster to occur are the operation of structures during extreme flood event. Destruction or damage to the dam structure is, therefore, part of the extreme event scenario.

5.3. NATURAL FLOODPLAINS

Floodplains are defined for river basin districts for which no historical floods have been identified, and no information is available on areas where floods are likely to occur. This applies to the following river basins: Swieza, Banowka and Dniester, for rivers with a catchment area exceeding 10 km2, for which there is no more detailed information on the range of flood areas.

Determining floodplains involves analyses based primarily on the topography (DTM) and the course of watercourses (MPHP10k). Based on the DTM and the course of the watercourses from MPHP10k, cross-sections are drawn through the watercourse bed and the floodplain valley. The density of the drawn cross-sections depends on the shape of the valley and the sinuosity of a given watercourse. Next, each cross-section should be assigned a theoretical water table elevation. This value is determined using an expert method, based on the presence of drainless areas near the watercourse bed (previously determined based on the DTM) and the terrain (high bank, embankments, distinct terrain elevations). Moreover, topographic maps (to locate, e.g. oxbow lakes and additional verification of the course of flood terraces) and orthophoto maps should be used to determine the elevation. When determining floodplains, geological maps are not analysed due to the scale of the study, which does not allow for sufficient detailing of analyses based on DTM. Soil and agricultural maps are also not used due to the availability of such studies.

Subsequently, the range of the floodplains is developed based on the cross-section elevations thus determined. In the final step, the designated area should be verified to maintain its continuity along the watercourse and eliminate errors made in the earlier stage of defining these areas.

For floodplains, the attribute structure should be used as for the layers with probable river side areas, taking into account the attributes needed to describe and analyse these areas according to the structure of the PFRA database (Appendix 1), the methodology for determining the potential adverse consequences of floods (Section 5.4.) and the possibility of carrying out analyses according to the PFRA scheme.

5.4. METHODOLOGY AND CRITERIA FOR DETERMINING THE POTENTIAL ADVERSE CONSEQUENCES OF FUTURE FLOODS AND HOW TO ASSESS THEM

The following factors are considered in assessing the potential adverse consequences of floods that may occur in the future:

1) Topography (including terrain, slopes in the catchment area) – with regard to the possibility of flood formation/development;

The ranges of flood hazard areas defined for probable floods using hydraulic modelling are taken into account; the use of topographic data is essential in this case (geodetic cross sections reflecting the actual geometry of the riverbed and the digital terrain model of the floodplains);

2) Location of watercourses and their general hydrological and geomorphological characteristics, including floodplains as natural retention areas – with regard to the possibility for flood formation/development;

The ranges of flood hazard areas defined for probable floods using hydraulic modelling, which includes river network schematisation and hydrological data, and the ranges of natural floodplains were considered (analyses based on terrain, DTM, and course of watercourses, MPHP10k; assumptions presented in Section 5.3);

3) Effectiveness of existing flood protection structures (including the presence of water reservoirs and hydrotechnical structures, with particular emphasis on flood protection and its potential effectiveness) – with regard to counteracting the consequences of floods;

The ranges of flood hazard areas defined for probable floods using hydraulic modelling, which includes existing flood protection structures and the principles of their operation, were considered.

4) Location of inhabited areas (including the urban centres, with consideration of the location of residential buildings and social facilities in flood hazard areas) – with regard to the presence of these areas and their flood hazard;

The following indicators of potential adverse flood consequences were considered: estimated number of residents at risk of flooding, number of residential buildings at risk, number of buildings of particular social interest at risk, and area of residential development; assumptions presented in Section 5.4.1;

5) Location of areas where economic activities are carried out (including the presence of industrial, agricultural, and urban areas - where service and communication activities are carried in flood hazard areas) – with regard to the presence of these areas and their flood hazard;

The following indicators of the potential adverse flood consequences were considered: the surface of hazard areas in the different use classes (residential areas, industrial areas, transport areas, forest areas, recreational and leisure areas, arable land and permanent crops, grassland, other areas), number of threatened industrial plants; assumptions presented in Section 5.4.1;

6) Forecast of long-term developments, including the impact of land use change and the impact of climate change on floods;

The following criteria for the forecast of long-term developments were considered: the impact of land use in terms of population change and in terms of the changes in built-up/sealed areas, the impact of climate change on floods; assumptions presented in Section 6.

5.4.1. FLUVIAL FLOODS

The potential adverse consequences of floods that may occur in the future, taking into account the different categories (human life and health, environment, cultural heritage, and economic activity) are determined similarly to the detailed assessment of the adverse consequences of past floods (Section 4.3. of the methodology). A summary of potential adverse consequences is presented in Table 19.

Table 19: Potential adverse consequences of floods

No.	Type of data	Unit	Source of data
1	Total areas of flood hazard areas	km^2	GIS analysis based on flood extent
ADVERSE CONSEQUENCES ON HUMAN LIFE AND HEALTH			
2	Estimated number of residents at risk of flooding	people	FRM, GIS analysis based on BDOT10k, according to the FRM Methodology
3	Number of residential buildings at risk	quantity	FRM, GIS analysis based on BDOT10k, according to the FRM Methodology
4	Number of buildings of particular social importance at risk (hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, police units, fire protection units, border guard units, social welfare homes, facilities providing 24-hour care for the disabled, chronically ill or elderly, hospices, prisons, correctional facilities, detention centres)	quantity	FRM, GIS analysis based on BDOT10k, according to the FRM Methodology
5	Adverse consequences of floods on human life and health – subcategories	EC codes	Analysis of the indicators corresponding to this subcategory: B11 - residential buildings B12 - buildings of particular social importance
ADVERSE CONSEQUENCES ON THE ENVIRONMENT			
6	Number of water intakes at risk: surface, underground	quantity	FRM, GIS analysis based on BDOT10k according to the FRM Methodology
7	Area of nature forms at risk of flooding: Natura 2000 areas, national parks, nature reserves	km^2	FRM, GIS analysis based on GDOŚ data according to the FRM Methodology

No.	Type of data	Unit	Source of data
8	Number of industrial plants at risk: – plants with an increased or high risk of industrial accident (ZDR or ZZR); – installations that may, in the event of a flood, cause significant pollution of individual natural elements or the environment as a whole, the operation of which requires obtaining an integrated permit (IPPC) – other industrial plants	quantity	FRM, GIS analysis based on BDOT10k according to the FRM Methodology
9	Number of sewage treatment plants at risk	quantity	FRM, GIS analysis based on BDOT10k according to the FRM Methodology
10	Number of sewage pumping stations at risk	quantity	FRM, GIS analysis based on BDOT10k according to the FRM Methodology
11	Area of landfill sites at risk	km^2	FRM, GIS analysis based on BDOT10k according to the FRM Methodology
12	Area of cemeteries at risk	km^2	FRM, GIS analysis based on BDOT10k according to the FRM Methodology
13	Adverse consequences of floods on the environment – subcategories	EC codes	Analysis of indicators corresponding to this subcategory: B22 - protected areas, water intakes, bathing areas B23 - industrial plants, cemeteries, landfills, sewage treatment plants, pumping stations
ADVERSE CONSEQUENCES ON CULTURAL HERITAGE			
14	Number of culturally valuable sites and areas at risk (immovable monuments, museums, open-air museums, libraries, archives, extermination monuments, UNESCO World Heritage sites)	quantity	FRM, GIS analysis based on NID data according to the FRM Methodology
15	Adverse consequences of floods on cultural heritage – subcategories	EC codes	Analysis of indicators corresponding to this subcategory: B31 – culturally valuable objects
ADVERSE CONSEQUENCES ON ECONOMIC ACTIVITY			
16	Areas at risk in the following use classes: residential areas, industrial areas, transport areas, forests, recreational and leisure areas, arable land and permanent crops, grassland, other areas	km^2	FRM, GIS analysis based on NID data according to the FRM Methodology

No.	Type of data	Unit	Source of data
17	Value of potential flood losses	PLN	FRM
18	Adverse consequences of floods on economic activity – subcategories	EC codes	Analysis of indicators corresponding to this subcategory: B41 – residential areas B42 – transport areas B43 – arable land, grassland, forests B44 – industrial sites B45 – recreational and leisure areas or other areas

For the individual categories of adverse flood consequences, the division into subcategories presented in Section 4.1.6 should be considered.

The above analyses mainly use data contained in the Report on the analysis of changes in flood hazard and risk (2022) - for FHA. For other areas, BDOT10k is used.

The following are considered as probable flood areas with potentially adverse consequences of floods (PF according to Art. 4d FD):

- all areas that in the 1st and 2nd cycles were identified in the PFRA as areas of potential significant flood risk and for which flood hazard maps are developed;
- other areas designated using hydraulic modelling, developed as part of other projects;
- natural floodplains with at least 10 residential buildings or more than 50 people at risk of flooding.

5.4.2. PLUVIAL FLOODS

In the case of pluvial floods, due to their specificity, the areas referred to in Article 4.2d [PF according to Art.4 4d FD] are not designated. Pluvial floods are usually small-area and short-term (compared to fluvial floods). In addition, the floodplain areas designated based on the Bluespot analysis are very general and represent only an approximate range of flooding.

5.4.3. GROUNDWATER FLOODS

In the case of groundwater floods, its potential adverse consequences are not determined. It is because of the specific nature of groundwater floods compared to other described types (A11, A12, A15), including, in particular, the local scale of this phenomenon, its less violent course, and the relatively small amount of water that may occur above the surface area makes the potential adverse consequences of such events much smaller than in the case of other types of floods.

Moreover, groundwater floods with the highest probability of occurrence largely coincide with areas at risk of fluvial floods for which the potential adverse consequences will be determined.

5.4.4. FLOODS FROM DAMMING STRUCTURES

The potential adverse consequences of floods are determined in a similar way as in the case of fluvial floods with a natural exceedance mechanism.

6. FORECAST OF LONG-TERM DEVELOPMENTS

The forecast of long-term developments in terms of flood risk concerns the following elements:

- the impact of land use changes,
- the impact of climate change on the occurrence of floods.

The indicators specified in Table 20 are used to describe the forecast of long-term developments.

Table 20: Indicators for describing the forecast of long-term developments in terms of flood risk

No.	Criterion	Indicator	Unit	Source of data
1	Impact of land use development on population changes	Population changes	People	GUS (2011 and 2021)
2	Impact of land use development in terms of change of built-up/sealed areas	Percentage of areas for which an increase/decrease in flood hazard was demonstrated	% + / -	CLC (2012 and 2018)
3	Impact of climate change on floods - high flows	Percentage change – the trend of change in the forecasted high flows Q90 between 2021 and 2050 (for two scenarios: RCP 4.5: moderate greenhouse gas emissions scenario and RCP 8.5: high greenhouse emissions scenario); trend analyses of maximum annual flows	%	CHASE-PL Project, PFRA[10] (2nd cycle)
4	Impact of climate change on floods – monthly mean air temperature	Percentage change – the trend of change in the forecasted mean air temperature between 2021 and 2050 (for two scenarios: RCP 4.5: moderate greenhouse gas emissions scenario and RCP 8.5: high greenhouse emissions scenario)	°C	KLIMADA. 2 Project[11]
5	Impact of climate change on floods - number of days per year with daily precipitation ≥ 20 mm	Percentage change – the trend of change in the forecasted number of days per year with daily precipitation ≥ 20 mm between 2021 and 2050 (for two scenarios: RCP 4.5: moderate greenhouse gas emissions scenario and RCP 8.5: high greenhouse gas emissions scenario)	Numer of days, %	KLIMADA. 2 Project

[10] data source: https://climateimpact.sggw.pl/map/
[11] data source: https://klimada2.ios.gov.pl/klimat-scenariusze/

According to the PFRA review and update scheme (Section 3), the forecast of long-term developments is taken into account at each stage of the analysis of areas where flooding may occur, i.e.:

- for areas for which no data on historical floods is available (e.g. natural floodplains) - it should be verified whether it is probable that a flood may occur in this area in the future;
- to indicate significant historical floods with significant adverse consequences (Art. 4.2b of the FD) - it should be verified whether it is probable that a flood may occur in this area in the future;
- to indicate historical floods that have not had significant adverse consequences in the past (Art. 4.2c of the FD) - it should be verified whether it is probable that a flood may occur in this area in the future;
- for areas of significant flood risk - it should be verified whether the forecast of long-term developments will affect the designation of areas of significant flood risk (whether the flood risk is likely to be significant).

In each of the above stages, the forecast of the long-term developments is carried out in the same way, based on the same criteria, but for different spatial units.

In the case of the analysis of historical floods (to determine significant historical floods), the spatial unit for the forecast of the long-term developments is the range of the historical flood. The forecast is assessed only based on the values specified for individual criteria (without assigning them a score).

In the case of flood risk assessment for the designation of areas of significant flood risk, the forecast of long-term developments is analysed in the hexagon structure. The forecast is assessed based on the values determined for individual criteria and an appropriate score is assigned to them.

Criteria 1-3 are a direct continuation of the methodological assumptions used in the 2nd planning cycle of the PFRA. Criteria 4-5 were added in the 3rd planning cycle.

CRITERION 1. THE IMPACT OF LAND USE DEVELOPMENT ON CHANGE IN POPULATION NUMBER is to calculate the population change for individual spatial units based on demographic data in kilometer grids from 2011 and 2021 (GUS). The obtained results are subject to correlation with population data determined from BDOT10k.

Scores are assigned according to the adopted classification:

Change in population [persons]	Number of points
< - 200	-5
<-200; -100)	-4
<-100; -50)	-3

Change in population [persons]	Number of points
<-50; -5)	-2
<-5; 0)	-1
0	0
(0; 5)	1
<5; 50)	2
<50; 100)	3
<100; 200)	4
≥ 200	5

CRITERION 2: THE IMPACT OF LAND USE DEVELOPMENT ON CHANGE IN THE BUILT-UP (SEALED) AREAS is to calculate the percentage of areas for which a decrease in flood hazard is demonstrated and areas for which an increase in flood hazard is demonstrated (based on changes in land cover forms according to CLC 2012 and 2018).

Scores are assigned according to the adopted classification:

Change in sealed areas [%]	Number of points
< -40	-5
<-40; -30)	-4
<-30; -20)	-3
<-20; -10)	-2
<-10; 0)	-1
0	0
(0; 10)	1
<10; 20)	2
<20; 30)	3
<30; 40)	4
≥ 40	5

CRITERION 3: THE IMPACT OF CLIMATE CHANGE ON FLOODS – HIGH FLOWS is to assign two values to spatial units (based on data from the 2nd planning cycle of the PFRA: CHASE-PL, trend analysis):

– percentage change in the high flow Q90 in 2021-2050 (the so-called near future) for the RCP 4.5 scenario based on CHASE-PL data,

– percentage change in the high flow Q90 in 2021-2050 (the so-called near future) for the RCP 8.5 scenario based on CHASE-PL data.

In the case of the Przymorze rivers, spatial units should be assigned one value for the percentage change in high flow resulting from the trend analysis.

Scores are assigned according to the adopted classification:

Forecasted flow change [%]	Number of points
< -40	-5
<-40; -30)	-4
<-30; -20)	-3
<-20; -10)	-2
<-10; 0)	-1
0	0
(0; 10)	1
<10; 20)	2
<20; 30)	3
<30; 40)	4
≥ 40	5

In the case of the Przymorze rivers, the assigned score must be doubled in the final assessment.

CRITERION 4: THE IMPACT OF CLIMATE CHANGE ON FLOODS – MONTHLY MEAN AIR TEMPERATURE involves assigning two values to spatial units (based on data from the KLIMADA.2 project):

- changes in the monthly mean air temperature in 2011-2050 (the so-called near future) for the RCP 4.5 scenario;
- changes in the monthly mean air temperature in 2011-2050 (the so-called near future) for the RCP 8.5 scenario.

CRITERION 5: THE IMPACT OF CLIMATE CHANGE ON FLOODS – NUMBER OF DAYS PER YEAR WITH DAILY PRECIPITATION ≥ 20 MM involves assigning two values to spatial units (based on data from the KLIMADA.2 project):

- changes in the number of days per year with daily precipitation ≥ 20 mm in 2011-2050 (the so-called near future) for the RCP 4.5 scenario;
- changes in the number of days per year with daily precipitation ≥ 20 mm in 2011-2050 (the so-called near future) for the RCP 8.5 scenario.

For criteria 4 to 5, the spatial distribution of the parameters (mean air temperature and maximum precipitation) shall be used.

Each criterion 1 to 3 shall be assigned an appropriate number of points resulting from the distribution of indicator values - on a scale from -5 (most significant potential decrease in flood risk) to 5 (most significant potential increase in flood risk), with a value of 0 indicating potential no change in flood risk due to long-term developments. Scale step: 1.

The total number of points results from the sum of the points for the individual criteria - ultimately, the information on potential changes in flood risk resulting from the forecast of long-term developments is determined with threshold values set based on the distribution of values.

For criteria 4-5, the assessment is descriptive by specifying the nature of the changes (increase, decrease, no change).

For the spatial variability of individual criteria for large areas, the following assumptions are made:

- for historical flood areas, if it is not possible to determine the average value of a criterion, the least favourable variant with regard to flood risk is assumed,
- for areas of potential flood risk of and for APSFR, it is possible to average the results for hexagons (by adopting the total value from all hexagons – for the criteria regarding the impact of land use on flood risk).

The forecast of long-term developments is carried out taking into account the type of flood.

The criteria: land use impact in terms of population change and land use impact in terms of change in built-up, sealed areas are determined in the same way for all flood types (except for groundwater floods).

The criterion: the impact of climate change on floods varies depending on the type of flood:

- for **fluvial floods (A11) and floods arising from artificial water-bearing infrastructure (A15)** - the trend of change in the forecasted high flows Q90 in 2021-2050 is determined (based on the results of the CHASE-PL project), in the absence of results, trend analyses of the maximum annual flows are used;
- for **fluvial floods (A11) with blockage mechanism (A24)** - the trend of change in the forecasted average air temperature in 2021-2050 is additionally determined (impact on the formation/deposition of ice cover);
- for **pluvial floods (A12)** - the trend of change in the forecasted number of days in a year with daily precipitation ≥ 20 mm is determined.

The following determinants are considered for **groundwater floods (A13).**

Climate change and various land-use changes can potentially change the frequency and distribution of groundwater floods. They may also adversely affect the increase in the amplitude of fluctuations in the groundwater table on the short and long-term scales.

Groundwater is the most stable element of the hydrological cycle on Earth. Its resources are generally considered a factor that can mitigate the effects of climate change in the context of water supply stability. Water in the atmosphere and surface waters respond much more to climate change. The most significant potential effects of climate change on groundwater should be expected in the zones with the strongest connection between groundwater and surface water, i.e., mainly in the coastal zones of rivers. An increase in the frequency of high surface water levels, as well as a possible increase in the amplitude of their fluctuations as potential effects of climate change, may translate directly into a temporary local damming of groundwater in natural drainage zones and thus into an increase in the frequency and extent of groundwater floods. Due to, on the one hand, the high uncertainty of the results of long-term climate forecasts and the frequent contradiction of forecast trends, and, on the other hand, the complexity of the groundwater-surface water interaction processes, it is currently not possible to provide more detailed information. Moreover, no works based on historical data regarding the impact of climate change on the occurrence and extent of groundwater floods have been identified in Poland.

Certainly, the scale of the effects of climate change may, at least to some extent, be modulated by measures taken in water management, such as extending the water cycle path in the catchment and renaturation or revitalisation of rivers with "giving the rivers" space for their free meandering, increasing the forest cover of the catchment. These measures can significantly reduce the undesirable effects of floods and climate change.

Considering future demographic and economic changes, as well as the resulting changes in land use in the form of continued urban expansion in its traditional form, i.e. an increase in the surface of built-up areas or sealed areas resulting in difficulties or lack of infiltration of rainwater into the aquifer, a decrease in the frequency of groundwater flood and an increase in the number of pluvial floods should be expected, especially where inefficient storm sewage systems exist. On the other hand, the expansion of underground infrastructure in the form of facilities that may become barriers to groundwater in the directions of its natural runoff (e.g. tunnels, underground garages) in situations of heavy precipitation may contribute to local damming and groundwater floods in places not naturally predisposed to it.

In view of the lack of detailed data on urbanisation and future population changes across the country in the units listed as areas of potential flood risk from groundwater, the analysis of a forecast of long-term developments in this area is waived.

7. AREAS OF POTENTIAL SIGNIFICANT FLOOD RISK

7.1. METHODOLOGY AND CRITERIA FOR SELECTING AREAS OF POTENTIAL SIGNIFICANT FLOOD RISK

Identification of APSFR is carried out according to the PFRA review and update scheme (Section 3), and includes stages related to the designation of the following areas:

1) **Areas of potential flood risk** - these are areas for which analyses are carried out to identify APSFR; according to the PFRA scheme, they are determined based on the identification/assessment of historical floods and probable floods as the sum of the areas of historical floods and probable floods (i.e. floods referred to in Articles 4.2 b, 4.2c and 4.2d of the FD);
2) **Areas of potential significant flood risk** (areas of significant flood risk) - these are areas where the existence of a significant flood risk is confirmed or its occurrence is probable.

The basis for identifying areas of potential flood risk is information on:

1) The spatial range of historical floods, i.e. the floods referred to in Article 4.2b and 4.2c of the FD;
2) The spatial range of probable floods, i.e. the floods referred to in Article 4.2d of the FD.

For areas of potential flood risk, **a flood risk assessment is carried out, comprising the current situation of flood risk and the prospective changes** to the flood risk as a result of a forecast of long-term developments, by which areas of potential significant flood risk are identified, i.e. APSFR.

Identification of areas of potential flood risk and areas of potential significant flood risk is carried out, considering the type of flood.

7.1.1 FLUVIAL FLOODS

The extent of areas of potential flood risk is defined as the sum of the areas of historical floods and probable floods (i.e. floods referred to in Articles 4.2b, 4.2c and 4.2d of the FD) - in the form of the maximum extent for individual rivers.

It should be noted that the extent of areas of potential flood risk includes at least all rivers for which areas of potential flood risk were identified in the 2nd planning cycle.

Flood risk assessment is carried out in a system of spatial analytical units in the form of hexagons.

The selection of spatial units for the analysis of flood risk assessment is an essential element of the analysis and determines its course. In the 2nd planning cycle of the PFRA, spatial analytical units were applied for this purpose, resulting from the intersection of areas at potential flood risk and basic catchments (MPHP10k). However, based on the analysis of the results, it is more reasonable to apply spatial units in the form of a regular grid, preferably in the form of hexagons. This unit was also used in the risk assessment for the FRMP in the 1st planning cycle. A comparison of both types of units is presented in Table 21.

Table 21: Comparison of spatial units for flood risk assessment analysis

No.	Element of comparison	Unit – the result of the intersection of areas of potential flood risk and elementary catchments	Unit – regular grid (hexagon)
1	Area - size	Different area of units - there can be a large size dispersion	Same area for all units
2	Area- shape	Diverse, in some cases problematic in terms of analysis (and results), so called ”cuttings”	Same for all units
3	Consideration of the hydrographic structure	YES	NO
4	Use in analysis	Need for standardisation	Direct
5	Consideration of point objects in the analysis	Affects the analysis - possibility of obtaining a satisfactory distribution of results	Affects the analysis - limited number of results
6	Consideration of linear objects in the analysis	Does not affect the analysis	
7	Consideration of area objects in the analysis	Does not affect the analysis	
8	Possibility to obtain information for areas of potential flood risk	YES - aggregation of results	

Flood risk assessment takes into account:

– current situation of flood risk,
– prospective changes in flood risk.

Flood risk assessment includes:

1) In the case of the current situation of flood risk - defining criteria for assessing the adverse consequences of floods,

2) In the case of prospective changes in flood risk - determining criteria for the forecast of long-term developments (described in Section 6 of the Methodology).

FLOOD RISK ASSESSMENT CRITERIA:

1) The impact of floods on human life and health: population density [people/km2];
2) The impact of floods on areas of economic activity and infrastructure: percentage of individual classes of land cover forms: inhabited areas, industrial areas, communication infrastructure (roads, railways), agriculture, forests, and others [%];
3) The impact of floods on cultural heritage: number of culturally valuable objects [quantity];
4) The impact of floods on the environment: percentage of nature protection forms (national parks, landscape parks, nature reserves, and Natura 2000 areas) [%].

These criteria were used in the PFRA of the 2nd planning cycle (only a minor modification is made to include hexagons as a spatial unit), which ensures methodological continuity in subsequent cycles. Individual criteria are assigned an appropriate number of points, resulting from the distribution of values, referring to the values used in the 2nd cycle.

CRITERION 1. THE IMPACT OF FLOODS ON HUMAN LIVE AND HEALTH is to calculate the population density for individual spatial units, i.e. hexagons, based on the number of buildings from BDOT10k (analogously to the case of determining the consequences of floods in the form of an estimated number of inhabitants affected by the flood, Section 4.2.7).

Scores are assigned according to the adopted classification:

Population density [people/km^2]	Number of points
≥ 1000	12
<900; 1000)	11
<800; 900)	10
<700; 800)	9
<600; 700)	8
<500; 600)	7
<400; 500)	6
<300; 400)	5
<200; 300)	4
<100; 200)	3
<50; 100)	2
< 50	1

CRITERION 2. THE IMPACT OF FLOODS ON AREAS OF ECONOMIC ACTIVITY AND INFRASTRUCTURE is to calculate the percentage share of individual classes of land cover forms (inhabited areas, industrial areas, communication infrastructure: roads and railways,

agricultural areas, forests, and others; based on BDOT 10k from 2023) for individual spatial units, i.e. hexagons.

Scores are assigned according to the adopted classification:

Classification of land cover forms	**Number of points**
Inhabited areas	5
Industrial areas	4
Communication infrastructure, roads and railways	3
Agricultural areas	2
Forests	1
Other	0

The score is calculated according to the formula:

$$P \quad = 0{,}05 \cdot A_{os} + 0{,}04 \cdot A_{przem} + 0{,}03 \cdot A_{infr} + 0{,}02 \cdot A_{roln} + 0{,}01 \cdot A_{las}$$

where:

P number of points for the criterion – the impact of floods on areas of economic activity and infrastructure

A_{os} percentage of the spatial unit area for the land cover form: inhabited areas

A_{przem} percentage of the spatial unit area for the land cover form: industrial areas

A_{infr} percentage of the spatial unit area for the land cover form: communication infrastructure, roads, railways

A_{roln} percentage of the spatial unit area for the land cover form: agricultural areas

A_{las} percentage of the spatial unit area for the land cover form: forests

CRITERION 3. THE IMPACT OF FLOODS ON CULTURAL HERITAGE is to calculate the number of historic buildings (all historic buildings converted to point form) for individual spatial units, i.e. hexagons, based on NID data from 2023.

Scores are assigned according to the adopted classification:

Historic buildings [quantity]	**Number of points**
≥ 16	5
<10; 15>	4
<5; 9>	3
<2; 4>	2
1	1
0	0

CRITERION 4. THE IMPACT OF FLOODS ON THE ENVIRONMENT is to calculate the percentage of nature conservation forms (including national parks, landscape parks, nature reserves and Natura 2000 areas based on GDOŚ data from 2024) for individual spatial units, i.e. hexagons.

Scores are assigned according to the adopted classification:

Percentage [%]	Number of points
(66; 100>	3
(33; 66>	2
(0; 33>	1
0	0

FINAL SCORING

The scores obtained for individual hexagons based on individual essential criteria are added up. The total values allow for the assessment of the current flood risk situation considering all categories of adverse flood consequences (in the system of individual spatial units, i.e. hexagons).

In addition to the above-mentioned assessment of the current situation of flood risk, the prospective changes in flood risk (resulting from the forecast of long-term developments) are also taken into account in the flood risk assessment. This assessment is also obtained in the form of points in the system of individual spatial units, i.e. hexagons (Section 6 of the Methodology).

Finally, to determine the APSFR, the sum of scores is used to assess the state of current flood risk and to assess prospective changes in flood risk as follows:

$$P = P_{akt} + 0{,}03 \cdot P_{persp} \cdot P_{akt}$$

where:

P total number of flood risk assessment points

P_{akt} the sum of flood risk assessment points for the current state

P_{persp} the sum of flood risk assessment points for prospective changes (including the forecast of long-term developments)

The coefficient of 0.03 used in the formula means that the prospective change in flood risk can amount to a maximum of 60% of the initial value, i.e. for the current state.

The total number of flood risk assessment points is determined for all hexagons comprising the individual areas of potential flood risk.

The flood risk assessment (as total points) for individual areas of potential flood risk is obtained from the weighted average of total points of flood risk assessments for all hexagons included within the range of a given area of potential flood risk.

Weighted average – is an average of the elements considering the influence of the weight of individual elements (elements with a higher weight have a more significant impact on the average value). For the calculation of the weighted average score for a given area of potential flood risk, the elements are individual hexagons (included in the extent of a given area of potential flood risk) with a specific score and a specific area (which is taken as the weight).

$$S = \frac{\sum_{i=1}^{n}(P_i A_i)}{\sum_{i=1}^{n} A_i}$$

where:

S weighted average of the scores for a given area of potential flood risk

Pi number of points for hexagon „i" falling within the range of a given area of potential flood risk

Ai area of hexagon „i" falling within the range of a given area of potential flood risk

DESIGNATION OF APSFR

In the 3rd planning cycle, it was assumed that all APSFR designated in the 1st and 2nd cycles will remain in force. It is also possible to determine the new APSFR.

Therefore, the flood risk assessment described above is only an auxiliary element in the process of designation of areas of potential significant flood risk (APSFR).Whereas, the expert assessment is the basis for the designation of new APSFR.

The expert assessment takes into account:

1. indications of the regional water management authorities (PGW WP);

2. comments submitted by various entities on the PFRA results;

3. results of the flood risk assessment for individual spatial units, i.e. hexagons (particularly helpful when it is necessary to assess not the entire stream, but only its section).

The obtained APSFR should be presented as spatial layers (surface and linear) and tabular summaries. The starting and ending mileage of the APSFR determined in the 1st and 2nd cycles must be consistent with the mileage indicated on the flood hazard maps. Therefore, the APSFR layers from the 1st and 2nd cycles should be revised, adjusting the geometry and the attribute values to the km from the FHM. The km values should be given with an accuracy of 0.1 km. A new mileage should be developed for the new APSFR.

ADVERSE CONSEQUENCES OF FLOODS FOR APSFR

For all designated APSFR, 4 categories of adverse consequences of floods should be defined: human health and life, environment, cultural heritage and economic activity, considering the division into subcategories, specified in Section 4.1.6.

To define the adverse consequences of floods for designated APSFR, detailed flood risk assessment criteria are applied.

DETAILED CRITERIA FOR FLOOD RISK ASSESSMENT:

1) **for the category of adverse consequences of floods: human life and health:**
   - estimated number of inhabitants [people];
   - residential buildings [number];
   - buildings of particular social importance, including hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, police units, fire protection units, border guard units, social welfare homes, facilities providing 24-hour care for disabled, chronically ill or elderly people, hospices, penitentiaries, correctional facilities, detention centres [number];
2) **for the category of adverse consequences of floods: economic activity:**
   - land use classes: residential areas, industrial areas, communication areas, forests, leisure and recreation areas, arable land and permanent crops, grasslands, surface waters, other areas - area + percentage [km^2; %];
3) **for the category of adverse consequences of floods: environment:**
   - water intakes: surface, underground [quantity];
   - forms of nature protection: Natura 2000 areas, national parks, nature reserves [km^2; %];
   - industrial plants [quantity];
   - sewage treatment plants [quantity];
   - sewage pumping stations [quantity];
   - waste landfills [km^2; %];
   - cemeteries [km^2; %];
4) **for the category of adverse consequences of floods: cultural heritage**
   - culturally valuable objects and sites: immovable monuments, museums, open-air museums, libraries, archives, extermination memorials, UNESCO world heritage sites [quantity]

7.1.2. PLUVIAL FLOODS

Due to the specific nature of pluvial floods, no areas of potential significant flood risk are identified.

7.1.3. GROUNDWATER FLOODS

Due to the specific nature of groundwater floods, no areas of potential significant flood risk are identified.

7.1.4. FLOODS FROM DAMMING STRUCTURES

The APSFR are identified as in the case of fluvial floods.

7.2. FLOOD RISK ANALYSIS

7.2.1. APSFR CLASSIFICATION METHOD FOR FLOOD RISK CLASSES

To assess trends in flood risk changes, a classification of flood risk should be made for each APSFR. The basis for this classification is the flood risk assessment carried out, as described in section 7.1.

The APSFR classification consists of 5 classes from 1 to 5, where class 1 represents the APSFR with the lowest flood risk and class 5 represents the APSFR with the highest flood risk:

Class	Flood risk
1	very low
2	low
3	moderate
4	high
5	very high

The classification of APSFR is carried out considering the flood type (in relation to the flood source).

The following indicators are used to determine the above-mentioned classes (used in the flood risk assessment in the form of criteria: impact of flooding on human life and health, impact of flooding on areas of economic activity including infrastructure, impact of flooding on cultural heritage):

- population [people],
- area of settled areas [m^2],
- area of industrial areas [m^2],
- area of areas with communication infrastructure [m^2],
- area of agricultural areas [m^2],
- number of culturally valuable objects [quantity].

The above values were determined for APSFR.

For each indicator, based on the distribution of values for all APSFR, a flood risk class should be determined using the following assumptions:

- class 1: values below percentile-20,
- class 2: values between percentile-20 and percentile-40,
- class 3: values between percentile-40 and percentile-80,
- class 4: values between percentile-80 and percentile-95,
- class 5: values above percentile-95.

The resulting flood risk class for APSFR is adopted based on the classes assigned to individual indicators – the final value is determined by the case of the highest risk class among all indicators.

In addition, the APSFR classification obtained in this way should be verified based on the analysis of the flood risk assessment scores for the current state determined for individual APSFR (based on the weighted average of the scores determined for individual hexagons included in the APSFR). APSFR in the class with very high flood risk should be considered as APSFR for which the value of the flood risk assessment scores for the current state is greater than or equal to the percentile-99 value determined on the basis of the distribution of values for all APSFR. This approach allows for the classification of the APSFR flood risk assessment to take into account the local scale of flood risk (absolute values prefer APSFR with a large surface area; here, we can distinguish smaller APSFR, where the risk is high).

7.2.2. TRENDS IN FLOOD RISK CHANGES

The assessment of trends in flood risk changes concerns changes in flood risk in subsequent planning cycles. For this purpose, it is necessary to analyse the possibility of conducting such an assessment, considering the methodological assumptions of APSFR identification in individual planning cycles, with particular regard to the data availability - and thus the possibility of conducting relevant comparative analyses.

The assessment of trends in flood risk changes should be conducted analogously for all types of floods, considering their specificity.

8. SCOPE, SOURCES AND CHARACTERISTICS OF DATA FOR PFRA

The key data required to develop a preliminary flood risk assessment is described below, and a summary of all necessary data, including data source, formats and timeliness is presented in Table 22:

1) Data from the National Geodetic and Cartographic Resources (PZGiK) – current geodetic and cartographic information including mainly digital terrain model, topographic maps on a scale of 1:10,000, orthophoto maps, Database of Topographic Objects on a scale of 1:10,000, the state register of borders and areas of territorial division units of the country.
2) Data regarding publications obtained from PGW WP (KZGW), IMGW-PIB, and Internet materials.
3) Information from the UW on the applications submitted by JST (in particular years):
    a) to include a municipality or a town (belonging to this municipality) in the regulation of the Prime Minister referred to in Article 2 of the Act of 11 August 2001 on special principles of reconstruction, renovation and demolition of buildings destroyed or damaged due to natural disasters. (Journal of Laws 2020, item 764);
    b) to include a municipality or a town (belonging to this municipality) in the regulation of the Prime Minister referred to in Article 1 of the Act of 16 September 2011 on specific solutions related to removing the consequences of floods (Journal of Laws of 2023, item 272);
    c) information from the UW on the applications submitted (in particular years) by the JST **for financial assistance from the state budget funds** from part 85 - Budgets of voivodes, section 852 - Social assistance, chapter 85278 - Removal of the effects of natural disasters **and from the purpose reserve for preventing and removing the effects of natural disasters in the form of purpose-specific benefits** referred to in the Act of 12 March 2004 on social assistance (Journal of Laws 2023, item 901);
    d) information from the UW on applications submitted (in particular years) by JST for financial assistance in the form of a special-purpose grant from the state budget for co-financing own tasks related to renovation, rebuilding and reconstruction of buildings destroyed or damaged as a result of events having a characteristics of a natural disaster.

    The information obtained from the UW will mainly allow for determining the consequences of the floods, i.e. the losses in terms of human life and health, economic activity and the environment.
4) PSP data - database of PSP interventions from Poland for the years 2018-2023.

5) Data from PGW WP (KZGW) - Map of the Hydrographic Division of Poland at a scale of 1:10,000, RZGW boundaries for the whole of Poland, boundaries of water supervision and catchment management, boundaries of river basin districts and water regions, data from the KZGW operational centre regarding the occurrence of floods.
6) IMGW-PIB data - data included in bulletins, hydrological data regarding water stages and flows for the culmination of the flood wave, date of beginning and end of floods, duration of flood, Q/H characteristic zones, precipitation data, literature data, and other information collected in the archive IMGW-PIB. The acquired data will allow for supplementing the attributes of hydrological type floods and preparing descriptions of significant floods.

Table 22: Scope, sources, and characteristics of data for PFRA

No.	Scope of data	Sources of data	Format of data	Timeliness
1	Topographic maps 1:10 000	**GUGiK**	WMS, WMTS	1994-2024
2	Orthophotomaps		*tif, WMS, WMTS	2021-2024
3	State register of boundaries and areas of the territorial divisions units of the country (PRG)		*shp, WMS, WMTS	2023-2024
4	National Register of Geographical Names (PRNG)		*shp, WMS, WMTS	2024
5	Digital terrain model		*xyz, *asc, *tif, TIN, WMS, WMTS	2011-2024
6	Index of DTM sheets, orthophotomaps		*shp, WMS, WMTS	2023-2024
7	BDO 250k		*shp, WMS, WMTS	2024
8	BDOT10k		*shp, WMS, WMTS	2018-2023
9	RZGW borders for the whole of Poland		*shp	2024
10	Boundaries of river basin districts		*shp	2024
11	Boundaries of water regions	**PGW-WP (KZGW, RZGW)** **IMGW-PIB**	*shp	2024
12	Boundaries of water surveillance		*shp	2024
13	Boundaries of the catchment areas		*shp	2024
14	Map of Hydrographic Division of Poland 1:10 000		*shp	2024
15	Literature data on historical floods and other sources		-	-
16	Database of preliminary flood risk assessment (from the 2nd planning cycle)		geobaza	2018
17	Methodology for preliminary flood risk assessment		*docx	2018

No.	Scope of data	Sources of data	Format of data	Timeliness
	(from the 2nd planning cycle)			
18	Report on the review and update of the preliminary flood risk assessment		*docx, *xlsx	2018
19	PFRA from groundwater - methodology, databases of inputs and analysis results, maps (from the 2nd planning cycle)		*shp, *pdf, *xml, *docx, geobaza	2018
20	Report to the EC from the 2nd planning cycle, including schemes: CA, UoM, PFRA, APSFR, FHRM;		*accdb, *shp, *docx, *xml, *gml	2020
21	Report to the EC from the competent authorities and management units in Poland on matters related to the implementation of the Floods Directive		*docx, *pdf	2020
22	Methodology for developing flood hazard maps and flood risk maps in the 2nd planning cycle		*docx, *xlsx	2020
23	Report on the review and update of flood hazard and flood risk maps		*docx, *xlsx	2022
24	Database of flood hazard maps and flood risk maps		*shp	2022
25	Report on the analysis of changes in flood hazard and risk with spatial layers		*docx, *xlsx, *shp	2022
26	Reports on the preparation of hydrological data for the needs of hydraulic modelling, task 1, task 1DII		*docx, *xlsx	2020, 2021
27	Report on analysis and diagnosis of problems including spatial layers (1st planning cycle)		*pdf, *shp, *docx, *xlsx	2015
28	Report on the review of the diagnosis of problems, including analysis of the spatial distribution of flood risks with spatial layers (2nd planning cycle)		*pdf, *shp, *docx, *xlsx	2020
29	Letters/conclusions received by PGW WP to be taken into account in the review and update of the PFRA		*docx, *pdf, *jpg	2019-2023
30	Flood data from individual RZGW		*docx, *pdf, *jpg, *shp	2018-2024
31	Literature data on historical floods and other sources		-	-
32	Hydrological data		*doc, *xls, *pdf,*tif, *jpg and others	1960-2022
33	Meteorological data	**IMGW-PIB** **PIG-PIB**	*doc, *xls, *pdf,*tif, *jpg and others	-
34	Detailed geological map of Poland at a scale of 1:50,000		geobaza, *jpg, *pdf, WMS	2024
35	Lithogenetic map of Poland at a scale of 1:50,000		geobaza	2024
36	Geological map of Poland at a scale of 1:200,000	**PIG-PIB**	geobaza	2024

No.	Scope of data	Sources of data	Format of data	Timeliness
37	MIDAS – the System of Protection and Management of Mineral Resources of Poland	**GDOŚ**	Geobaza, WMS	2024
38	Hydrogeological map of Poland at a scale of 1: 50,000		geobaza, *jpg, *pdf	2024
39	Hydrogeological map of Poland at a scale of 1: 50,000 - First Aquifer - Occurrence and Hydrodynamics		geobaza, *shp, *pdf	2024
40	Central Hydrogeological Data Bank		geobaza, *shp, *pdf	2024
41	Groundwater Monitoring Database		geobaza , *pdf	2024
42	Map of areas at risk of inundations		*shp, geobaza, WMS	2007
43	Forms of nature protection (Natura 2000, national parks, nature reserves)		*shp	2024
44	Distribution of natural habitats		*shp, WMS	2019
45	GIS - Wetlands	**ITP-PIB** Institute of Technology and Life Sciences - National Research Institute	geobaza	2004-2006
46	"Register of Monuments" database	**NID** National Heritage Institute	*shp	2023
47	Description of historical floods	**UW**	Copies of conclusions and protocols submitted by JST after the floods	2018-2023
48	Location on maps			
49	Information on flood losses	**UW** **GIOŚ** **Sat4Envi/Copernicus**	Copies of conclusions and protocols submitted by JST after the floods *shp rasters	2018-2023 2018 2014-2024
50	Corine Land Cover			
51	Satellite images of floods			
52	Data on flood risk elements - for flood impact assessment and flood risk assessment	**BDOT**	*shp	2023

No.	Scope of data	Sources of data	Format of data	Timeliness
53	Data on flood risk elements - for flood impact assessment and flood risk assessment	**FRM (2nd cycle)**	*shp	2020
54	Data on the impact of climate change on the occurrence of floods	**PFRA (2nd cycle) CHASE-PL**	*shp	2018
55	Data on the impact of climate change on the occurrence of floods	**KLIMADA**.2	.xlsx	2023
56	Database on PSP interventions for the whole of Poland	**PSP**	*xlsx	2018-2023

9. SPATIAL DATABASE FOR PRELIMINARY FLOOD RISK ASSESSMENT

Spatial databases of the preliminary flood risk assessment are prepared in a file geodatabase (gdb) in the PL-1992 coordinate reference system. Additionally, a copy of the PFRA database will be prepared in the *shp format, which will include the same scope of information as the gdb database with necessary modifications resulting from the specificity of the *shp format.

The preliminary flood risk assessment database in the 3rd planning cycle (WORP_RRRR_vNNN.gdb) includes the following groups of spatial layers:

1) Reference layers:

a) Administration and management:

- River basin district boundaries,
- Water regions boundaries,
- Regional Water Management Authorities (RZGW) boundaries,
- Catchment management boundaries,
- Coastal belt boundaries,
- Maritime office boundaries,
- Country border,
- Voivodeship boundaries
- County boundaries,
- Municipal boundaries,

b) Hydrography:

- Rivers,
- Mileage of rivers covered by PFRA,
- Mileage of coast [entire coast].

2) Layers of preliminary flood risk assessment:

a) Historical floods:

- Significant historical floods (1 flood = 1 record),

b) Probable floods:

- Probable floods - rivers,
- Probable floods – reservoirs;

c) Areas of potential significant flood risk:

- Rivers for which APSFR have been designated,
- Areas of potential significant flood risk for rivers,
- Areas of potential significant flood risk from damming structures;

A detailed description of the attribute structure of the PFRA database is set out in Appendix 1 and includes layer name, layer name alias, layer description, layer type and attributes (field name, data type, mandatory field, dictionary, data source, description).

10. MAPS OF PRELIMINARY FLOOD RISK ASSESSMENT

PFRA maps are illustrative maps presenting the following thematic areas:

– a map of river basin districts showing the topography and a map of river basin districts showing land use,
– a map of significant historical floods (HF),
– a map of areas where flooding is likely to occur (PF),
– a map of areas of potential significant flood risk (APSFR).

Maps of river basin districts showing the topography and land use (according to Art. 4.2a of the FD) are prepared for the entire area of Poland and for individual river basin districts.

Maps of historical floods, probable floods and APSFR are prepared for the entire area of Poland, for individual river basin districts, water regions and for voivodeships.

A detailed description of individual PFRA maps is included in Appendix 2.

11. METHOD AND SCOPE OF CONSIDERING THE SEAWATER PFRA, INCLUDING INTERNAL MARINE WATERS

The draft seawater PFRA, including internal marine waters, is prepared by the minister in charge of the maritime economy. This project is an integral element of the draft PFRA, therefore it is necessary to include it in the review and update of the PFRA.

The inclusion of the seawater PFRA in the review and update of PFRA concerns the following aspects:

1) the report and methodology of the seawater PFRA should be considered as appendices to the PFRA review and update report;

2) PFRA review and update report should include a section dedicated to seawater floods describing the following issues:

- methodological assumptions of the PFRA review and update,
- historical floods,
- probable floods,
- areas of potential significant flood risk,
- long-term development forecast,

3) the appendices to the report on the review and update of the PFRA should include summaries covering:

- significant floods (HF according to Art. 4b and 4c FD and PF according to Art. 4d FD),
- areas of potential significant flood risk;

4) the spatial layers of the seawater PFRA should be included in the PFRA database;

5) the results of the seawater PFRA should be included on the PFRA maps in terms of:

- maps of significant historical floods,
- maps of areas where flooding is likely to occur,
- maps of areas of potential significant flood risk.

12. METHOD AND SCOPE OF INFORMATION EXCHANGE WITH NEIGHBOURING COUNTRIES

The issues concerning the exchange of information with other EU Member States on the PFRA are defined in the Water Law Act:

> Art. 168. 7. The preparation of a preliminary flood risk assessment for river basin districts, parts of which are located on the territory of other European Union Member States, is preceded by the exchange of information necessary to prepare this assessment with the competent authorities of these countries. Information is exchanged in the way and scope specified in separate regulations.

The requirement to exchange information regarding the PFRA is also indicated in the FD:

> Article 4.3. In the case of international river basin districts or management units referred to in Article 3.2. (b) shared with other Member States, Member States shall ensure the exchange of relevant information between the competent authorities concerned.

Information exchange should take place within each river basin district. It is assumed, that according to legal requirements, the exchange of information with Poland's neighbouring countries that are EU Member States is obligatory, for non-EU Member States it is optional.

Table 23 shows the location of Poland's neighbouring countries in individual river basin districts, with an indication of the form of cooperation.

Table 23: Location of Poland's neighbouring countries in river basin districts

River basin district	Neighbouring country	Form of cooperation
Oder	Germany (EU)	International Commission for the Protection of the Oder against Pollution
		Polish-German Commission for Border Waters
	Czech Republic (EU)	International Commission for the Protection of the Oder against Pollution
		Polish-Czech Commission for Border Waters
Vistula	Russia (non-EU)*	--
	Belarus (non-EU*)*	--
	Ukraine (non-EU)	Polish-Ukrainian Commission for Border Waters
	Slovakia (EU)	Polish-Slovak Commission for Border Waters
Banowka	Russia (non-EU)	--
Dniester	Ukraine (non-EU)*)*	Polish-Ukrainian Commission for Border Waters
Danube	Slovakia (EU)	Polish-Slovak Commission for Border Waters
Elbe	Czech Republic (EU)	Polish-Czech Commission for Border Waters International Commission for the Protection of the Elbe River

River basin district	Neighbouring country	Form of cooperation
Nemunas	Lithuania (EU)	Polish-Lithuanian Commission for Border Waters
Pregolya	Russia (non-EU)	--
Swieza	Russia (non-EU)	--

Below is a detailed description of the forms of cooperation between Poland and neighbouring countries for particular river basin districts.

ODER RIVER BASIN DISTRICT

International Commission for the Protection of the Oder River against Pollution

The International Commission for the Protection of the Oder against Pollution (ICPO) is one of the international commissions in Europe dealing with rivers and lakes whose catchment areas are shared by more than one country. The cooperation covers all three countries in the Oder catchment area: Poland, the Czech Republic, and Germany. The formal basis for cooperation is the international Agreement of 11 April 1996 between the Government of the Republic of Poland, the Government of the Czech Republic, the Government of the Federal Republic of Germany, and the European Community. The Agreement entered into force after ratification on 26 April 1999.

The key objectives of the ICPO are:

- prevention of pollution of the Oder and the Baltic Sea waters; measures to reduce pollution,
- maintenance and protection of aquatic and coastal ecosystems, while preserving species diversity,
- to enable the use of the Oder waters as drinking water and water used for agriculture;
- prevention and sustainable reduction of the risk of flood damage,
- coordination of the implementation in the Oder river basin of the Framework Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000, establishing a framework for community action in the field of water policy, as well as Directive 2007/60/EC of the European Parliament and the Council of 23 October 2007 on the assessment and management of flood risks.

The topic of floods within the ICPO is dealt with by G2 Flood Working Group.

Polish-Czech Commission for Border Waters

The formal basis for bilateral cooperation is the Agreement between the Governments of the Republic of Poland and the Czech Republic on cooperation in border waters, in the field of water management of 20 April 2015 (ratified by Poland on 17 December 2015).

The Agreement is a mutual commitment to cooperation on water management in border waters. Its objectives are:

- ensuring the protection, mutual coordination and rational use of border waters and improving their quality, as well as preserving and restoring ecosystems dependent on waters, including their biodiversity,
- coordinating efforts to mitigate the adverse effects of floods and drought.

The Polish-Czech Commission for Border Waters has been established to implement the provisions of the agreement. The cooperation and data exchange in the field of floods is handled by the HyP Working Group on Hydrology, Hydrogeology and Flood Protection.

Polish-German Commission for Border Waters

The formal basis for bilateral cooperation is the Agreement between the Governments of the Republic of Poland and the Federal Republic of Germany on cooperation in the field of water management in border waters of 19 May 1992 (ratified by Poland on 26 September 1996).

The Agreement is a mutual commitment to cooperation on water management in border waters. Its objectives are:

- ensuring the rational management and protection of border waters and improve their quality;
- ensuring that ecosystems are preserved and, if necessary, restoring them.

The Polish-German Commission for Border Waters has been established to coordinate and implement the tasks of the agreement. The cooperation and data exchange in the field of floods is handled by the W4 Working Group on the Maintenance of Border Waters.

VISTULA RIVER BASIN DISTRICT

Polish-Ukrainian Commission for Border Waters

The formal basis for bilateral cooperation is the Agreement between the Governments of the Republic of Poland and Ukraine on cooperation in the field of water management in border waters of 10 October 1996.

The Agreement is a mutual commitment to cooperation on water management in border waters. Its objectives are:

- protecting and using border waters, protecting against damage caused by border waters;

- ensuring rational management of border waters and improving their quality, as well as preserving ecosystems.

The Polish-Ukrainian Commission for Border Waters has been established to coordinate and implement the tasks of the agreement. The cooperation and data exchange in the field of floods is handled by the OP Working Group on Flood Protection, Regulation and Drainage.

Polish-Slovakian Commission for Border Waters

The formal basis for bilateral cooperation is the Agreement between the Governments of the Republic of Poland and the Slovak Republic on cooperation in the field of water management in border waters of 14 May 1997.

The Agreement is a mutual commitment to cooperation on water management in border waters. Its objectives are:

- using and protecting border waters against pollution,
- maintaining and improving the ecological status of the border waters and establishing rules for their shared use.

The Polish-Slovakian Commission for Border Waters has been established to coordinate and implement the tasks of the agreement. The cooperation and data exchange in the field of floods is handled by the HyP Working Group on Hydrology and Flood Protection.

Cooperation with Belarus

Formally, the cooperation is based on the Agreement between the Governments of the Republic of Poland and the Republic of Belarus on cooperation in the field of protection and rational use of transboundary waters of 7 February 2020.

Cooperation based on this agreement does not take place due to the lack of diplomatic relations between the parties. Neither a Polish-Belarusian commission for transboundary waters nor its working groups have been established. There is only bilateral cooperation at the level of regional water management institutions, which includes renovation works on the Augustów Canal. These works are carried out only to the extent necessary to prevent failures of hydrotechnical devices.

Cooperation with Russia

Formally, the cooperation with the Russian Federation in water management is based on the Agreement between the Governments of the People's Republic of Poland and the Union of Soviet Socialist Republics on water management in border waters of 17 July 1964. This agreement is in force on a succession basis and is subject to automatic extension for subsequent five-year periods, while the Russian side shows no practical interest in its implementation.

PREGOLYA RIVER BASIN DISTRICT

The formal basis for cooperation with Russia is analogous to that of the Vistula river basin district (detailed description for the Vistula river basin district).

NEMUNAS RIVER BASIN DISTRICT

Polish-Lithuanian Commission for Border Waters

The formal basis for bilateral cooperation is the Agreement between the Governments of the Republic of Poland and the Republic of Lithuania on cooperation in the field of use and protection of border waters of 7 June 2005.

The agreement is a mutual commitment to cooperation on water management in border waters. Its objectives are:

- economic, scientific, technical, and organisational cooperation in the field of border waters use and protection;
- coordination of activities affecting border waters;
- joint planning of measures to protect border waters.

The Polish-Lithuanian Commission for Border Waters has been established to coordinate and implement the tasks of the agreement. The cooperation and data exchange in the field of floods is handled by Working Group No.1 on the development of water management plans and flood risk management.

DNIESTER RIVER BASIN DISTRICT

Cooperation and exchange of information for the Dniester river basin district takes place within the framework of the Polish-Ukrainian Commission for Border Waters (detailed description for the Vistula river basin district).

ELBE RIVER BASIN DISTRICT

International Commission for the Protection of the Elbe River

The International Commission for the Protection of the Elbe River (ICPER) is one of the functioning international commissions in Europe dealing with rivers and lakes whose catchment areas fall within the territories of more than one country. The cooperation covers countries located in the Elbe basin district: Germany, the Czech Republic (contracting parties), Austria and Poland (observers). The formal basis for the cooperation is the international Agreement of 8 October 1990 between the Federal Republic of Germany, the Czech and Slovak Federal Republics, and the European Economic Community. The agreement entered into force on 13 August 1993.

The primary objectives of the ICPER are:

- sustainable water use, in particular promoting the drinking water intake as a result of river water infiltration and enabling agriculture to use water and sediments;
- striving to achieve natural ecosystems;

– defining a continuous strategy to reduce the cargoes entering the North Sea from the Elbe basin.

The topic of floods within the ICPER is dealt with by the FP (Flood Protection) Working Group.

In addition, cooperation and exchange of information for the Elbe basin district takes place within the framework of the Polish-Czech Commission for Border Waters (detailed description for the Oder River basin district).

Actions to exchange information with neighbouring countries (EU and non-EU) on the review and update of the PFRA in the 3rd planning cycle are carried out based on existing international agreements on cooperation in the field of water management (bilateral agreements on border waters and agreements on international river commissions).

To ensure the exchange of information, briefing notes should be prepared for the review and update of the PFRA in the 3rd planning cycle, separately for each neighbouring country, excluding non-cooperating countries.

The note will include:

1) Introduction;

2) Information on the PRFA for the relevant river basin district;

3) A List of APSFR for border rivers designated in the 1st and 2nd planning cycles in Poland – with an overview map;

4) Scope and methodology of the PFRA review and update;

5) Identified floods on border rivers between 2018 and 2023.

6) List of rivers or sections of border rivers for which APSFRs have been designated in the 3rd planning cycle together with an overview map.

The information will be prepared in two language versions: Polish and English.

13. CHANGES TO THE DEVELOPMENT OF THE REVIEW AND UPDATE OF THE PRELIMINARY FLOOD RISK ASSESSMENT

In the review and update of the PFRA in the 3rd planning cycle, methodological changes were introduced concerning the following stages of the analysis:

1) Identification and description of historical floods.

2) Identification and description of probable floods.

3) Identification of areas of potential flood risk.

4) Flood risk assessment.

5) Forecast of long-term developments.

6) Identification of areas of potential significant flood risk.

The comparison of individual elements of the PFRA analysis in subsequent planning cycles (in the 2nd and 3rd cycle) is presented in Table 24.

Table 24: Comparison of elements of the PFRA analysis in the 2nd and 3rd planning cycle

Element of analysis	Inclusion in the 2nd cycle	Inclusion in the 3rd cycle
Identification and description of historical floods	– data from surveys conducted, among others, in local government units were used to identify historical floods, – all identified historical floods were considered as significant	– all possible data sources were used to identify historical floods, including literature data, hydrological and meteorological data, satellite data, data from the UW on local government units that reported events bearing the characteristics of natural disasters and conclusions related to the removal of flood consequences, – particular attention was paid to determining the spatial range of the flood – the range of each flood was presented in a surface form (in the case of point information, it was changed to a polygon form), the continuity of the flood ranges was aggregated and supplemented, – the assessment of the consequences of historical floods was extended – in the case of lack of actual data on the adverse consequences of floods obtained from the competent institutions collecting this data, they

Element of analysis	Inclusion in the 2nd cycle	Inclusion in the 3rd cycle
		were estimated based on spatial analyses of the flood ranges, – based on the assessment of the consequences, significant historical floods were distinguished –
Identification and description of probable floods	– all possible data sources regarding hypothetical floods, determined from historical data assuming a certain probability of flooding, including the FHM, were used to identify probable floods, – all probable floods were considered as floods with potential adverse effects	– the 1% scenario from FHM was used to identify probable floods, – analyses were extended for pluvial floods and groundwater floods, – the scope of information on probable floods was extended to include an assessment of potential consequences, taking into account the risk elements presented on the FRM, – based on the assessment of consequences, probable floods with potential adverse consequences were distinguished
Identification of areas of potential flood risk	– to identify areas of potential flood risk, probable flood areas were included, primarily with a flood probability of 1% (and possibly with a different flood probability in the case when information on floods with a probability of 1% was not available), historical flood areas, areas of potential flood risk from the 2011 PFRA, as well as floodplains (treated as natural retention areas)	– areas of potential flood risk were treated explicitly as the sum of areas of significant historical floods and probable floods with potential adverse consequences (in the form of maximum range)

Element of analysis	Inclusion in the 2nd cycle	Inclusion in the 3rd cycle
Flood risk assessment	– the analytical units were spatial units formed from the intersection of areas of potential flood risk with the MPHP elementary catchments, – the following criteria were applied to assess the adverse consequences of floods: 1/ Direct impact of floods on human life and health: population density; 2/ Impact of floods on areas of economic activity with infrastructure: percentage of individual classes of land cover types, i.e. settled areas, industrial areas, communication infrastructure (roads, railways), agriculture, forests, other; 3/ Impact of floods on cultural heritage: density of culturally valuable objects; 4/ Impact of floods on the environment: percentage of nature protection forms (national parks, landscape parks, nature reserves and Natura 2000 areas), – the assessment for individual criteria was made using a scoring scale, – the final score was determined uniformly for all analytical units.	– the analytical units were spatial units in the form of a regular grid (hexagons), – analogous criteria for assessing the adverse consequences of floods were applied as in the PFRA in the 2nd cycle, with the following differences: 1/ Impact of floods on human live and health: the data source for calculating population density has been changed (in the 2nd cycle – GUS data, in the 3rd cycle – BDOT); 2/ The density of culturally valuable objects has been replaced by the number of culturally valuable objects; – the assessment for individual criteria was made using the scoring scale applied in the 2nd cycle, extended by the value 0 (no flood risk), – the final score was determined uniformly for all analytical units and the final score was determined based on a weighted average for the area of potential flood risk, including all hexagons within its range.
Forecast of long-term developments	– the following criteria for the forecast of long-term developments were applied: 1/ Impact of land use development on population change: population change; 2/ Impact of land use development on change in built-up areas or sealed areas: percentage of areas for which a decrease in flood risk has been demonstrated and areas for which an increase in flood risk has been demonstrated; 3/ Impact of climate change on the occurrence of floods: change in the projected volume of high flows Q90 between 2021 and 2050 (for two	– analogous criteria for the forecast of long-term development were applied as in the PFRA in the 2nd cycle – the scope of assessment criteria has been extended to include the impact of climate change on the occurrence of floods – the number of days per year with daily precipitation ≥ 20 mm (for pluvial floods) and the change in mean air temperature (impact on the formation/deposition of ice cover)

Element of analysis	Inclusion in the 2nd cycle	Inclusion in the 3rd cycle
	scenarios, i.e. RCP 4.5: moderate greenhouse gas emission scenario and RCP 8.5: high greenhouse gas emission scenario)	
Identification of areas of potential significant flood risk	– the basis for the identification of APSFR was an expert assessment; the flood risk assessment including the above criteria was a supporting assessment	– as in the PFRA in the 2nd cycle, the expert assessment was the basis for the identification of the APSFR; the flood risk assessment including the above criteria was a supporting assessment – flood risk analyses were introduced for the classification of APSFR

LIST OF APPENDICES

Appendix 1 - Description of the PFRA database structure

Appendix 2 - Description of the preliminary flood risk assessment maps

LIST OF FIGURES

It should be emphasised that the essence of residual risk is inherently integrated into the flood risk management concept. When defining measures in this area (e.g. within the framework of the FRMP), it is important to be aware of the residual risk and its genesis, which are linked, on the one hand, to the nature of flooding as a natural phenomenon (it can and will occur - and may even intensify due to climate change) and, on the other hand - to the historical circumstances of the location of urban and industrial centres (generating the most adverse consequences of floods) in the vicinity of rivers.

LIST OF TABLES

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