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THE REPORT ON THE REVIEW AND UPDATE OF THE FLOOD HAZARD MAPS AND FLOOD RISK MAPS

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LIST OF ABBREVIATIONS

BDOT10k	Topographical Objects Database corresponding to the details of the topographic map in the scale of 1:10,000
Floods Directive	Directive 2007/60/EC of the European Parliament and of the European Council of 23 October, 2007 on the assessment and management of flood risk (so-called Floods Directive)
GIOŚ	Chief Inspector of Environmental Protection
GUGIK	Head Office of Geodesy and Cartography
GUS	Central Statistical Office
IMGW-PIB	Institute of Meteorology and Water Management – National Research Institute
ISOK	IT System of the Country's Protection Against Extraordinary Threats
KG PSP	National Headquarters of the State Fire Service
KZGW	National Water Management Board
MKOOpZ	International Commission for Protection of the Oder River against Pollution
MPHP10k	Map of the Hydrographic Division of Poland at a scale of 1:10,000
FHM	Flood Hazard Maps (Polish abbreviation “MZP”)
FRM	Flood Risk Maps (Polish abbreviation “MRP”)
DSM	Digital Surface Model
DTM	Digital Terrain Model
ONNP	Flood-prone Area
OZP	Flood Hazard Area
PGW WP	State Water Holding Polish Waters
PZD	Poviat Roads Administration
WFD	Directive 2000/60/EC of the European Parliament and of the European Council of 23 October, 2000 establishing a framework for Community action in the field of water policy (the so-called Water Framework Directive – WFD).
RZGW	Regional Water Management Authorities
EU	European Union
UM	Maritime Offices
WIOŚ	Voivodeship Inspectorate for Environmental Protection
PFRA	Preliminary Flood Risk Assessment (Polish abbreviation “WORP”)
WZ	Event of total destruction of the flood embankment
WZD	Voivodeship Roads Administration

DEFINITIONS

basin district	area of land and sea made up of one or more neighbouring river basins, together with associated groundwater, internal marine waters, transitional waters and coastal waters, being the main water management spatial unit [Water Law Act]
flood-prone areas	areas indicated in the preliminary flood risk assessment where there is or is likely to be a significant flood risk [Water Law Act]
flood hazard areas	areas where there is a possibility of floods with a certain probability or floods as a result of an extreme event, presented in the flood hazard maps, i.e.: 1) areas with a low probability of flooding of 0.2% (once every 500 years); 2) areas with a medium probability of flooding of 1% (once every 100 years); 3) areas with a high probability of flooding of 10% (once every 10 years); 4) areas including flooded terrain in case of: a) damage or destruction of the flood embankment, b) damage or destruction of the storm embankment, c) damage or destruction of the damming structure.
special flood hazard areas	special flood hazard areas: a) areas with a medium probability of flooding of 1% (once every 100 years); b) areas with a high probability of flooding of 10% (once every 10 years); c) areas between the bank line and the embankment or natural high bank into which the embankment is built, as well as islands and mudflats (formed naturally on land covered by surface waters), which are registered plots; d) technical belt of the sea coast constituting a zone of direct interaction between sea and land. [Water Law]
flooding	temporary water cover of land that is not normally covered by water, in particular caused by water exceedance in natural watercourses, bodies of water, canals and from the sea water, excluding water cover caused by water exceedance in sewage systems [Water Law]
flood risk	combination of the probability of a flood and the potential adverse consequences of a flood on human life and health, the environment, cultural heritage and economic activity [Water Law]

1 INTRODUCTION

The review and update of flood hazard maps (FHM) and flood risk maps (FRM) in the second planning cycle for the implementation of Directive 2007/60/EC of the European Parliament and of the European Council of 23 October, 2007 on the assessment and management of flood risks (Floods Directive), was implemented under the project financed from the funds of the Operational Programme Infrastructure and Environment 2014-2020, Priority Axis II: Environmental protection including adaptation to climate change, Measure 2.1 Adaptation to climate change with protection and improvement of resilience to natural disasters and environmental monitoring.

This report takes into account the results of the following tasks:

- Review and update of flood hazard maps and flood risk maps – implementation period: 2017-2020; project number: POIS.02.01.00-00-0013/16; Contractor: PGW WP – KZGW; Leader: IMGW-PIB, Arcadis sp. z o.o., MGGP S.A.; Controller: DHI Polska Sp. z o.o.;
- Development of flood hazard maps and flood risk maps for areas exposed to flooding for damming structures' damage or destruction (7) p. 1 – implementation period: 2019-2020; project number: POIS.02.01.00-00-0013/16; Contractor: PGW WP – KZGW; Leader: MGGP S.A.; Controller: DHI Polska Sp. z o.o.;
- Review and update of flood hazard maps and flood risk maps from the sea water, including internal sea waters in the jurisdiction of the Maritime Office in Gdynia – implementation period: 2017-2020; project number: POIS.02.01.00-00-0023/17-00; Contractor: Maritime Office in Gdynia; Leader: IMGW-PIB;
- Review and update of flood hazard maps and flood risk maps from the sea water, including internal sea waters in the jurisdiction of the Maritime Office in Słupsk – implementation period: 2017-2019; project number: POIS.02.01.00-00-0022/17-00; Contractor: City Hall in Słupsk; Leader: Multiconsult Poland;
- Review and update of flood hazard maps and flood risk maps from the sea water, including internal sea waters in the jurisdiction of the Maritime Office in Szczecin – implementation period: 2017-2019; project number: POIS.02.01.00-00-0021/17-00; Contractor: City Hall in Szczecin, Leader: Multiconsult Poland;
- Development of flood hazard maps and flood risk maps for areas exposed to flooding for damming structures' damage or destruction (19) p. 2 – implementation period: 2020-2022; project number: POIS.02.01.00-00-0013/16; Contractor: PGW WP – KZGW; Leader: MGGP S.A.; Controller: PGW WP / DHI Polska Sp. z o.o.;
- Development of flood hazard maps and flood risk maps (from the rivers) to the extent resulting from the review and update of the preliminary flood risk assessment together with publication – implementation period: 2020-2022; project number: POIS.02.01.00-00-0013/16; Contractor: PGW WP – KZGW; Leader: Multiconsult Poland; Controller: DHI Polska Sp. z o.o.

In the first planning cycle (2010-2015), flood hazard maps and flood risk maps were developed within the framework of the "IT System for Country Protection against Emergency Hazards" (ISOK) project, financed by the European Regional Development Fund under the Operational Programme Innovative Economy 2007-2013.

The FHM and FRM developed in the first planning cycle were reviewed in the second planning cycle (2016-2021) and, where necessary, updated, and new maps were elaborated for the areas and types of floods identified as a result of the review and update of the preliminary flood risk assessment completed in 2018.

2 LEGAL GROUNDS

Flood hazard maps and flood risk maps are prepared on the basis of the following legal acts:

1) Directive 2007/60/EC of the European Parliament and of the European Council of 23 October, 2007 on the assessment and management of flood risks (Floods Directive);
2) Act of 20 July, 2017 – Water Law (Journal of Laws of 2021, item 2233, as amended);
3) Regulation of the Minister of Maritime Economy and Inland Navigation of 4 October, 2018 on the development of flood hazard maps and flood risk maps (Journal of Laws of 2018, item 2031).

The Floods Directive introduced the obligation to develop planning documents, including flood hazard maps and flood risk maps (Article 6), as a basis for the assessment of flood risk and taking up measures to reduce the negative impacts of floods on human health and life, economic activity, the environment and cultural heritage.

The provisions of the Directive were implemented into the Polish legal system by the Act amending the Water Law and certain other acts of 5 January, 2011 (Journal of Laws of 2001, No. 32, item 159), which entered into force on 18 March, 2011. On its basis, flood hazard maps and flood risk maps were prepared in the first planning cycle. Detailed requirements for the preparation of the maps were then of the Regulation of the Minister of the Environment, the Minister of Transport, Construction and Maritime Economy, the Minister of Administration and Digitization and the Minister of Internal Affairs of 21 December, 2012 on the preparation of flood hazard maps and flood risk maps (Journal of Laws of 2013, item 104).

A new law of 20 July, 2017 entered into force on 1 January, 2018 – Water Law, hereinafter referred to as the "Water Law Act", which maintains the validity of the flood hazard maps and flood risk maps developed to date (Article 555, paragraph 2, points 4 and 5), and orders their review by 22 December, 2019 and, if necessary, their updating. Under Article 169, paragraph 8 of the Act, the flood hazard maps and flood risk maps are reviewed every 6 years and updated if necessary.

In accordance with Article 169, paragraph 1 of the Water Law Act, flood hazard maps and flood risk maps are created for areas exposed to flooding indicated in the preliminary flood risk assessment.

The Water Law Act (in Articles 169 – 171) defines the general scope and manner of preparing flood hazard maps and flood risk maps, as well as the procedure for their opinion and agreement.

Based on the Act of 20 July, 2017 – Water Law, a new Regulation of the Minister of Maritime Economy and Inland Navigation of 4 October, 2018 on the development of flood hazard maps and flood risk maps (Journal of Laws 2018, item 2031), hereinafter referred to as the "Regulation", was issued.

According to the Water Law Act (Article 169, item 2), flood hazard maps present in particular:

1) areas with a low probability of flooding of 0.2% or where an extreme event is likely to occur;
2) special flood hazard areas:
    a) areas with a medium probability of flooding of 1%,
    b) areas with a high probability of flooding of 10%,
3) areas exposed to flooding in case of damage or destruction of a flood embankment;
4) areas exposed to flooding in case of damage or destruction of a storm embankment;
5) areas exposed to flooding in case of damage or destruction of dams.

For areas referred to in Article 169, paragraph 2 of the Act, flood risk maps are prepared. Flood risk maps (in accordance with Article 170, paragraph 2) present the potential negative consequences associated with floods, taking into account:

1) estimated number of inhabitants likely to be affected by the flood;
2) types of economic activities;
3) installations which may, in the event of flooding, cause significant pollution of individual natural elements or the environment as a whole;
4) the occurrence of:
    a) water abstractions, water abstraction protection zones or protected areas of inland water reservoirs,
    b) bathing waters,
    c) Natura 2000 areas, national parks and nature reserves;
5) potential sources of water pollution.

The detailed scope and requirements for the development of flood hazard maps and flood risk maps, as well as the scale of the maps, are laid down in the Regulation. A detailed description of maps is also presented later in this report.

Article 171, paragraph 1 and Article 240, paragraph 2, point 6 of the Water Law Act provides that draft flood hazard maps and flood risk maps are prepared by the Polish Waters in consultation with relevant voivodes. Whereas, under Article 171, paragraph 2, draft flood hazard maps and flood risk maps from the sea water, including internal sea waters, are prepared by directors of maritime offices. Draft flood hazard maps and flood risk maps from the sea water, including internal sea waters, are an integral part of the draft flood hazard maps and flood risk maps.

The minister in charge of water management approves the flood hazard maps and flood risk maps, passes them on in electronic form to the administration authorities indicated in Article 171, paragraph 4 of the Water Law Act and makes them public by posting them on the website of the Public Information Bulletin.

Prior to creating the flood hazard maps and flood risk maps for river basins, parts of which are located within the territory of other countries, actions are taken to exchange information with the competent authorities of those countries.

3 FLOOD TYPES

3.1 FLOOD CLASSIFICATION

According to the classification adopted for the implementation of the Flood Directive Reporting Guidance in the European Union, 2019, floods are classified according to their source (origin), their mechanism of origin and their characteristics (features such as the severity of the phenomenon).

Division of the flood by source:

- Fluvial flood [A11];
- Pluvial flood [A12];
- Groundwater flood [A13];
- Sea water flood [A14]
- Artificial water-bearing infrastructure flood [A15].

Division of floods due to the mechanism of their origin:

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

Division of floods by characteristics:

- Flash flood, caused by heavy precipitation on a relatively small area [A31];
- Snow melt [A32];
- Other rapid onset flood [A33];
- Medium onset flood [A34];
- Slow onset flood [A35];
- Debris flood [A36];
- High velocity flow [A37];
- Deep flood [A38].

The above classification is presented in Table 1, with reference to the classification of flood types used in Poland, which was in force prior to the implementation of the Floods Directive.

Table 1. Flood classification

TYPES OF FLOODS BY SOURCE		TYPES OF FLOODS IN PL BEFORE DP	[EU] FLOOD CODE		
Name	**Description**	**Name**	**Source**	**Mech.**	**Char.**
Fluvial flood [FLUVIAL]	Flood associated with exceedance of river waters, streams, mountain creeks, canals, lakes, including flooding resulting from snow melting.	Precipitation flood[1] (from river)	A11	A21	-
		Flash flood[2]	A11	A21	A31
		Melt flood[3]	A11	A21	A32
		Winter flood[4]	A11	A24	-
		Water overflowing the embankment[6]	A11	A22	-
		Destruction or damage of an embankment[6]	A11	A23	-
Pluvial flood [PLUVIAL]	Flood related to the flooding of the terrain with water coming directly from precipitation or snow melting may include urban storm floods or excess water in non-urban areas.	Flash flood – not related to a river	A12	A21	A31
		Urban flooding – a flash flood in the city	A12	A21	A31
Groundwater flood	Flood associated with exceedance due to rising water level above ground level; it may include rising groundwater and underground water due to high surface water levels.	Inundation from groundwater	A13	A21	-
Flood from the sea water [SEA WATER]	Flood related to the flooding of the site by sea water, including estuarial river sections and coastal lakes	Storm flooding[5]	A14	A21	-
		Destruction or damage of the embankment / storm embankment[6]	A14	A23	-
Flood from hydrotechnical structures [ARTIFICIAL WATER-BEARING INFRASTRUCTURE FLOOD]	Flood related to the flooding of land by water from hydrotechnical infrastructure or as a result of failure of such infrastructure	Destruction or damage of the damming structure[7]	A15	A23	-

[1] Pluvial floods (summer):
- heavy – local floods from mountain streams and small lowland watercourses (catchment area A < 50 km²) caused by local storms and heavy rains;
- frontal – wide range floods in mountainous, foothill and lowland areas;
- widespread – similar in its genesis to that of the frontal ones; the reason for them is precipitation with productivity influenced by orography (lay of the land); it occurs in mountainous areas.

[2] Flash flood – a special case of pluvial (heavy) flooding, with a local range, very fast course and short duration (usually less than 6 hours), caused by high capacity rainfall, often of storm character; it can happen in any place, most often in mountainous areas; favourable conditions for their occurrence are also found in urban areas (*urban flooding*); it can also be caused by failure of hydrotechnical equipment.

[3] Melt flood – caused by rapid melting of the snow cover.

[4] Winter floods:
- blocking – occurring during the ice float, as a result of the accumulation of orifices, most often in the narrowing of channels, river bends and bridge sections;
- frazil – caused by the rapid and abundant formation of frazil ice and bottom ice, which clogs the cross-section of the river and causes the water level to exceed.

[5] Storm flood – caused by storm winds blowing towards the coastline; these winds impede the flow of rivers entering the sea, causing the rise of water levels in riverbeds and sea floodplains, as well as the intrusion of sea water into the river mouth.

[6] Flood protection structures – artificial water reservoirs with a flood reserve, dry flood protection reservoirs, flood polders, flood embankments with their functional objects, relief canals, steering constructions in estuaries to the sea, pumping stations to prevent floods or flooding, flood and storm gates, breakwaters and coastal protection structures.

[7] Damming structures – structures that allow constant or periodic exceedance of surface water above an adjacent area or natural water level.

3.2 TYPES OF FLOODS FOR WHICH FHM AND FRM ARE PREPARED

As required by the Floods Directive, flood hazard maps and flood risk maps are prepared for the areas and types of floods indicated in the preliminary flood risk assessment. As a result of the review and update of the PFRA in 2018, the following significant flood types in Poland were identified (by source):

1) fluvial flood – in two scenarios:
   - natural flood;
   - destruction of flood embankments;
2) flood from the sea – in two scenarios:
   - natural flood;
   - destruction of flood or storm embankments;
3) Flood from artificial water bearing infrastructure – related to flooding of the area in the event of damage or destruction of damming structures.

For river and sea water floods, FHM and FRM were already developed in the first planning cycle. In the second planning cycle, the review and update of the preliminary flood risk assessment additionally identified areas exposed to flooding as a result of damage or destruction of damming structures.

3.3 DESCRIPTION OF FLOOD SCENARIOS

3.3.1 FHM AND FRM FOR FLUVIAL FLOODS

In the second planning cycle, fluvial flood hazard maps and flood risk maps were developed for the following flood scenarios:

1) Areas with a low probability of flooding of 0.2% (once every 500 years);
2) Areas with a medium probability of flooding of 1% (once every 100 years);
3) Areas with a high probability of flooding of 10% (once every 10 years);
4) Areas exposed to flooding for embankment damage or destruction (designated for flow with 1% probability of occurrence) – scenario of total destruction of the embankment.

In the first planning cycle, a scenario of embankment destruction in the selected section was developed. However, it did not allow to present comprehensively the hazard associated with embankment failure, as it is not possible to analyse all potential embankment damage sites. Therefore, in the second cycle, only the scenario of total destruction of the embankment was taken into account, which makes it possible to determine the flood hazard in any location.

A scenario of total destruction of embankments is set up for all embanked rivers identified in the preliminary flood risk assessment.

The assumed probability values were based on experience from the flood protection studies previously developed by directors of regional water management authorities and were finally agreed at the stage of amending the Water Law Act, transposing the provisions of the Floods Directive.

3.3.2 FHM AND FRM FOR SEA WATER FLOODS

Flood hazard maps and flood risk maps from the sea water, including internal marine waters, were developed for the following flood scenarios:

1) Areas with a low probability of flooding of 0.2% (once every 500 years);
2) Areas with a medium probability of flooding of 1% (once every 100 years);
3) Areas exposed to flooding in case of destruction or damage of the flood or storm embankment (determined for water level with 1% probability of occurrence) – scenario of total destruction of the flood or storm embankment.

Pursuant to Article 169, paragraph 4 of the Water Law Act, the scenario of high probability of flooding (10%) is not performed for flood hazard maps from the sea water, due to the adequate protection provided in the coastal area. Coastal protection is implemented on the basis of:

- Act on the establishment of a multiannual "Programme for the protection of the sea coast";
- Act on Maritime Areas of the Republic of Poland and maritime administration – hereinafter referred to as the Act on maritime areas;
- Act on the protection of shipping and maritime ports.

The Act on Maritime Areas introduces the concept of a coastal zone, which includes a technical zone, which is a zone of direct interaction between sea and land. The technical belt is an area designed to maintain the coast in a condition consistent with safety requirements and environmental protection. As a result, along Polish coasts, during storm floods with a 10% probability of occurrence, only beaches and sometimes the foot of dunes are flooded, and along the inner sea coasts, only those parts of the coast that should be flooded for ecological reasons. Over the entire length of the coastline (including in sea harbours and marinas), the coast condition fully protects against flooding from the sea water with a 5% probability of occurrence.

3.3.3 FHM AND FRM FOR FLOODING FROM DAMMING STRUCTURES

In accordance with Article 169, paragraph 2, point 3, letter c of the Water Law Act, flood hazard maps present: areas including areas exposed to flooding for damming structure damage or destruction.

There may be many probable disaster scenarios for damming structures. Taking into account the objectives for which FHM and FRM are developed (flood protection, public information about potential flood risks, emergency management and evacuation planning), it is assumed that the flood hazard maps will present a scenario causing the maximum possible flooding of areas below the reservoir. This scenario boils down to the destruction of the dam over a certain section allowing the reservoir to be completely emptied. The most probable conditions for the occurrence of the catastrophe are the work of the structure during an extreme flooding.

Flows with a 1% probability of occurrence and higher (medium and high probability flood scenarios), taking into account the method of disposition of water discharges from the reservoir described in the water management manuals, do not cause a sudden increase in the reservoir's filling that could lead to its disaster.

Destruction or damage to the damming structure is therefore part of the scenario of extreme events referred to in Article 169, section 2, point 1 of the Water Law Act and Article 6, section 3, point a) of the Floods Directive.

When developing the variants, a hypothetical wave was taken into account, which is likely to enable the conditions determining the start of the catastrophe process to occur, for the adopted assumptions regarding the failure of release valves and filling of the initial reservoir. Hypothetical floods were assumed with a maximum flow equal to the authoritative flow or control flow with a probability of exceedance of 0.02% to 0.5%, depending on the class of structure (according to the Regulation of the Minister of Environment of 2007 on technical conditions to be met by hydrotechnical structures and their location). For some reservoirs (Besko, Chańcza, Świnna Poręba), hypothetical floods with a probability of exceedance of 0.1% or 0.01% were also assumed. In addition, failures of the release equipment were assumed, resulting in a reduction in the discharge of water from the reservoir, with only those facilities for which the assumed inflow did not result in water overflowing the dam crest being assumed for the reservoirs in Part 2 of the works.

A detailed description of the selection and development of alternatives was described in the report on the implementation of FHM and FRM for areas exposed to flooding in the event of damage or destruction of damming structures (2021), constituting Annex 10.

A summary of all flood scenarios for which FHM and FRM have been developed in the second planning cycle for the different types of floods is presented in Table 2.

Table 2. Flood scenarios according to the type of flood.

FLOOD TYPE DUE TO:		**FLOOD SCENARIOS**
SOURCE	**MECHANISM**	
Fluvial flood	Natural flood	Areas with a low probability of flooding of 0.2% (once every 500 years)
		Areas with a medium probability of flooding of 1% (once every 100 years)
		Areas with a high probability of flooding of 10% (once every 10 years)
	Destruction of flood embankments	Areas exposed to flooding in the event of total destruction of the embankment – determined for a flow with a 1% probability of occurrence
Flood from the sea water	Natural flood	Areas with a low probability of flooding of 0.2% (once every 500 years)
		Areas with a medium probability of flooding of 1% (once every 100 years)
	Destruction of flood or storm embankments	Areas exposed to flooding in the event of total destruction of the flood or storm embankment – determined for a water level with a 1% probability of occurrence
Flood from artificial water bearing infrastructure	Destruction or damage to damming structures	Areas exposed to flooding for damming structure damage or destruction – extreme event scenario; determined for flows with different probabilities of occurrence, depending on the class of structure

4 SCOPE OF DEVELOPMENT OF FHM AND FRM IN THE SECOND PLANNING CYCLE

All the FHM and FRM developed in the first planning cycle (2010-2015) were reviewed in the second planning cycle (2016-2021).

Moreover, as a result of the review and update of the preliminary flood risk assessment (2018), additional areas exposed to the flood risk were identified, for which new FHM and FRM should be developed.

Due to the large scope of works, the new FHM and FRM were updated and created in several phases, distributed over time. The following chapters describe the scope of works in particular periods.

4.1 SCOPE OF THE FHM AND FRM REVIEW AND UPDATE FOR FLUVIAL FLOODS

As a result of the review of the maps for fluvial floods developed in the first planning cycle, about 7,000 kilometres of rivers were indicated for about 14,500 km kilometres of rivers for updating the flood hazard maps and all flood risk maps.

Detailed results of the review were included in the Report on the implementation of the review of the FHM and the FRM, which constitutes Annex 5.

4.1.1 SCOPE OF THE FHM AND FRM UPDATE (2018)

Pursuant to Article 171, section 9 of the Water Law Act, which provides that the maps may be reviewed and, if necessary, updated more frequently than every six years, some of the flood hazard maps and flood risk maps created in the first planning cycle (about 0.2 thousand river kilometres) were indicated for updating in 2018.

On 19 September, 2018, the updated flood hazard maps and flood risk maps were made public in the Public Information Bulletin of the Ministry of Maritime Economy and Inland Navigation.

The update concerned selected sections of rivers for which an urgent need to update the maps was identified during the consultation phase of the Flood Risk Management Plans (FRMPs) in 2015, due to, inter alia, implemented investments or significant changes in the lay of the land.

The rivers or river sections for which new FHM and FRM were updated in 2018 are shown in Figure 1.

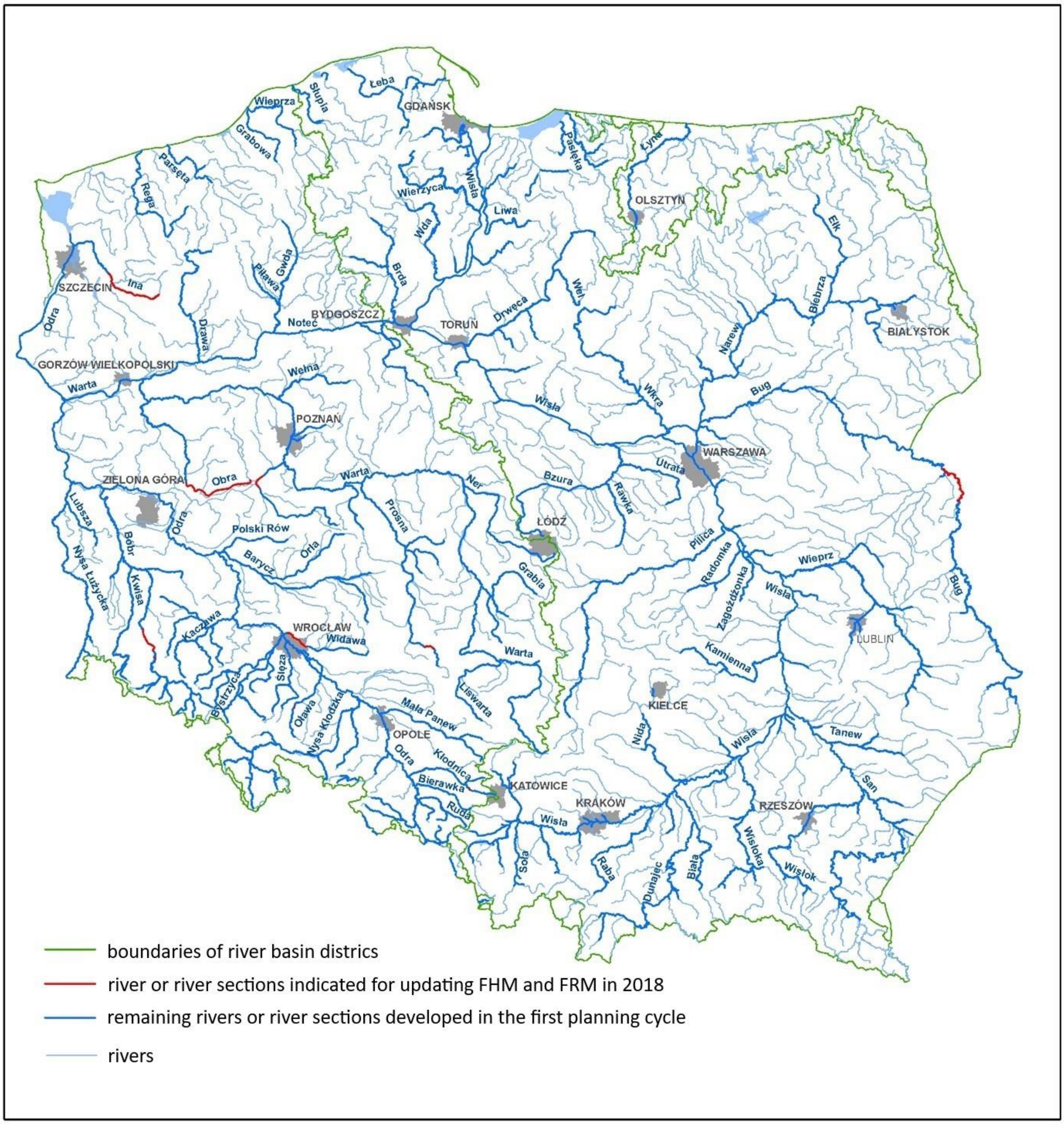

Figure 1. The rivers or river sections for which new FHM and FRM were updated in 2018.

4.1.2 SCOPE OF THE FHM AND FRM UPDATE (2020)

Until 2020, flood hazard maps were updated for about 7,000 river kilometres and all flood risk maps, i.e. for about 14,500 km of rivers.

On 22 October, 2020, the updated flood hazard maps and flood risk maps were made public in the Public Information Bulletin of the Ministry of Climate and Environment.

As part of the Project, river chainage was verified on the basis of the geometry provided in the Map of the Hydrographic Division of Poland at a scale of 1:10,000. Accordingly, the number of kilometres given in the report on the development of FHM and FRM in the first planning cycle (2015) and in the report on the review of FHM and FRM may differ from the number of kilometres given in this report. As a rule, this does not change the spatial scope of the FHM and FRM for a given river, but only changes the scope of the chainage reference points by which a given section is described.

Table 3 shows the number of areas of potential significant flood risk (APSFR) and the number of river kilometres for which the FHM and FRM were updated per river basin district.

Table 3. Number of APSFR and river kilometres for which FHM and FRM have been updated.

Scope of works	**FRM update**		**FHM**	
Scenarios	**10; 1; 0.2%**	**10; 1; 0.2%**	**10; 1; 0.2%**	**10; 1; 0.2%**
River basin area	**Number of km**	**Number of APSFR**	**Number of km**	**Number of APSFR**
Oder	6,775.2	94	2,737.3	54
Vistula	7,616.5	165	4,345.9	133
Pregola	165.6	1	0.0	0
Total	**14,557.3**	**260**	**7,083.2**	**187**

A detailed tabular overview of the rivers and river sections for which FHM and FRM for fluvial floods were developed in the natural flood scenarios (10; 1; 0.2%), with information on the scope of works in the second planning cycle, is presented in Annex 6.1 of the Report.

A detailed tabular overview of the rivers and river sections for which FHM and FRM for fluvial floods were developed in the scenario of total destruction of embankments, with information on the scope of works in the in the second planning cycle, is presented in Annex 6.2 of the Report.

The rivers or river sections for which new FHM and FRM were updated in 2020 are shown in Figure 2.

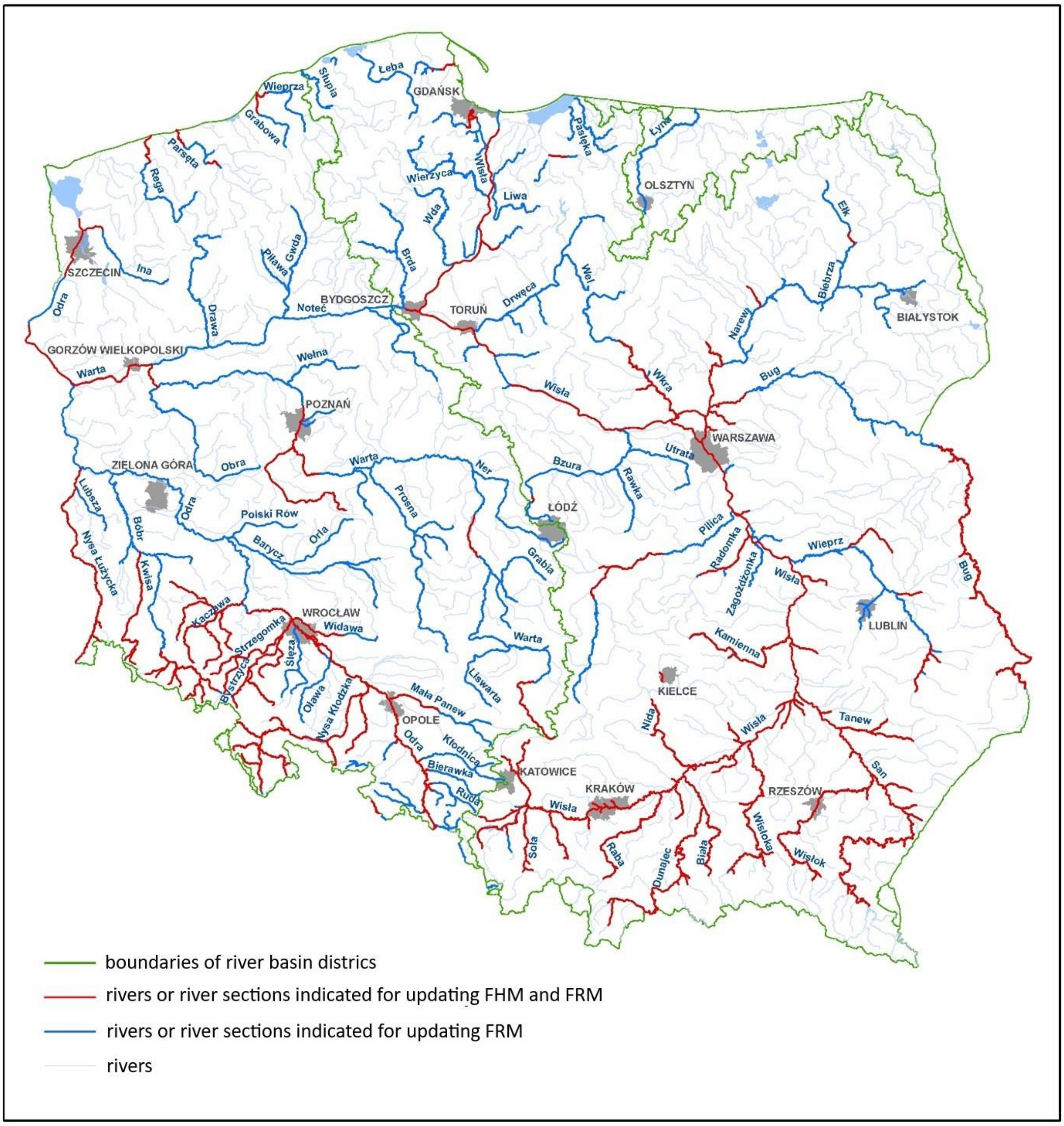

Figure 2. The rivers or river sections for which new FHM and FRM were updated in 2020.

4.1.3 SCOPE OF THE FHM AND FRM UPDATE (2022)

In 2022, for selected river sections, the existing flood hazard maps and flood risk maps, published in 2020, were updated. The legal basis of this activity is Article 171, section 9 of the Water Law Act, which provides that the flood hazard maps and flood risk maps may be reviewed and, if necessary, updated more frequently than every six years, and if such an update is made, it must be repeated in accordance with the principle expressed in paragraph 8, i.e. within the deadlines resulting from the Floods Directive.

The flood hazard maps and flood risk maps published in 2020 considered the investments completed until 2019. In some cases, it was necessary to update the flood risk areas due to the completion of flood protection investments at a later date. In addition, as a result of using the existing maps, comments were made by internal users (PGW WP units) as well as external users.

Accordingly, the FHM and FRM were reviewed as a result of the comments made. In justified cases, selected river sections were identified for updating the maps.

A detailed list of the river sections for which the FHM and FRM were updated in 2022, as a result of the review, together with a description of the reasons for the update, is included in Annex 6.1a.

The river sections for which FHM and FRM were updated in 2022 are shown in Figure 3.

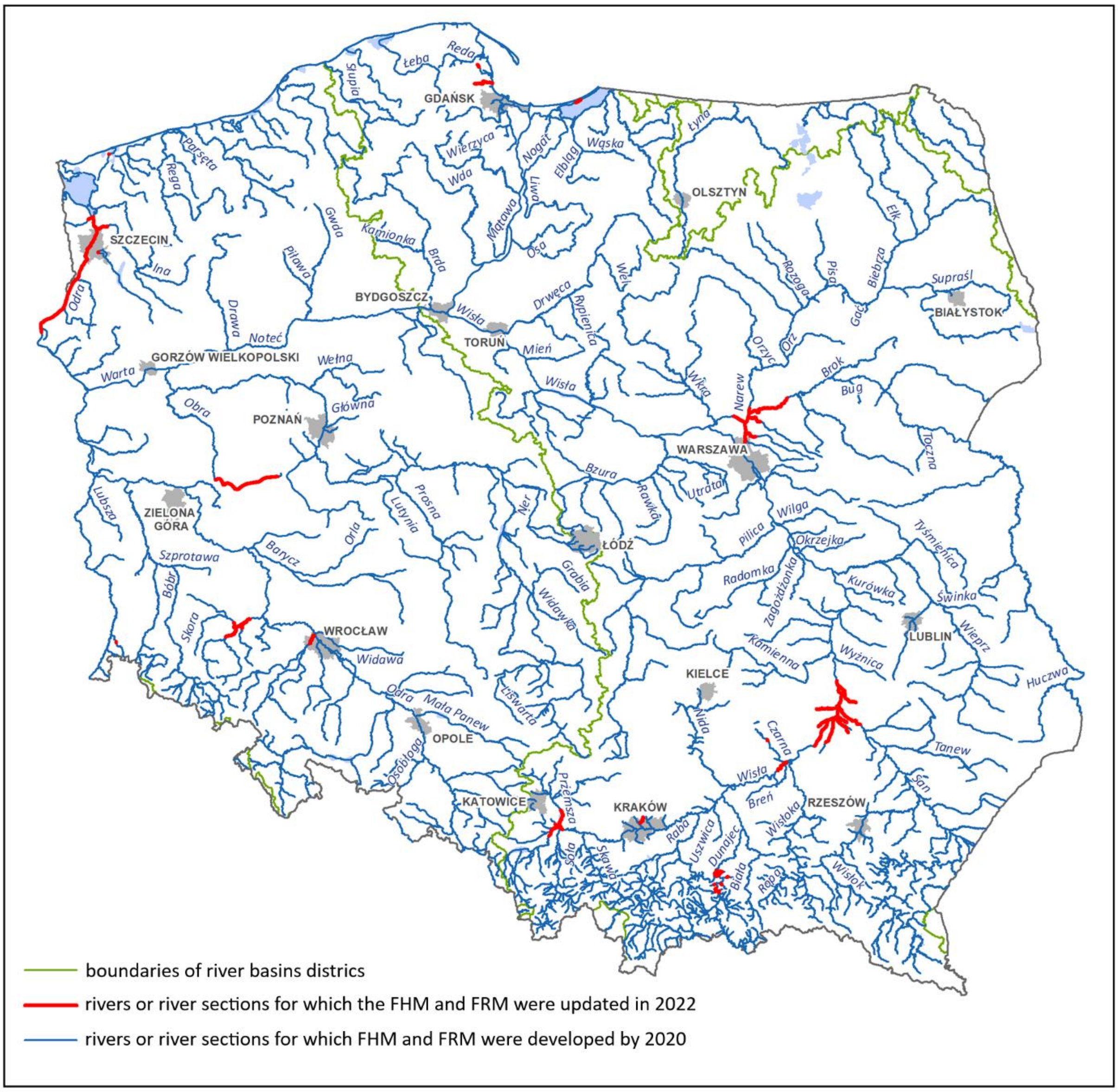

Figure 3. The rivers or river sections for which new FHM and FRM were updated in 2022.

4.2 SCOPE OF DEVELOPMENT OF THE NEW FHM AND FRM FOR FLUVIAL FLOODS

As a result of the review and update of the preliminary flood risk assessment (2018), additional areas of potential significant flood risk were identified for which new FHM and FRM should be developed. For fluvial floods, about 14.8 thousand kilometres of rivers were indicated for developing the new FHM and FRM.

4.2.1 SCOPE OF DEVELOPMENT OF THE NEW FHM AND FRM (2020)

New FHM and FRM identified as a result of the review and update of the preliminary flood risk assessment were developed until 2020 for approximately 13,800 km of rivers of 14,800 km of rivers.

On 22 October 2020, the maps were made public in the Public Information Bulletin of the Ministry of Climate and Environment.

Table 4 shows the number of areas of potential significant flood hazards and the number of river kilometres for which new FHM and FRM were developed in 2020.

Table 4. Number of APSFR and river kilometres for which new FHM and FRM were developed in 2020.

Scope of works	**New FHM and FRM (2020)**	
Scenarios	**10; 1; 0.2%**	**10; 1; 0.2%**
River basin area	**Number of km**	**Number of APSFR**
Oder	2,772.3	109
Vistula	10,480.9	535
Pregola	279.6	6
Neman	209.7	2
Elbe	13.5	1
Total	**13,756.0**	**653**

A detailed tabular overview of the rivers and river sections for which FHM and FRM for fluvial floods were developed in the natural flood scenarios (10; 1; 0.2%), with information on the scope of works in the second planning cycle, is presented in Annex 6.1 of the Report.

A detailed tabular overview of the rivers and river sections for which FHM and FRM for fluvial floods were developed in the scenario of total destruction of embankments with information on the scope of works in the in the second planning cycle, is presented in Annex 6.2 of the Report.

The rivers or river sections for which FHM and FRM were developed in 2020 are shown in Figure 4.

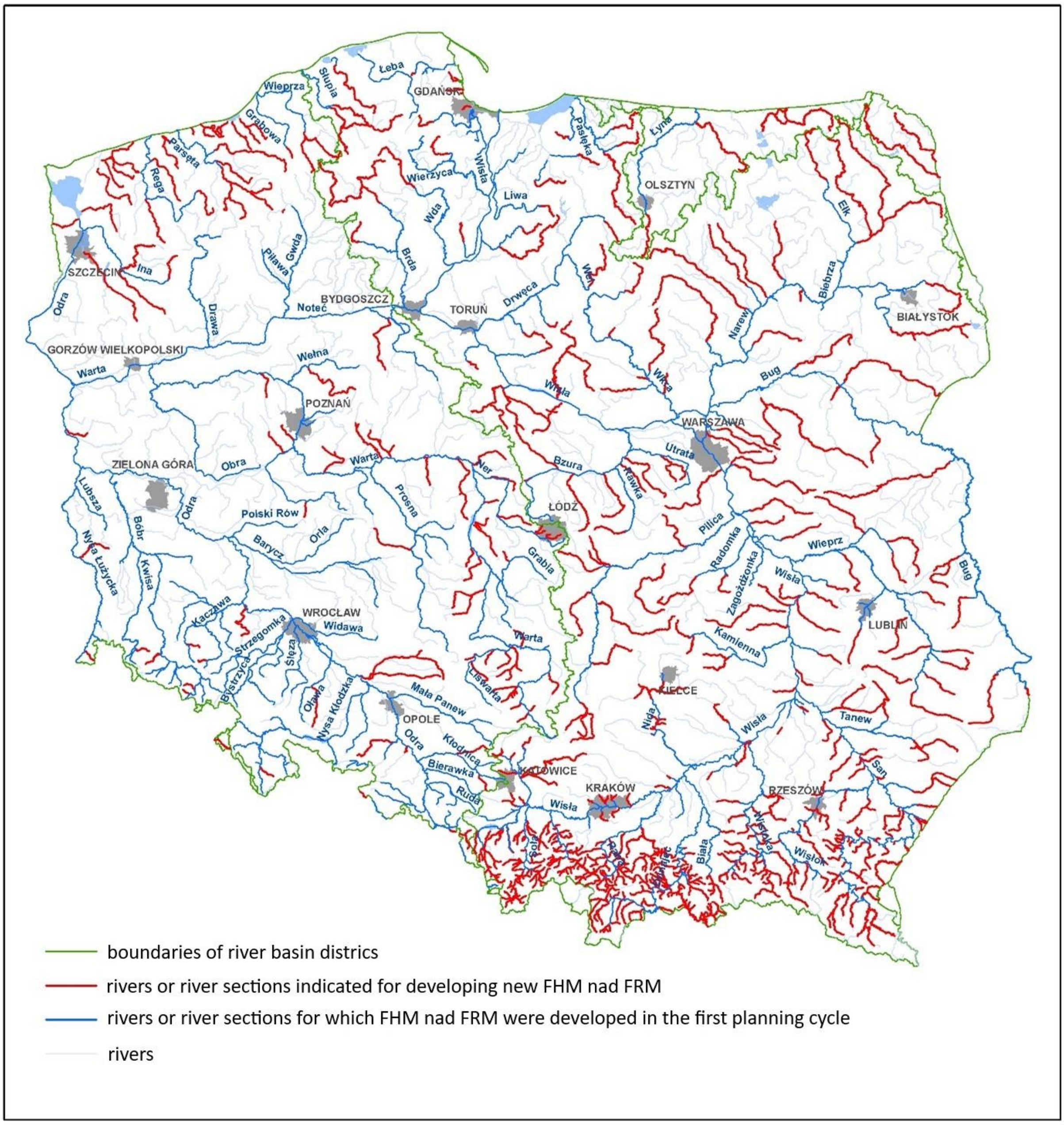

Figure 4. The rivers or river sections for which new FHM and FRM were developed in 2020.

4.2.2 SCOPE OF DEVELOPMENT OF THE NEW FHM AND FRM (2022)

On 7 September, 2022, FHM and FRM were published for the remaining approximately 1,000 km of rivers.

Table 5 presents the number of areas of potential significant flood hazards and the number of river kilometres for which new FHM and FRM were developed in 2022.

Table 5. Number of APSFR and river kilometres for which new FHM and FRM were developed in 2022.

Scope of works	New FHM and FRM (2022)	
Scenarios	**10; 1; 0.2%**	**10; 1; 0.2%**
River basin area	**Number of km**	**Number of APSFR**
Oder	772.0	38
Vistula	218.6	12
Pregola	10.9	2
Neman	0.0	0
Danube	26.2	1
Elbe	0.0	0
Total	**1,027.7**	**53**

A detailed tabular overview of the rivers and river sections for which FHM and FRM for fluvial floods were developed in the natural flood scenarios (10; 1; 0.2%), with information on the scope of works in the second planning cycle, is presented in Annex 6.1 of the Report.

The rivers or river sections for which FHM and FRM were developed in 2022 are shown in Figure 5.

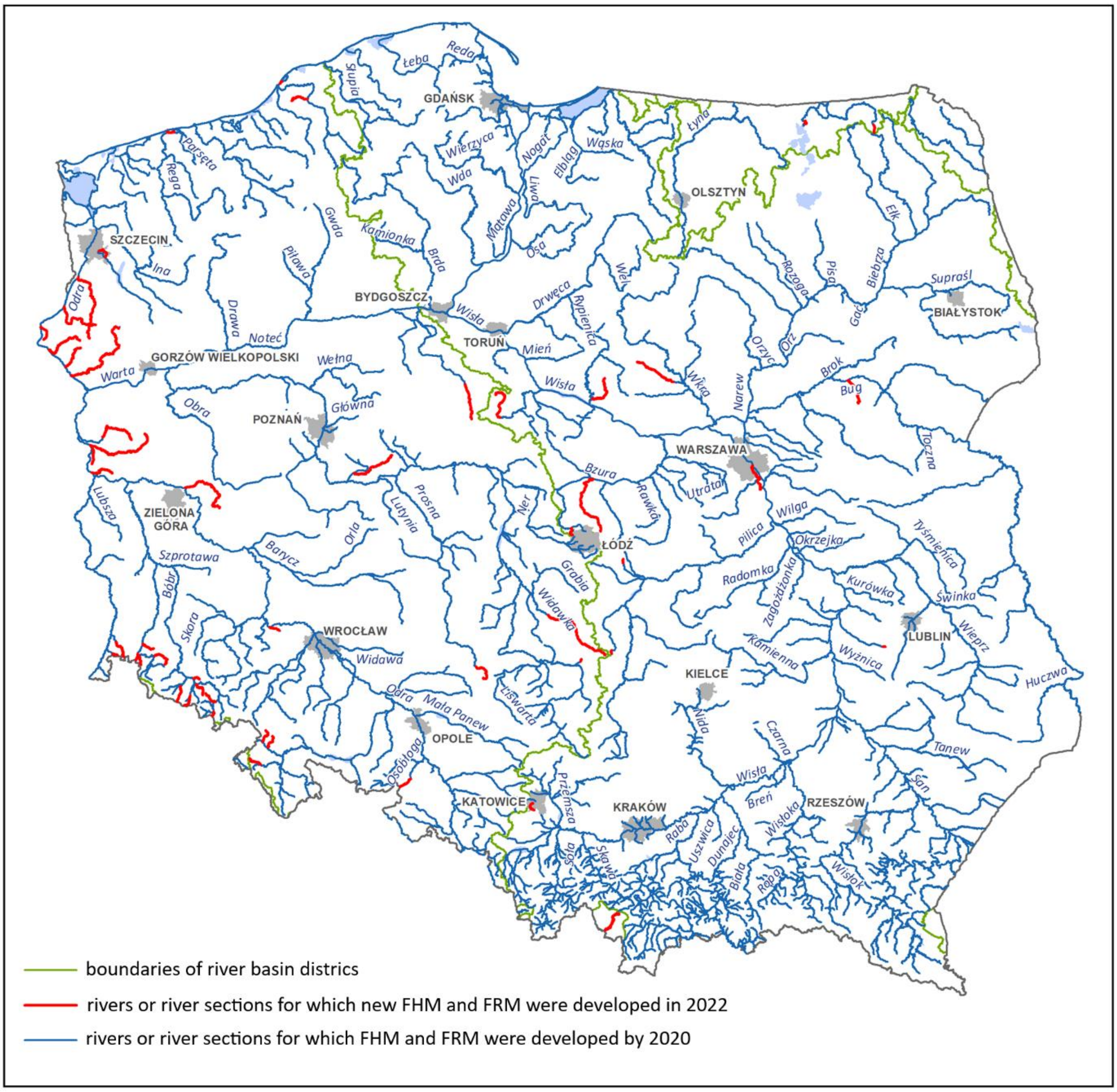

Figure 5. The rivers or river sections for which new FHM and FRM were developed in 2022.

4.3 SCOPE OF THE FHM AND FRM REVIEW AND UPDATE FOR SEA WATER FLOODS

The review and update of FHM and FRM from the sea water, including internal sea waters, hereinafter referred to as the review and update of FHM and FRM from the sea water, was commissioned by Maritime Offices in Gdynia, Słupsk and Szczecin.

A sea-side review and update of the FHM and FRM was undertaken for the entire territorial area of operations of the directors of the Maritime Offices. The coverage (Figure 6) of the study is consistent with the results of the review and update of the preliminary flood risk assessment for the sea water in the second planning cycle performed by the Ministry of Maritime Affairs and Inland Navigation in 2018.

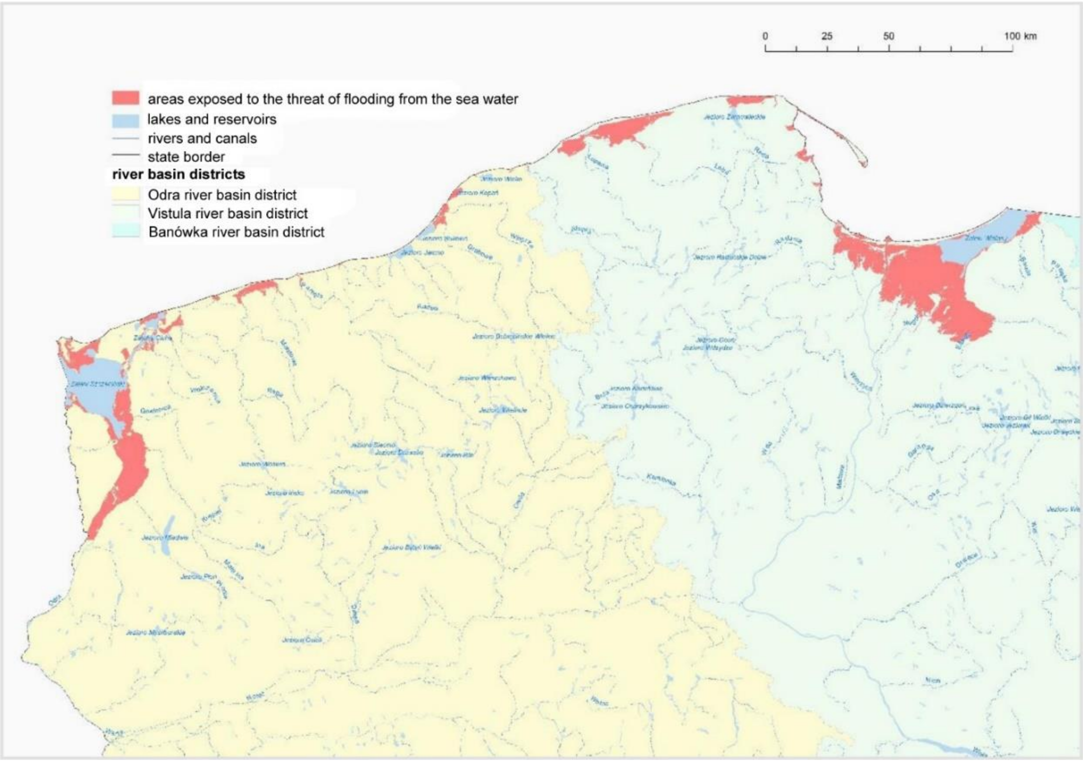

Figure 6. APSFR for the sea water flood.

The updated and new FHM and FRM from the sea water were published in 2020 for:

- 495 km of the Baltic Sea coastline (coastal area);
- 269 km of the coastline of two large basins: Szczecin Lagoon and Vistula Lagoon;
- 453 km of estuarial sections of the rivers flowing into the sea and internal sea waters were, in order to determine the threat from storm flood in their catchment areas.

Table 6 presents the length of the coastal and estuarial sections of the rivers that flow into the sea and internal sea waters for which the update was carried out and new FHM and FRM were developed, divided into river basin district.

A detailed tabular overview of the coastal and estuarial sections of the coastal rivers for which the update was undertaken and the new FHM and FRM are presented in Annex 6.3 of the Report.

Reports on the implementation of the FHM and FRM for sea water flood are provided in Annexes 7 to 9.

Table 6. Number of APSFR and kilometres of rivers or coastal areas for which FHM and FRM have been developed.

Scope of works		Update of FHM and FRM		New FHM and FRM	
Scenarios		**1%; 0.2%**	**1%; 0.2%**	**1%; 0.2%**	**1%; 0.2%**
River basin area Coastal / river area		**Number of km**	**Number of APSFR**	**Number of km**	**Number of APSFR**
Oder	Coastal area	98.9	9	95.2	11
	Estuarial river sections	160.4	18	40.5	13
	Szczecin Lagoon	167.0	1	0.0	-
	Total	426.3	27	135.7	24
Vistula	Coastal area	202.2	15	98.8	6
	Estuarial river sections	251.6	30	0.6	4
	Vistula Lagoon	102.0	1	0.0	-
	Total	555.8	46	99.4	10
Total		**982.1**	**73**	**235.1**	**34**

Published in 2020 valid sea-side flood hazard maps and flood risk maps for two areas were updated in 2022.

The list of the sea-side FHM and FRM updated in 2022 together with a description of the reasons for the update, is included in Annex 6.1a.

4.4 SCOPE OF FHM AND FRM FOR FLOODING FROM DAMMING STRUCTURES

The review and update of the PFRA in 2018 also identified as significant areas exposed to flood from damming structures. A total of 26 damming structures were identified, for which flood hazard maps and flood risk maps should be developed in the second planning cycle.

In 2020, FHM and FRM were developed for 7 damming structures (p. 1): Besko, Chańcza, Świnna Poręba, Przeczyce, Słup, Mietków and Dobromierz, for which the results of hydraulic modelling in the form of maximum water level ordinates and water depths were available, developed in earlier projects carried out by RZGW in Kraków and IMGW-PIB.

In 2022, FHM and FRM were developed for the remaining 19 damming structures (p. 2): Bukówka, Czorsztyn-Niedzica, Dębe, Dobczyce, Goczałkowice, Jeziorsko, Koronowo, Mylof, Nysa, Otmuchów, Pakość, Poraj, Porąbka, Rożnów, Solina, Sulejów, Tresna, Turawa, Włocławek.

A report on the implementation of the FHM and FRM for flood-prone areas for damming structures' damage or destruction (2021) is contained in Annex 10.

The detailed scope of FHM and FRM for all 26 damming structures is presented in Annex 6.4 of the Report.

The of FHM and FRM for damming structures is presented in Figure 7.

Figure 7. The scope of FHM and FRM sheets for flood for damming structures.

4.5 SUMMARY

Flood hazard maps and flood risk maps were developed in the first planning cycle for floods from the river and for floods from the sea water.

In the second planning cycle, FHM and FRM cover three types of floods by source:

1) fluvial flooding – in two scenarios: natural flooding (10%, 1%; 0.2%) and destruction of flood embankments (WZ);
2) flood from the sea – in two scenarios: natural flooding (1%; 0.2%) and destruction of flood or storm embankments (WZ);
3) flood associated with flooding in case of damage or destruction of damming structures (BP).

For floods from the rivers, flood hazard maps were updated for about 7,000 river kilometres and all flood risk maps for about 14,500 km, and new FHM and FRM for about 14,800 km of rivers were made.

For the sea water floods, the development of updates and new FRM and FRM covered about 1.2 thousand kilometres of coastal areas and estuarial river sections.

For the floods from damming structures, FHM and FRM were made for 26 objects.

Table 7 presents the scope of the FHM and FRM by planning cycle, river basin area and type of flood (due to the source and mechanism of flood).

Table 7. Number of APSFR and kilometres of rivers or coastal areas for which FHM and FRM have been developed by river basin areas and type of flood.

TYPE OF FLOODING	FLUVIAL FLOODS		FLOODS FROM THE SEA WATER		FLOODS FROM DAMMING STRUCTURES	TOTAL
Scenarios	10%; 1%; 0.2%		1%; 0.2%			
River basin area	Number of km	Number of APSFR	Number of km	Number of APSFR	Number of APSFR	Number of APSFR
1st cycle						
Oder	6,775.2	94	426.3	27	-	115
Vistula	7,616.5	165	555.8	46	-	199
Pregola	165.6	1	-	-	-	1
Total 1st cycle	**14,557.3**	**260**	**982.1**	**73**	**-**	**315**
2nd cycle						
Oder	3,544.3	146	135.7	24	10	174
Vistula	10,699.5	543	99.4	10	16	569
Pregola	290.5	8	-	-	-	8
Neman	209.7	2	-	-	-	2
Danube	26.2	1				1
Elbe	13.5	1	-	-	-	1
Total 2nd cycle	**14,783.7**	**701**	**235.1**	**34**	**26**	**755**
1st and 2nd cycle						
Oder	**10,319.5**	**225**	**562.0**	**47**	**10**	**267**
Vistula	**18,316.0**	**575**	**655.2**	**53**	**16**	**630**
Pregola	**456.1**	**8**	**-**	**-**	**-**	**8**
Neman	**209.7**	**2**	**-**	**-**	**-**	**2**
Danube	**26.2**	**1**	**-**	**-**	**-**	**1**
Elbe	**13.5**	**1**	**-**	**-**	**-**	**1**
TOTAL	**29,341.0**	**812**	**1,217.2**	**100**	**26**	**909**

5 FORM OF FHM AND FRM

The FHM and FRM have been developed in electronic form, including spatial database and cartographic versions, in accordance with the Regulation.

5.1 SPATIAL DATABASES

The spatial database of FHM and FRM has been developed in *. shp format, in the rectangular PL-1992 coordinate system.

The FHM and FRM database is divided by types of floods and constitutes 3 separate databases for each:

1) fluvial floods;
2) floods from the sea water;
3) floods from damming structures;

divided into river basin areas.

The catalogue and attribute structure of the databases is consistent, and considers the specificity of the flood type.

The FHM and FRM database includes:

REFERENCE LAYERS:

1) natural watercourses and canals;
2) other watercourses;
3) surface water;
4) roads;
5) railroads;
6) voivodeship;
7) poviat;
8) municipality;
9) 1:10,000 scale sheet division of maps for the PL-1992 system.

For sea water maps, additionally:

1) boundary of a technical belt;
2) boundary of a safety belt;
3) harbours and marinas.

LAYERS OF FLOOD HAZARD MAPS:

1) flood hazard area for rivers – a separate layer for each scenario: 10%, 1%, 0.2% and the scenario of total destruction of flood embankments (WZ);

2) water depth – a separate layer for each scenario: 10%, 1%, 0.2% and WZ;
3) water flow velocity – separate layer for each scenario: 10%, 1%, 0.2%;
4) water flow directions – separate layer for each scenario: 10%, 1%, 0.2%;
5) maximum ordinates of the water level;
6) crest ordinates of flood embankments in cross-sections;
7) places where the water overflows through the flood embankment;
8) place where the embankment was completely destroyed;
9) flood embankments;
10) chainage;
11) maximum flow rate values.

For flood hazard maps for floods from for sea water flood:

1) flood hazard area from the sea water – a separate layer for each scenario: 1%, 0.2% and a scenario of total destruction of flood or storm embankments;
2) water depth – a separate layer for each scenario: 1%, 0.2% and a scenario of total destruction of flood or storm embankments;
3) chainage;
4) coastline chainage;
5) places where water overflows through the flood or stork embankment – a separate layer for each scenario: 1%, 0.2%.
6) boundary of a safety belt;
7) boundary of a technical belt;
8) maximum ordinates of the water level;
9) flood embankments;
10) ordinates of flood or storm embankments.

For flood hazard maps for floods from damming structures:

1) flood hazards area for the scenario of damage or destruction of the damming structure;
2) water depth;
3) maximum ordinates of the water level;
4) crest ordinates of flood embankments in cross-sections;
5) damming structures;
6) places of damage or destruction of the damming structure;
7) flood embankments;

8) chainage.

LAYERS OF FLOOD RISK MAPS:

1) land use with calculated potential flood damages – separate layer for each scenario: 10%, 1%, 0.2% and WZ;
2) land use – separate layer for each scenario: 10%, 1%, 0.2% and WZ;
3) buildings;
4) industrial plants;
5) water abstractions;
6) water abstraction protection zones;
7) bathing waters;
8) forms of nature conservation;
9) culturally valuable areas;
10) culturally valuable objects;
11) zoos;
12) cemeteries (potential pollution sources);
13) landfill sites (potential pollution sources);
14) wastewater treatment plants and wastewater pumping stations (potential pollution sources);
15) localities.

For flood risk maps for floods from sea water:

1) land use with calculated potential flood damages from the sea water – separate layer for each scenario: 1%, 0.2% and a scenario of total destruction of flood or storm embankments;
2) boundaries of the safety and technical belt as a reference;

For flood risk maps for floods from damming structures:

1) land use with calculated potential flood damages for the scenario or destruction of the damming structure.

A detailed description of the attribute structure of the FHM and FRM databases is included in the methodologies for developing FHM and FRM in the second planning cycle for the different types of floods (Annexes 1-3) and includes the following elements: layer names, layer types, layer description, data source and attributes (field name, field type, description, attribute source).

Metadata and indexes in *. shp format have been prepared for the FHM and FRM database, including information on the scope of the data, its updates and the date and version of the study.

5.2 CARTOGRAPHIC VERSIONS

The cartographic versions of FHM and FRM have been developed in the form of raster files, divided into sheet frames corresponding to sheets of topographic maps at a scale of 1:10,000, in a rectangular PL-1992 flat coordinate system.

Cartographic versions were prepared in the following formats: pdf and geotiff. Files in the pdf format present a full map composition containing the map content and extra-block elements (i.e. title, legend, scale, etc.). Files in geotiff format contain only the content of the map (without extra-blocks) with associated georeferenced information (information on location in space).

The base for FHM and FRM are orthophotos with a field pixel value of no more than 0.5 m.

Flood hazard maps in a cartographic version are prepared in two thematic sets:

1) flood hazard map with water depth;
2) flood hazard map with water flow velocity.

In accordance with the Regulation (§ 5, paragraph 3), flood hazard maps with the water flow velocity are prepared only for cities which are the seat of the voivodeship self-government authorities or a voivode, cities with poviat rights and other cities with more than 100,000 inhabitants, located in areas with the probability of flooding from the river side: 10%, 1%, 0.2% (natural flood scenarios). For other types of floods, i.e. from the sea water, from damming structures, and for the total destruction of the embankment, flood hazard maps with the water flow velocity are not prepared.

Flood risk maps in cartographic version are prepared for all types of floods in two sets of themes:

1) flood risk map – potential adverse consequences for human life and health, as well as the value of potential flood damages;
2) flood risk map – potential adverse consequences for the environment, cultural heritage and economic activity.

In accordance with the Regulation (§ 5, paragraph 2), cartographic versions of the FHM and FRM are prepared separately for each of the flood hazard areas referred to in Article 169, paragraph 2 of the Water Law Act, divided into types of floods and flood scenarios.

All types of cartographic versions of FHM and FRM are listed in Tables 8 and 9.

Table 8. Types of cartographic version of flood hazard maps for particular types of floods

No.	MAP TITLE
FHM FOR FLUVIAL FLOODS	
1	Flood hazard map with water depth Areas with a medium probability of flooding of 1% (once every 100 years)
2	Flood hazard map with water flow velocity Areas with a medium probability of flooding of 1% (once every 100 years)
3	Flood hazard map with water depth Areas with a high probability of flooding of 10% (once every 10 years)
4	Flood hazard map with water flow velocity Areas with a high probability of flooding of 10% (once every 10 years)
5	Flood hazard map with water depth Areas with a low probability of flooding of 0.2% (once every 500 years)
6	Flood hazard map with water flow velocity Areas with a low probability of flooding of 0.2% (once every 500 years)
7	Flood hazard map with water depth Areas exposed to flooding in the event of total destruction of the embankment
FHM FOR SEA WATER FLOOD	
8	Flood hazard map from the sea water, including internal sea waters, with water depth Areas with a medium probability of flooding of 1% (once every 100 years)
9	Flood hazard map from the sea water, including internal sea waters, with water depth Areas with a low probability of flooding of 0.2% (once every 500 years)
10	Flood hazard map from the sea water, including internal sea waters, with water depth Areas exposed to flooding in the event of total destruction of the storm embankment
FHM FOR FLOODS FROM DAMMING STRUCTURES	
11	Flood hazard map with water depth Areas exposed to flooding for damming structure damage or destruction

Table 9. Types of cartographic version of flood hazard maps for particular types of floods

No.	MAP TITLE
FRM FOR FLUVIAL FLOODS	
1	Flood risk map – potential adverse consequences for human life and health, and the value of potential flood damages Areas with a medium probability of flooding of 1% (once every 100 years)
2	Flood risk map – potential adverse consequences for the environment, cultural heritage and economic activities Areas with a medium probability of flooding of 1% (once every 100 years)
3	Flood risk map – potential adverse consequences for human life and health, and the value of potential flood damages Areas with a high probability of flooding of 10% (once every 10 years)
4	Flood risk map – potential adverse consequences for the environment, cultural heritage and economic activity Areas with a high probability of flooding of 10% (once every 10 years)
5	Flood risk map – potential adverse consequences for human life and health, and the value of potential flood damages Areas with a low probability of flooding of 0.2% (once every 500 years)

No.	MAP TITLE
6	Flood risk map – potential adverse consequences for the environment, cultural heritage and economic activities Areas with a low probability of flooding of 0.2% (once every 500 years)
7	Flood risk map – potential adverse consequences for human life and health, and the value of potential flood damages Areas exposed to flooding if the embankment is completely destroyed
8	Flood risk map – potential adverse consequences for the environment, cultural heritage and economic activities Areas subject to flooding in the event of total destruction of the embankment
FRM FOR SEA WATER FLOODS	
9	Maps of flood risks from the sea water, including internal marine waters – potential adverse consequences for human life and health, and values of potential flood damages Areas with a medium probability of flooding of 1% (once every 100 years)
10	Maps of flood risks from the sea water, including internal marine waters – potential adverse consequences on the environment, cultural heritage and economic activity Areas with a medium probability of flooding of 1% (once every 100 years)
11	Maps of flood risks from the sea water, including internal marine waters – potential adverse consequences for human life and health, and values of potential flood damages Areas with a low probability of flooding of 0.2% (once every 500 years)
12	Maps of flood risks from the sea water, including internal marine waters – potential adverse consequences on the environment, cultural heritage and economic activity Areas with a low probability of flooding of 0.2% (once every 500 years)
13	Maps of flood risks from the sea water, including internal marine waters – potential adverse consequences for human life and health, and values of potential flood damages Scenario of total destruction of the storm embankment
14	Maps of flood risks from the sea water, including internal marine waters – potential adverse consequences on the environment, cultural heritage and economic activity Scenario of total destruction of the storm embankment
FRM FOR FLOODS FROM DAMMING STRUCTURES	
15	Flood risk map – potential adverse consequences for human life and health, and the value of potential flood damages Areas exposed to flooding for damming structure damage or destruction
16	Flood risk map – potential adverse consequences for the environment, cultural heritage and economic activities Areas exposed to flooding for damming structure damage or destruction

A detailed description of all types of maps is presented in the FHM and FRM development methodologies in the second planning cycle for each type of floods (Annexes 1-3).

6 FHM AND FRM CONTENT

6.1 FLOOD HAZARD MAPS

Flood hazard maps are prepared for areas of potential significant flood risk (APSFR) identified in the preliminary flood risk assessment, i.e. areas where there is or is likely to be a significant flood risk.

6.1.1 FLOOD HAZARD MAP WITH WATER DEPTH

According to the Regulation, the flood hazard maps present the water depth in four ranges, which determine the degree of danger to people and the way in which the construction objects are affected:

1) $h \leq 0.5$ m – means a low hazard to people and buildings;
2) $0.5 < h \leq 2.0$ m – means a medium hazard to people, due to the possibility of evacuation to the higher floors of buildings, but high due to material damages;
3) $2.0 < h \leq 4.0$ m – means a high hazard to people, but very high due to material damages; not only the ground floors but also the upper floors of buildings may be flooded;
4) $h > 4$ m – means a very high hazard to people and a very high hazard of total property damage;

The cartographic version of flood hazard maps with water depth includes the following elements:

1) flood hazard area;
2) water depths;
3) maximum water level ordinates resulting from mathematical hydraulic modelling;
4) crest ordinates of flood embankments in cross-sections, which were used for model calculations;
5) flood embankments;
6) natural watercourses and canals, and their names;
7) chainage of rivers marked every 500 m.

For flood hazard maps for floods from sea water, additional consideration is given to:

1) chainage of the sea coast marked every 0.5 km;
2) boundaries of the sea coast technical belt;
3) boundaries of the sea coast protection zone;
4) boundaries of harbours and marinas.

For flood hazard maps for floods from damming structures, the following elements are taken into account, among others:

1) flood risk area for the scenario of damage or destruction of damming structures;

2) water depths;
3) maximum ordinates of the water level;
4) crest ordinates of flood embankments or side dams;
5) flood embankments;
6) side dams;
7) damming structures;
8) natural watercourses and canals, and their names;
9) chainage of rivers marked every 500 m.

6.1.2 FLOOD HAZARD MAP WITH WATER FLOW VELOCITY

According to the Regulation, flood hazard maps present the velocity of water flow in four ranges, which determine the degree of danger to people and the manner of impact on buildings:

1) $v \leq 0.5$ m/s – low velocity, water has small impact on objects;
2) 0.5 m/s < $v \leq 1$ m/s – medium velocity, water has a moderate impact on objects and is able to move objects of small size and weight; it is a threat to people;
3) 1 m/s < $v \leq 2$ m/s – high velocity, water has a strong impact on objects and is able to move objects of relatively large size and weight; it is a serious threat to people;
4) $v > 2$ m/s – very high velocity, water has a very strong impact on objects and is able to move objects of very large size and weight, and to disturb the structure of static objects; it is a very serious threat to people.

The cartographic version of the flood hazard maps with the water flow velocity takes into account, among other things, the following elements:

1) flood hazard area;
2) water flow velocities;
3) water flow directions;
4) maximum water level ordinates resulting from mathematical hydraulic modelling;
5) crest ordinates of flood embankments in cross-sections, which were used for model calculations;
6) flood embankments;
7) natural watercourses and canals, and their names;
8) chainage of rivers marked every 500 m.

6.2 FLOOD RISK MAPS

in accordance with Article 170 of the Water Law Act, flood risk maps are prepared for the flood hazard areas for which flood hazard maps have been drafted.

Flood risk is defined in Article 16, paragraph 48 of the Water Law Act and means a combination of the probability of flooding and its potential adverse consequences for human life and health, the environment, cultural heritage and economic activity.

Flood risk maps indicate the values of potential flood damages and show objects exposed to flooding with a certain probability of occurrence. These are facilities enabling to evaluate flood risks to human health and life, the environment, cultural heritage and economic activities, i.e. groups for which the adverse consequences of floods should be reduced in accordance with the objectives of the Floods Directive.

The range of flood risk elements shown on the maps is the same for all types of floods.

6.2.1 FLOOD RISK MAP – POTENTIAL ADVERSE CONSEQUENCES FOR HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES

The cartographic version of the flood risk maps highlighting the potential adverse consequences for human life and health and the value of potential flood damages comprises, inter alia, the following elements:

1) estimated number of inhabitants exposed to flooding – given under the name of the town or village;
2) residential buildings in the flood hazard area [in two water depth ranges: below and above 2 m];
3) buildings of social importance in the flood hazard area [in two water depth ranges: below and above 2 m];
4) objects of particular social importance, including:
    a) hospitals,
    b) schools,
    c) kindergartens,
    d) nurseries,
    e) hotels,
    f) shopping and service centres,
    g) Police units,
    h) fire protection units,
    i) Border Guard units,
    j) social welfare homes, facilities providing 24-hour care for the disabled, the chronically ill or elderly and hospices,
    k) penitentiaries, correctional and custodial facilities;
5) values of potential flood damages.

6.2.2 FLOOD RISK MAP – POTENTIAL ADVERSE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITIES

The cartographic version of the flood risk maps highlighting the potential adverse consequences for the environment, cultural heritage and economic activities comprises, inter alia, the following elements:

1) land use classes:
    a) residential areas,
    b) industrial areas,
    c) transport areas,
    d) forests,
    e) recreational areas,
    f) arable land and permanent crops,
    g) grassland,
    h) surface water,
    i) other areas;
2) surface water and groundwater abstractions;
3) water abstraction protection zones;
4) bathing waters;
5) Natura 2000 areas, national parks and nature reserves;
6) zoos;
7) immovable monuments, in particular those covered by forms of protection of the monuments in the Act on Protection and Care of Monuments;
8) monuments included in the World Heritage List;
9) extermination monuments referred to in Article 2 of the Act on the Protection of the Grounds of Former Nazi Death Camps;
10) open-air museums and museums entered in the National Register of Museums referred to in the Act on Museums;
11) libraries with collections constituting the national library resource referred to in the Library Act;
12) archives with collections constituting the national archival resource referred to in the Act on National Archival Resource and Archives;
    a) installations which, in the event of flooding, may cause significant pollution of individual natural elements or of the environment as a whole, for the operation of

which it is required to obtain the integrated permit referred to in the Act – Environmental Protection Law, in the following categories of industrial activity:

b) energy industry,

c) production and processing of metals,

d) mineral industry,

e) chemical industry,

f) waste management,

g) other activities, including

- production and processing of paper and wood,
- intensive rearing of poultry and pigs,
- production and processing of plant and animal raw materials;

13) industrial plants whose installations do not require the integrated permit referred to in the Act – Environmental Protection Law, and which may pose a threat, including plants posing a threat of a serious industrial accident within the meaning of this Act;

14) potential sources of water pollution, in particular:

a) wastewater treatment plants,

b) wastewater pumping stations,

c) landfills,

d) cemeteries.

7 INPUT DATA FOR FHM AND FRM

The timeliness of the input data is a key element affecting the timeliness of FHM and FRM. When developing the FHM and FRM, great emphasis was placed on obtaining the most up-to-date input data available for a given area, in accordance with the guidelines of the Regulation and Methodology.

The data and source materials utilised to prepare the FHM and FRM for fluvial floods, together with their timeliness, are summarised in Tables 10 and 11.

A detailed description of the data used to develop the FRM and FRM from the sea water is provided in the Methodology for the development of flood hazard maps and flood risk maps from the sea in the second planning cycle, provided as Annex 2.

A detailed description of the data used to prepare the FHM and FRM for damming structures is presented in the FHM and FRM for damming structures report, provided as Annex 10.

Table 10. Summary of input data to the FHM and FRM for fluvial floods.

No.	Data	Data source	Format	Timeliness of data in maps of 2020	Timeliness of data in maps of 2022
1	Execution/post-construction projects, data on investments having a significant impact on the extent of floods	General Directorate for National Roads and Motorways/PZD/WZD	*xyz, *shp, *dwg, *dat, *pdf, *.doc	2009-2019	2010-2021
2	Orthophotomaps (field pixel size: 0.5 m; 0.25 m, 0.1 m)	Head Office of Geodesy and Cartography	*tif	2010-2018	2010-2020
3	National Registry of Plot Boundaries and Areas of State Territory Division Units		*shp	2018	2022
4	National Register of Geographical Names		*shp	2018	2018
5	Topographical Object Database BDOT10k		*shp	2018	2018
6	Digital Terrain Model (DTM) and Digital Surface Model (DSM)		*xyz, *asc, *tif, *las, TIN	2010-2018	2010-2020
7	Map index 1:10,000		*shp	n.a.	n.a.
8	National Official Register of Territorial Division (Teryt)	Central Statistical Office	*xml, *csv	2017	2022
9	Hydrological and meteorological data	Institute of Meteorology and Water Management – National Research Institute	*doc, *xls, *pdf, *pdf, *tif, *jpg and others*	1956-2016 (most river stations) 1987-2016 (marine stations)	1987-2016
10	Riverbed cross-sections and water constructions, digital terrain model, orthophotomaps, Lausitzer Neisse river	International Commission for the Protection of the Oder river against Pollution – data from the Länder of Saxony and Brandenburg, Germany,	*shp, *xls, *txt, *jpg, *pdf	2009-2018	n.a.
11	Digital terrain model of Lower Oder DGM-W Oder-2011	WSA Oder-Havel	*xyz, *asc, *tif	n.a.	2011-2012
12	Riverbed cross-sections: Brennica, Przemsza catchment	State Water Holding – Polish Waters – Regional Water Management Authority/National Water Management Authority	*jpg, *pdf	2000-2016 2015-2016	n.a.
13	As-built cross-sections acquired as a part of the modernisation of the Wroclaw Water System		*txt	2015	n.a.
14	Execution/post-construction projects, data on investments having a significant impact on the extent of floods		*xyz, *shp, *dwg, *dat, *pdf, *.doc	2010-2019	2010-2022

No.	Data	Data source	Format	Timeliness of data in maps of 2020	Timeliness of data in maps of 2022
15	Riverbed cross-sections obtained from API development		*xns11	2013-2015	n.a.
16	Riverbed cross-sections for the Żuławy area acquired under SMORP 2012		*shp	2012	n.a.
17	Riverbed cross-sections with photo documentation and inventory of hydrotechnical and transport structures – developed within the ISOK project		*shp, *xls, *txt, *jpg, *pdf	2012-2013	2012-2013
18	Valley cross-sections, including riverbed cross-sections together with photo documentation and inventory of hydrotechnical and transport structures – developed within the project		*shp, *xls, *jpg, *pdf, *dxf	2018-2019	2020-2021
19	Analytical data on the current flood protection system for the development of flood risk management plans for river basin areas and water regions		*xls, *shp, *doc	2013	2021
20	Project data: Identification of pressures in water regions and river basin areas – Part I: Creation of a national database on hydromorphological changes		geobase	2017	n.a.
21	Current reservoir water management manuals / reservoir design or post-design documentation		*xyz, *shp, *dwg, *asc, *dat, *pdf, *.doc	1998-2017	1990-2021
22	Map of Hydrographic Division of Poland MPHP10k		*shp	2017	2020
23	Riverbed and bridge cross-sections for the Lower Vistula River section – project for the Lower Vistula Cascade		*jpg, *pdf	2016-2017	n.a.
24	Bridge sections and water structures of Nysa Kłodzka Valley – Nysa Kłodzka basin and tributaries		*.xls	2018	n.a.
25	Riverbed and bridge cross-sections for the Kamienny Potok – Odra-Vistula Flood Management Project		*shp, *xls, *jpg, *pdf, *dwg	n.a.	2017
26	Riverbed and bridge cross-sections for the Radomierkia – draft Master Plan for the Bóbr River Catchment area – The concept of implementing the FRMP in the Bóbr River catchment area in the terms of the identification of investment priorities in the water region of the Middle Oder River		*shp, *xls, *dxf, *jpg, *pdf	n.a.	2019
27	Inventory of hydrotechnical structures along the banks: Western Oder at km from 0.0 to 29.5 Eastern Oder (Regalica) at km from 704.0 km to 730.0 Obnica at km from 0.0 to 1.1		*pdf	n.a.	2017
28	Routing of the technical and protection belt, harbours and marinas boundaries, kilometres of coastline	Maritime Offices	*shp, *dwg, *txt, *pdf	2019	2019
29	Storm embankments		*.shp	2019	2019
30	Execution/post-construction projects, data on investments having a significant impact on the extent of floods		*xyz, *shp, *dwg, *dat, *pdf, *.doc	2018-2019	2019
31	Data on investments carried out by Maritime Offices		*shp,* xls	2010-2019	2022
32	Data on embankments and water facilities	Management Board of Land Amelioration and Water Facilities / State Water Holding – Polish Waters	*xls, *doc, *jpg and others *	2010-2019	2010-2022
33	Execution/post-construction projects, data on investments having a significant		*xyz, *shp, *dwg, *dat,	2009-2019	2010-2022

No.	Data	Data source	Format	Timeliness of data in maps of 2020	Timeliness of data in maps of 2022
	impact on the extent of floods		*pdf, *.doc		
34	Execution/post-construction projects, data on investments having a significant impact on the extent of floods	Railway managers	*xyz, *shp, *dwg, *dat, *pdf, *.doc	2009-2019	2010-2021

Table 11. Summary of input data to the FRM for fluvial floods.

No.	Data	Data source	Format	Timeliness of data in maps of 2020	Timeliness of data in maps of 2022
1	Land use	Head Office of Geodesy and Cartography GUGiK – BDOT10k resource	.shp	2018	2018
2	Number of inhabitants	GUS - System of Address Identification of Streets, Real Estates, Buildings and Dwellings (NOBC) and Local Data Base	.xlsx,.txt, .docx,.shp, .pdf .xlsx	2018 2018	2018 2018
3	Address points	Head Office of Geodesy and Cartography, Geoportal, Dictionary services	.xml	2018	2018
4	Residential buildings and facilities of social importance (hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, social welfare homes, nursing homes, hospices, penitentiaries, correctional and custodial facilities, police units, fire protection units, Border Guard units)	Head Office of Geodesy and Cartography GUGiK – BDOT10k resource	.shp	2018	2018
5	Social welfare homes, 24-hour care facilities	Voivodeship offices	.shp, .xlsx, docx	2018	2018
6	Hospices	National Health Fund	.xlsx	2018	2018
7	Penitentiaries, custodial facilities	Central Board of the Prison Service	.xlsx	2018	2018
8	Correctional facilities	Ministry of Justice	.xlsx	2018	2018
9	Groundwater abstractions	Polish Geological Institute National Research Institute PGW WP – Identification of pressures*	.xlsx, .shp	2019 2018	2019 2018
10	Surface water abstractions	GUGiK – BDOT10k resource PGW WP – Identification of pressures	.shp .shp	2018 2018	2018 2018
11	Water abstractions protection zones	PGW WP	.shp	2018	2018
12	Bathing sites	Chief Sanitary Inspectorate	.shp,	2018	2018
13	Boundaries of Natura 2000 sites, including boundaries of special bird protection areas and special areas of habitat protection	General Directorate for Environmental Protection	.shp	2018	2018
14	Borders of national parks		.shp	2018	2018
15	Borders of nature reserves		.shp	2018	2018
16	Immovable monuments	National Heritage Institute	.shp	2018	2018
17	Sites included in the UNESCO World Heritage List		.shp	2018	2018
18	Extermination monuments	Act	.pdf	2019	2019
19	Open-air museums and museums listed in the National Register of Museums	Ministry of Culture and National Heritage	.xlsx	2018	2018
20	Libraries forming the national library resource	Regulation	.pdf	2019	2019
21	Archives forming the national archive resource	Ministry of Culture and National Heritage	.pdf	2018	2018

No.	Data	Data source	Format	Timeliness of data in maps of 2020	Timeliness of data in maps of 2022
22	Zoos	GUGiK – BDOT10k resource	.shp	2018	2018
23	Industrial plants	GUGiK – BDOT10k resource PGW WP – Identification of pressures	.shp .shp	2018 2018	2018
24	Industrial plants with a high and increased risk of a major industrial accident	GIOŚ WIOŚ KG PSP	.xlsx .xlsx, .docx, .pdf, .rtf .pdf	2018 2018 2018	2018 2018 2018
25	IPPC installations (register of installations with integrated permits)	Register of installations holding integrated permits	.xlsx	2018	2018
26	Cemeteries	GUGiK – BDOT10k resource	.shp	2018	2018
27	Landfills	GUGiK – BDOT10k resource PGW WP – Identification of pressures WIOŚ	.shp .shp, .xlsx, .mdb, .docx, .pdf	2018 2018 2018	2018 2018 2018
28	Wastewater treatment plants	WIOŚ PGW WP – Identification of pressures GUGiK – BDOT10k resource	.shp, .xlsx, .pdf .shp .shp	2018 2018 2018	2018
29	Wastewater pumping stations	GUGiK – BDOT10k resource	.shp	2018	2018
30	Values of potential flood damages calculated on the basis of potential damage factors for individual land use classes from 2016.	IMGW-PIB/ARCADIS/MGGP consortium	.shp	2019	2022
31	Localities	GUGiK – BDOT10k resource	.shp	2018	2018

Chapters 7.1 - 7.5 describe the key data used to determine flood hazard areas presented in the FHM and FRM.

7.1 DIGITAL TERRAIN MODEL

In accordance with the Regulation, the digital terrain model (DTM), created using the airborne laser scanning method (LIDAR) with a spatial resolution of 1 m and height accuracy of 0.2 m, obtained from the state surveying and cartographic resource, was used to prepare flood hazard maps.

The product is saved in the form of text files containing coordinates (X,Y,Z) of points in a regular grid with a spatial resolution of 1 m, as well as a raster with the same resolution. The points of the described products have been interpolated on the basis of the point cloud obtained from aerial laser scanning. The maximum medium height error is 0.2 m. The individual DTM data files correspond to sheets in the “1992” rectangular flat coordinate system at a scale of 1: 5,000.

Measurement data for the DTM and Digital Surface Model (DSM) were obtained in two point cloud standards:

Standard I – density 4-6 points/m², sheet scale 1: Standard I – density 4-6 points/m², sheet scale 1:2500 (area 1x1 km);

Standard II (for cities) – density 12 points/m², sheet scale 1: 1:1250 (area 0.5x0.5 km).

DTM timeliness depends on the area of the country and covers the period of 2010-2020.

7.2 VALLEY CROSS-SECTIONS

Valley cross-sections are the input data for the construction of hydraulic models. They cover the entire valley of the river, including:

1) the riverbed (riverbed cross-section);
2) flooding terraces (cross-section through terraces).

The part of the cross-section concerning the riverbed and a 20 m wide belt of land counting to the right and left of the upper edge of the slope of the riverbed outwards from the axis of the riverbed were made directly in field. Direct geodetic measurements were made in the national surveying coordinate system – 1992 (PUWG 1992), and in the Kronstadt 86 geodetic height system.

The part of the cross-section including floodplain terraces was determined based on the latest available digital terrain model. In the event that new investments affecting the flood risk in a given area were made after the DTM was completed, the DTM was updated with data on these investments.

The valley cross-sections were located in characteristic and representative places, in a way that ensures proper mapping of the valley. The riverbed cross-sections were located perpendicularly to the stream axis and the part of the valley cross-section concerning flood terraces perpendicularly to the course of a given valley. For embanked watercourses, the cross-sections through flood terraces were extended to the base of the downstream slope.

The riverbed cross-sections developed in the first planning cycle were located at distances of not more than 500 m in a mountainous area and no more than 1500 m in a lowland area. According to the Methodology of FHM and FRM elaborated in the second planning cycle (Annex 1), riverbed cross-sections were located at distances of not more than 500 m, counting according to the length of the watercourse, and for measurements for valley cross-sections for 2D modelling (for voivodeship cities and cities with poviat rights, as well as other cities with more than 100,000 inhabitants), at distances not exceeding 250 m.

For FHM developed in the first planning cycle, which were updated in the second cycle, the validity of the cross-sections was reviewed. In justified cases, with significant changes affecting the modelling results, i.e. a change in riverbed morphology or new investments, the valley cross-sections in the riverbed and terraced sections were updated.

The cross-sections were also determined for flowing reservoirs and flow lakes. In this case, the measurement of cross-sections on the watercourse before the inflow into the lake and after the outflow from the lake was considered. The cross-section measurements included, apart from the reservoir or lake itself, a belt of land about 20 m wide, counting to the right and left of the bank, except for embankment cases (10 m outside the embankment or side dam).

7.3 ENGINEERING STRUCTURES

As a part of geodetic works, a detailed inventory of engineering facilities located on the watercourses covered by the study was prepared, i.e.:

1) bridge structures (including bridges and footbridges);
2) hydrotechnical facilities (including dams, weirs and steps).

The inventory of engineering facilities consisted of identifying the actual locations of the facilities in field, with only facilities located on the sections of watercourses to be modelled that meet at least one of the following criteria:

For **bridge structures:**

1) pillars with a width (or diameter) of at least 0.5 m;
2) ordinates of the bottom of the structure lower than the level determined by adding 2 m to the ordinates of the upper edges of the bank slopes, with a thickness of their main horizontal structure exceeding 0.5 m;
3) having abutments that are wholly or partly within the riverbed section;

For **hydrotechnical facilities:**

1) anti-debris dams;
2) single facilities with an overflow threshold height of at least 0.8 m (except for step-rapids and ramps);
3) which are the initial and final facilities of a systematic or segmented threshold or step correction and have an overflow threshold height of at least 0.8 m;
4) large hydrotechnical facilities, such as steps and weirs with variable, controlled damming with adjustable closures.

7.4 FLOOD EMBANKMENTS

For of the FHM and FRM elaborated in the second planning cycle, the course of flood embankments was verified with the use of a digital terrain model, geodetic measurements and information from particular RZGW.

A geodetic inventory of flood embankments located on the sections of watercourses covered by the development of new and updated FHM was also taken, in areas where significant changes resulting from the implementation of various types of investments have taken place, which may affect the change in the level of flood hazard.

This inventory consisted of identifying the actual locations of the embankments in field and geodetic measurement of the ordinates in the place of the base of the upstream and downstream slope and the top of the embankments in the line of all valley cross-sections made. The measurements were made for all valley cross-sections (i.e. both “typical” cross-sections and cross-sections for engineering structures) in places where embankments occur.

The inventory was also made in the sections of embankments located between the cross-sections, so that the distances between successive measuring points (base of the upstream and downstream slope and the embankment top) do not exceed 50 m, counting along the embankment, with particular attention paid to places with local depressions of the embankment top ordinate.

7.5 HYDROLOGICAL DATA

7.5.1 DATA FOR FHM FOR FLUVIAL FLOODS

The hydrological data necessary for flow modelling in riverbeds and floodplains for all types of hydraulic modelling are included for controlled catchments:

1) hydrological characteristics of the water level gauge stations;
2) values of flows with a certain probability of exceedance (p=10%, p=1%, p=0.2%) calculated for water level gauge stations;
3) update of the coincidence of maximum flows on the main river and its tributaries;
4) Q/H flow curves for the two largest exceedances in the last 30 years;
5) hydrographs of water flows and water levels for selected two historical largest exceedances;
6) hydrographs of hypothetical wave flows.

For uncontrolled catchments, hydrological data include:

1) maximum flows with a certain probability of exceedance of p = 10%, 1% and 0.2%;
2) hypothetical waves with a certain probability of exceedance of p = 10%, 1% and 0.2%.

A detailed description of the preparation of hydrological data is included in the report on the preparation of hydrological data for hydraulic modelling, provided as Annex 4.

A brief description of the methods used to prepare hydrological data is given below.

The choice of the method for calculating maximum annual flows with a certain probability of exceedance for a given river cross-section depends on the availability of hydrological data:

1) a sufficiently long, at least 30-element, homogeneous flow string is available;
2) the string is too short (the number of elements is less than 30);
3) no measurement data, while the cross-section is located on a controlled river;
4) no measurement data, while the cross-section is located on an uncontrolled river.

Moreover, the choice of the method depends on the position of the calculative cross-section in relation to the water level gauge, having a sufficiently long sequence of homogeneous flows. Three cases are possible:

1) the calculative cross-section is located in the water level cross-section or is located at a short distance from it (increase of the catchment area between cross-sections of < 5% and there is no significant inflow in this section);

2) the calculative cross-section is located above or below the water level or between two gauges;
3) the calculative cross-section is located in an uncontrolled catchment area.

A synthetic description of the conditions and scope of application of the methods is given in Table 12 and Figure 8.

Table 12. Methods for calculating maximum annual flows with a certain probability of exceeding (Qpp) in controlled and uncontrolled catchments.

Term	Conditions Scope of application	Qpp estimation method
Controlled catchments		
Calculative cross-section located in the water level cross-section	long observation period	Direct
Design section uncontrolled on a controlled river	located above the water level gauge $A_G > A_X \geq 0.5\ A_G$	Extrapolation
	located between water level gauges $A_G < A_X < A_D$	Interpolation
	located below the water level gauge $A_D < A_X \leq 1.5\ A_D$	Extrapolation
Uncontrolled catchments		
Catchment with an area of $A_x \leq 50$ km^2	Non-urbanised catchments	Precipitation formula
	Urbanised catchment areas	Precipitation-drainage model
Catchment with an area of $A_x > 50$ km^2	North part of the country	Area-based regression equation Melt formula
	South part of the country	Area-based regression equation

Symbols: AG – catchment area closed with an upper water level gauge WG, AX – catchment area closed with a calculative cross-section, AD – catchment area closed with a lower water level gauge WD)

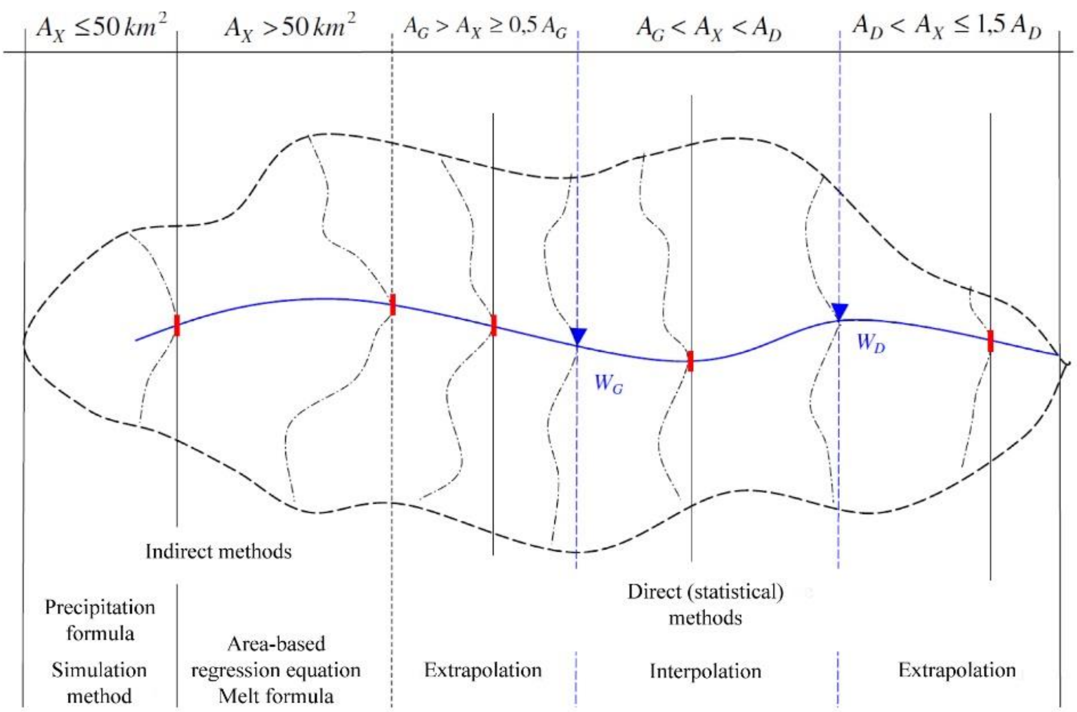

Figure 8. Methods for calculating maximum flows with a certain probability of exceedance in controlled and uncontrolled catchments (Update of methodology..., 2017 – amended).

CONTROLLED CATCHMENTS

The calculations of maximum annual flows with a certain probability of exceedance for controlled rivers in water gauge cross-sections were performed using a statistical method. The method assumes that maximum annual flows are subject to a certain distribution of probability, and the distribution parameters are estimated on the basis of a random sample, a series of maximum annual flows (WQ) observed in the past. The prerequisite is a homogeneous random sample with not less than 30 elements. The Pearson III type distribution is taken as the initial (default) distribution. In justified cases, another distribution is employed. The method with the highest reliability was applied to estimate the parameters of this distribution. The hypothesis about the compliance of the theoretical function of probability distribution with the empirical distribution was checked by means of the λ-Kolmogorov test at the significance level $\alpha = 0.05$ (the critical value of the Kolmogorov test statistics reduced by estimation of the distribution based on the sample was used).

The basis for the calculation of the maximum annual flows with a certain probability of exceedance was the homogeneous distribution sequences of the maximum annual flows from the hydrological multi-year period, covering at least 30 years until 2016. If data were not available until that year, e.g. because the station was removed, the available data series were used. WQ observation strings were subjected to homogeneity analysis using the Mann-Kendall test. If the heterogeneity of the data series was found, analyses were carried out which allowed the homogeneous sequence to emerge, without the possibility of maintaining the recommended multi-year period. Such a sequence was used for further calculations.

In justified cases, for which there were reasons to carry out analyses taking into account the selection of another distribution, the quality of Pearson's type III distribution was compared with the quality of other theoretical non-contradictory distributions, the parameters of which were estimated using the most reliable method. The inconsistencies between theoretical and empirical distributions were verified using the AIC criterion. The AIC criterion allows to select one of the most reliable functions from the group of the considered, non-contradictory distributions. All cases, which according to these criteria were considered as specific, were verified during hydraulic modelling.

If the calculative cross-section was located in the controlled catchment area above the water level gauge station, the method of extrapolation of maximum annual flows with a certain probability of exceedance, calculated for water level gauges, was applied, using the assumption that the catchment area to the calculative cross-section does not exceed 50% of the catchment area to the water level gauge station cross-section.

If the calculative cross-section was located in the controlled catchment area below the water level gauge station, the method of extrapolation of the maximum annual flows with a certain probability of exceedance, calculated for the water level gauges, was applied, using the assumption that the catchment area to the calculative cross-section does not exceed 150% of the catchment area to the water level gauge station cross-section.

If the calculative cross-section was located in the controlled catchment area between two water level gauge stations, the method of interpolation of the maximum annual flows with a certain probability of exceedance calculated for both water level gauges was applied assuming the proportionality of the flows to the catchment area.

For the controlled catchment areas where reservoirs are located for which the transformation of a wave by a reservoir has been carried out as part of the project, maximum annual flows with a certain probability of exceedance were assumed in the dam profiles, in line with the current water management manuals.

UNCONTROLLED CATCHMENTS

In uncontrolled catchments larger than 50 km², the territorial regression equation (Stachý, Fal 1987) was applied in cases where it is not possible to transfer information by extrapolation within the hydrological similarity.

In uncontrolled catchments with an area less than or equal to 50 km², non-urbanised, where the impermeable area is less than 5%, a precipitation formula was used to calculate maximum annual flows with a certain probability of exceedance.

In urbanised, uncontrolled catchments with an area less than or equal to 50 km² and with an impermeable area of more than 5%, a precipitation-drainage model with a linear conceptual Nash model was used to calculate maximum annual flows with a certain probability of exceedance. The input data were maximum annual precipitation with a certain probability of exceedance for different durations calculated from the formulas Bogdanowicz, Stachý (1998).

For areas where floods of the melting type dominate, the melting type formula was used.

For uncontrolled catchment areas where reservoirs are located and for which wave transformation through the reservoir are carried out, the dam profiles are based on maximum annual flows with a certain probability of exceedance according to the current water management manuals.

7.5.2 DATA FOR FHM FOR SEA WATER FLOODS

As in the first cycle, the hydrological data of sea levels from the last 30 years, including data up to and including 2016, were used to prepare flood risk maps from the sea water. The hydrological data were developed in accordance with the principles laid down in the Methodology for the development of the FHM and FRM from the sea water in the second planning cycle, provided as Annex 2.

Based on the following data:

1) hydrological stations covering water levels of mareographic stations located along the coast administered by maritime offices;
2) multi-year medium flows from water gauge stations located outside estuarial river sections;
3) physiographic characteristics of uncontrolled catchments necessary to perform hydromorphological characteristics of uncontrolled watercourses;
4) wind speed and direction (for model calibration and verification);

The following calculations were prepared and performed:

1) hydrological characteristics, determined over a period of not less than 10 years, including the following water levels of active mareographic stations located along the coast – WWW (multi-year highest level), SWW (average maximum level), SSW (multi-year average level), SNW (average minimum level), NNW (multi-year lowest level) with the given order of magnitude of zero water gauge, and for estuarial river sections with the given river course kilometre and catchment area;
2) medium flows and water levels in estuarial sections of controlled and uncontrolled rivers flowing into the sea and internal sea waters in the operating area of maritime offices – based on measurement sequences or empirical data;
3) water levels for adopted flood scenarios for relevant mareographic stations.

When calculating the water level with a certain probability of exceedance, the impact of the sea and the increase in sea level along the Polish Baltic coast caused by climate change under A2 emission scenario were considered.

The impact of the sea (wave) was determined depending on the analysed area. In case of:

1) estuarial river sections – the influence of waving is not taken into account;
2) the coasts of the open sea and the bay:
    a) natural – the increase of the water level taking into account the waving is determined as a value equal to 0.7 of depth at a place of the last wave refraction in front of the dune foot;
    b) built-up – the height of the wave and the possibility of its overflow to the background are calculated with the formulas included in the Coastal Engineering Manual (CEM 2004) and Die Küste (2007);
3) floods – waving is considered during modelling by means of force of the wind blowing over the surface of the water body in question;
4) coastal lakes – the influence of waving is not taken into account;
5) harbour reservoirs:
    a) without the presence of rivers – if the difference between the water level with a certain level of probability, with considering the climate change, and the ordinates of the port quays is greater than 0.8 m – the waving effect is ignored;
    b) otherwise, the wave distribution in the port areas is analysed (if the maritime office does not have the results of past analyses for the given port) and then the quay sections potentially at risk of overflow are selected and the amount of overflow is determined according to the Die Küste formula (2007);
    c) river estuaries – the impact of waving is determined analogously to the above, considering additionally the formation of backwaters on the river and the possibility of water exceedance from the riverbed in areas adjacent to the harbour.

In order to determine the hydrograph of hypothetical waves for specific probabilities of exceedance, a maximum of six (minimum five) of the largest observed exceedances in the last 30 years was selected. An additional selection criterion was the comparison of individual floods for similar course characteristics – waves with clearly deviating characteristics were rejected. Then all sequences were averaged, according to the Warsaw University of Technology's method of determining hypothetical waves modified for water levels (Jednorał, 2003). This method assumes matching the theoretical hydrograph (the so-called hypothetical storm flood) to the actual recorded exceedances. On the basis of the averaged wave, using the above-mentioned method, hypothetical waves were calculated for the probabilities of exceedance of 1% and 0.2%.

The determination of medium flows in estuarial river sections into the sea is necessary because they are taken into account as coastal conditions for the river in sea water flood scenarios. The flows characteristic for uncontrolled watercourses were calculated using the following methods: according to Iszkowski, modified by Byczkowski, according to Kollis, by the method of hydrological analogy or according to regional relationships.

For controlled rivers, the data relating to the gauge station above the impact of the backwater was used for calculations. Where the water gauge cross-section coincides with the calculative cross-section, the SQ, i.e. the medium flow from the annual medium flows, was calculated for data from the multi-year period (1951-2016). Where the calculative cross-section does not coincide with the water gauge cross-section, the extrapolation method was applied to transfer the observational sequence for SQ calculations.

7.5.3 DATA FOR FHM FOR FLOODING FROM DAMMING STRUCTURES

Hydrological data necessary for hydraulic modelling, being the basis for preparing the FHM and FRM for damming structures, comprise:

1) hydrographs of water flows and water levels and flow curves for water level gauge stations for selected two historical largest exceedances, adopted as the basis for calibration and verification of the hydraulic model;

2) hydrographs of flows for up to 6 historical waves at water level gauges authoritative for the determination of inflows to reservoirs, taken as the basis for determining the hypothetical wave at the inflow to the reservoir;

3) values of flows with a certain probability of exceedance and hydrographs of inflow to the reservoir based on them (hypothetical waves), taken as the basis for the scenario of damage or destruction of damming structure;

4) the boundary conditions in the valley downstream of the damming structure and, if necessary, in the recipient valley below and above the river estuary, where the damming structure's disaster has occurred, according to the hydrographic structure and the separated lateral tributaries concentrated and distributed along the section where the significant impact of the structure's disaster occurs.

After developing the FHM and FRM for the scenario of damage or destruction of the damming structure, the hydraulic models developed for river scenarios were used, hence in most cases there was no need to calibrate and verify the hydraulic models.

As for hypothetical waves for reservoirs, the hydrograph of inflow to the reservoir was generally assumed with a culmination equal to the control flow of the given damming structure, adopted on the basis of the current water management manual. For some reservoirs from the 1st part of the works (Besko, Chańcza, Świnna Poręba), hypothetical floods with a probability of exceedance of 0.1% or 0.01% were also considered.

The hydrographs of inflows to the reservoirs for the structures from the second part of the works were determined according to the guidelines given in the document "Update of methodology for calculating maximum flows and precipitation with a certain probability of exceedance in controlled and uncontrolled catchment and identification of models for the transformation of precipitation into runoff", i.e. the Strupczewski method. Where available, the parameters of the equations or reference hydrographs developed as part of the project "Review and update of flood hazard maps and flood risk maps" were used. In other cases, the parameters of the hypothetical hydrographs were calculated on the basis of available historical data.

For reservoirs from the first part of the works, the hydrographs of inflows to the reservoirs were determined in different ways, i.e. using the Hydroprojekt method (Besko), the Warsaw University of Technology's method (Mietków, Przeczyce), the Reitz-Kreps method (Chańcza, Słup) or based on the historical wave of 2001 (Świnna Poręba).

In addition, for the reservoirs from the second part of the works, boundary conditions from models prepared as part of the development of flood risk maps for river scenarios were used. In the valley below the damming structure, data from the low probability of flooding scenario of 0.2% was used, while in the recipient valley below and above the river mouth where the damming structure has failed, data from the low probability of flooding scenario of 0.2% was used (for the Vistula, Warta and Notec) or data from the high probability of flooding scenario of 10% (for the Oder).

8 SUMMARY OF METHODOLOGY FOR THE REVIEW AND UPDATE OF FHM AND FRM

8.1 METHODOLOGY FOR THE REVIEW OF FHM AND FRM

The review relates to the flood hazard maps and flood risk maps developed in the first planning cycle, i.e. those for fluvial and sea water floods.

8.1.1 SUMMARY OF THE METHODOLOGY FOR FLUVIAL FLOODS

The aim of the review of the FHM and FRM was to identify significant changes in flood hazards and risks, and to establish the scope of the FRM and FRM update.

A detailed description of how and to what extent the FHM and the FRM are reviewed is given in the Methodology for the development of the FHM and the FRM in the second planning cycle (Chapter 4), attached as Annex 1. The Methodology defines uniform rules for the implementation of the review and defines criteria for assessing the timeliness of the FHM and the FRM and for indicating them for updating.

The FHM and FRM were reviewed for the following scenarios:

1) Scenario I – areas with a low probability of flooding of 0.2% (once every 500 years);
2) Scenario II – areas with a medium probability of flooding of 1% (once every 100 years);
3) Scenario III – areas with a high probability of flooding of 10% (once every 10 years);
4) Scenario IV – areas exposed to flooding for embankment damage or destruction (designated for flow with 1% probability of occurrence) – scenario of total destruction of the flood embankment.

When identifying significant changes in flood hazard the following factors/criteria were taken into consideration:

1) changes in the lay of land and flood protection investments and other investments changing the hazard of flooding;
2) verification of the input data to the FHM used in the first planning cycle;
3) changes in the methodological assumptions for the development of the FHM and FRM;
4) comments to the FHM from administration authorities made in the first planning cycle.

Topographical changes and their impact on the change of the flood hazard and risk level were analysed for the review, including, in particular:

- checking the availability of a newer DTM in order to identify its changes to the DTM used for mapping in the first planning cycle and determine the impact of these changes on the level of flood hazard and risk;
- inventory of flood protection and other investments that may have a potential impact on the range of flood hazard areas (OZP), including the impact of mining activities on changes in the location of the land and the course of riverbeds.

When updating the maps, the account was taken of investments implemented since obtaining input data for the maps developed in the first planning cycle and investments planned for implementation by 2019. The review also analysed the investments that were considered when preparing the flood risk management plans for the first planning cycle (in the so-called W0 zero variant).

When verifying the input data to the FHM used in the first planning cycle, hydrological data and riverbed geometry (riverbed cross-sections) were analysed.

Changes in hydrological data may have resulted from extending the hydrological databases/information and changes in methodological assumptions for calculating hydrological data. For water level gauges located on the rivers covered by the modelling in the first planning cycle, maximum annual flows were calculated with a certain probability of exceedance, taking into account the data until 2016, and flow changes were then analysed, compared to those calculated in the first planning cycle.

The verification of input data also included a review of riverbed cross-sections for their timeliness, i.e.:

- the use of riverbed cross-sections from flood protection studies in the first planning cycle, in some cases,
- checking for the occurrence of natural factors, e.g. exceedances, which cause changes in the shape of riverbeds.

If the FHM to be updated is indicated, the methodology for developing the FHM and the FRM in the second planning cycle was used, with changes in the methodological assumptions for hydraulic modelling (compared to those used in the first planning cycle) being taken into account only if they affected the change in flood hazard levels.

The review also analysed the comments on the level of flood hazard identified in the FHM, made by the administration authorities in the first planning cycle, as well as during the survey conducted by the project: “Review and update of the preliminary flood risk assessment”.

The impact of the above factors/criteria on the change in the flood hazard level was determined on the basis of the significance scale (Table 13). The changes resulting from the impact of one (significant) or combined impact of several (less significant) factors on the flood hazard level in a given area were considered to be significant changes in flood hazard. These changes are characterised by significant changes in the water level and/or the range of the OZP.

Table 13. Significance scale of changes in flood hazard and risk.

Importance of changes	Description
Important	Major or significant changes that have a significant impact on the flood hazard and risk – these changes form the basis for updating the maps
Medium	Less important changes having a moderate impact on the on the flood hazard and risk – these changes may form the basis for updating the maps
Small	Small changes with small impact on the flood hazard and risk – these changes do not constitute grounds for updating the maps
None	No impact on flood hazard and risk

The assessment of the relevance of particular factors/criteria was based on the analysis of the impact of particular criteria (indicated in Table 14) on the level of flood hazard on the basis of expert assessment, and in special cases, for selected medium or small changes whose relevance was difficult to determine in the first stage of the review, on the basis of a detailed analysis with the possibility to use: GIS analysis, results of modelling from the first planning cycle, hydraulic calculations, other analyses.

Table 14. Criteria for assessing the impact of changes on the level of flood hazard from the rivers.

Criterion	**Description of the criterion**
Implementation of investments, topographical changes in the river valley, changes in riverbed cross-sections	
I1	Hydrotechnical investments (embankments, weirs, bridges, polders, reservoirs) and other investments
I2	Changes in riverbed route and cross-section (natural and regulatory)
I3	Changes in the river valley as a result of development and changes in use
Hydrology	
H1	Change in the value of probable flows with a certain probability of exceedance of Q10%, Q1%, Q0.2% between the values calculated in the first and second planning cycle
H2	Change of water level ordinates and water levels corresponding to the probability of exceedance for water level gauges estimated according to the methodology in the first planning cycle
Change of methodological assumptions	
M1	Use of unsteady flow
M2	Removing the limitation of the active cross-section to the width of the embankment spacing
M3	Impact of the operation of retention reservoirs (flood protection)
M4	Modelling change
Comments from administration authorities to the FHM	
U1	Comments of the institutions and administration authorities
Detailed analysis (optional)	
ZP1	Changing the position of the water level
ZP2	Changing the width of the water level

For each river or section of a river, the impact of the above factors/criteria on the change of flood hazard level has been determined. Where a river or river section is indicated for updating, the update covered all flood scenarios.

The final indications for the update of the FHM are presented in two categories:

1) update required (WA) – for changes that are relevant as a result of their comprehensive evaluation;
2) no need to update (BA) – for irrelevant changes and no impact on the flood hazard level.

The summary of the review of FHM and FRM was included in the Report on the implementation of the review of the FHM and the FRM, which constitutes Annex 5.

8.1.2 SUMMARY OF THE METHODOLOGY FOR SEA WATER FLOODS

The aim of the review of the FHM and FRM for sea water floods was to identify significant changes in the flood hazard and risk, and to establish the scope of update of the FHM and FRM from the sea water for the coastal and river sections identified by the analyses, and to identify the necessary data, taking into account their availability. For this purpose, the following was analysed:

1) changes in topography, including those resulting from the implementation of flood protection investments and others affecting the change in flood hazard;
2) input data;
3) methodological assumptions of map development;
4) comments made by the administration authorities.

The review of the FHM for sea water floods was divided into two stages:

Stage I – identification of changes qualifying for hydraulic modelling;

Stage II – execution of hydraulic modelling.

A detailed description of how and to what extent the FHM and FRM should be reviewed is contained in the Methodology for the development of the FHM and FRM from the sea water, in the second planning cycle (Chapter III.1), attached as Annex 2. The Methodology defines the uniform rules for the implementation of the review and defines criteria for assessing the timeliness of the FHM and the FRM and for indicating them for updating.

The FHM and FRM were reviewed for the following scenarios:

1) Scenario [H 0.2%] – low probability of flood, once every 500 years [H 0.2%];
2) Scenario [H 1%] – medium probability of a flood, once every 100 years [H 0.2%];
3) Scenario [Z1%] – total destruction of the indicated flood or storm embankment or other indicated elements of the bank protection system (protective structures of the technical belt) in the case of floods with a probability of occurrence once every 100 years [H 1%].

The purpose of the identification was to qualify the changes for hydraulic modelling. The results obtained were used to identify the changes that significantly affect the level of flood hazard determined in the first planning cycle. The determination of the relevance of changes was used to update the FHM.

The principle of identification and qualification of the changes indicated for hydraulic modelling was based on the identification of differences between the level of flood hazard developed in the first planning cycle and the potential impact of changes on its modification in the second planning cycle. The identification was made with the use of detailed analysis, including hydrological analyses, GIS analyses, detailed hydrological interpretation of the predicted impact of changes on the level of flood hazard in the area. The changes were examined taking into account the criteria described below (Table 15).

Table 15. Criteria for assessing the impact of changes on the level of flood hazard from the rivers.

Code of the criterion	Description of the criterion	Basis for assessment	Importance/measurement First planning cycle / Second planning cycle
INVESTMENTS AND TOPOGRAPHY			
I1	Hydrotechnical investments (embankments, weirs, bridges, polders, reservoirs, etc.)	Construction or reconstruction of existing hydrotechnical structures	Review and qualification of hydrotechnical investments, completed (after the first planning cycle) after 2010 and those planned to be completed by the end of 2019. which may have a significant impact on the modification of the flood hazard level. All investments which may have an impact on the modification of the flood hazard and risk level should be qualified to the stage of hydraulic modelling. The implementation in the model of significant hydrotechnical development will also be reviewed.
I2	Natural changes and regulation of the coastal river beds, bathymetry of the Baltic Sea, floodplains and sea lakes	Change of the active cross-section area of coastal rivers, change of the bathymetry of the Baltic Sea coastal zone, floodplains and coastal reservoirs	Qualification of the changes that may have a significant impact on the modification of the flood hazard level by comparing the bathymetry of the Baltic Sea coastal zone, floodplains, coastal lakes and changes in cross-sections of coastal watercourses between the first and second planning cycle. Any changes that may have an impact on modification of the flood hazard and risk level should be qualified to the stage of hydraulic modelling.
I3	Change in the valley of coastal watercourses, including changes in land cover	Changes in the valleys of coastal watercourses or the coastal zone of the Baltic Sea, floodplains and coastal reservoirs	Qualification of changes that may have a significant impact on the modification of the flood hazard level by comparing the terrain and land use between the first and second planning cycles. Any changes that may have an impact on modification of the flood hazard and risk level should be qualified to the stage of hydraulic modelling.
HYDROLOGY			
H2	The ordinate of the water level for a flood scenario with a certain probability of exceedance	Changes in updating values of probable levels with a certain probability of occurrence and flows in estuarial river sections	Qualification of changes in hydrological data by comparing the ordinates of waters with a certain probability of exceedance, calculated during the first and second planning cycle for individual mareographic stations/water level gauges, from which data were used during the implementation of the first planning cycle. Changes above 0 cm should be qualified as likely to have a significant impact on the level of flood hazard and risk, because even small changes can significantly modify the level of flood hazard and risk
HYDRAULIC MODELLING			
M1	Application of the model	Type of software or model in relation to the modelled area, in particular the transition from 2D models to hybrid models (1D/2D) in estuarial sections of sea rivers	An overview of the hydraulic models in terms of their suitability for the area being modelled. Qualification of models, performed in the first planning cycle, whose changes may have a significant impact on the modification of the level of flood hazard and risk in the second planning cycle

Code of the	Description of the	Basis for assessment	Importance/measurement
M2	Representation of the geometry and conditions of storm floods	Current geometry of the coastal river beds, bathymetry of the Baltic Sea coastline, floodplains, coastal lakes, implementation of model input data (e.g. coastal conditions)	Review of the models, performed in the first planning cycle, in the scope of implementation of the geometry of the beds of coastal watercourses, bathymetry of the Baltic Sea coastal zone, floods, coastal lakes, model input data (e.g. coastal and initial model conditions). Qualification of models, performed in the first planning cycle, whose changes may have a significant impact on the modification of the level of flood hazard and risk in the second planning cycle
M6	Specificity of individual water bodies	Changes in hydraulic modelling taking into account the differences in the specifics of individual sea basins	Review and comparison of methodological assumptions for hydraulic modelling used during the implementation of the first and second planning cycle. Qualification of changes in methodological assumptions, which may have a significant impact on the modification of the level of flood hazard and risk in the second planning cycle. In case of any changes in methodological assumptions for a given body of water, an update should be made for the whole area of the study.
COMMENTS			
U1	Comments and information provided by the offices, institutions and the public (including through the CMO survey)	Changes in the designated flood hazard zones and water ordinates with a certain probability of exceedance	Qualification of changes indicated by offices, institutions, society (also through the CMO survey).

Based on the location of the changes and investments identified at this stage in the particular coastal river estuaries, basins, fragments of the coast, hydraulic models were selected (sections, subsections) in the area where the changes and investments influence the defined range. hydraulic modelling was performed in the second planning cycle for these models.

The purpose of stage II of the FHM review was to identify significant changes that would be eligible for updates of the FHM from sea water. The significant changes were identified using hydraulic modelling and by analysing its results. The results of hydraulic modelling were used to determine the magnitude of three parameters: modifications of **the OZP area [PR1_ZAG]**, changes of **water ordinates with a certain probability of exceedance [PR2_ZAG]**, changes in **the context of flood risk [PR3_ZAG]**, which were the basis for identifying the changes with a significant, medium, small or no impact on the modification of the level of flood hazard and risk in a given area, determined in the first planning cycle.

The principle of final analysis of the impact of changes:

In the case of at least one significant change – and in at least one parameter – it was considered that in the area concerned there were changes which significantly modified the flood hazard level. A similar scheme was used for the remaining scale of changes (medium, small changes, no impact of changes).

Taking into account the changes in flood hazard and input data for the FHM, it was assumed that all FHM from the sea developed in the first planning cycle are the subject to updating.

The final indication for updating the FHM is shown in the following scale:

- update required AW (for significant changes),
- update recommended AZ (for medium changes),
- update optional AO (for small changes),
- no need to update N (for no changes).

Changes in the coverage of the OZP to the FRM in the second planning cycle required an update of the FRM. Changes to the FRM were also made in the case of significant changes to the input data referred to below. Taking into account the changes in flood risk and input data for the FRM it was assumed that all FRM from the sea developed during the first planning cycle would be updated.

For the scope of the FHM update, an FRM update was performed. For the modification of the flood hazard level to the FHM, the FRM was always changed. The FRM was also changed for significant changes in the input data between the first and second planning cycle.

8.2 METHODOLOGY FOR THE DEVELOPMENT OF FLOOD HAZARD MAPS

8.2.1 SUMMARY OF THE METHODOLOGY FOR FLUVIAL FLOODS (NATURAL EXCEEDANCE)

Flood hazard maps present the flood hazard areas with information on water depths and, where appropriate, water flow velocities and directions.

According to the Regulation, flood hazard areas are determined on the basis of water level ordinates obtained from mathematical hydraulic modelling.

The following modelling methods are used to produce the FHM:

1) One-dimensional modelling (1D) – obtaining results in the form of water level ordinates in cross-sections; as a result of one-dimensional modelling, flood hazard areas are determined along with water depth;
2) Two-dimensional (2D) modelling – obtaining results in the form of a digital water level model and water flow velocity raster; as a result of two-dimensional modelling, flood hazard areas with water depth and water flow velocities and directions are determined;
3) Hybrid modelling (1D/2D) – a combination of one-dimensional modelling for watercourse trays with two-dimensional modelling for floodplains.

According to the Regulation, two-dimensional modelling, as a result of which, in addition to the depth of water, water flow velocities and directions can also be obtained, was performed for voivodeship cities and cities with poviat rights, as well as other cities with population over 100,000.

For other areas, the appropriate type of modelling (one-dimensional, two-dimensional or hybrid) was analysed and selected, with particular regard to the possibility or necessity of using two-dimensional or hybrid modelling.

Two-dimensional or hybrid modelling was used for:

1) estuaries of rivers to the sea;
2) depressed areas, such as: Żuławy Wiślane, the area of coastal lakes and the area around the Szczecin Lagoon and the Vistula Lagoon;
3) river sections, where the 1D model would be too complicated and labour-intensive to schematise the river network, and the results of the one-dimensional modelling would be subject to a large error (based on a detailed analysis of the geometry of the river and valley, the layout of the main river network and tributaries, the location and layout of hydrotechnical and transport structures in relation to the riverbed) or river sections where, due to the width of the flood valley, the assumptions of one-dimensional flow are not met;
4) areas within the range of impact of mining settlements (mining damage).

The classic two-dimensional model was created for watercourses or their sections, whose bed morphology and topography of flood terraces allowed for appropriate mapping in the calculation raster.

Due to limited possibilities of implementing the hydrotechnical structures (e.g. weirs, culverts), classical two-dimensional models were created in areas where such hydrotechnical structures do not exist in significant number or do not significantly impact the flood hazard level.

Modelling was performed with DHI's MIKE software.

Model calculations were performed for unsteady flow conditions. In special cases, i.e. update of hydraulic models from the first cycle without changing hydrological data, also for steady flow. This approach was applied to the Oder river and the Lausitzer Neisse in the water region of the Central Oder. For the Oder river, the inclusion of the Racibórz reservoir in the model results in flattening the peak of flood waves, and the reduced flows remain in the inter-embankment area. Accordingly, the valley retention effect is relatively small. For the Lausitzer Neisse, modelling for steady flow results from the arrangements with the German side.

A detailed description of how to determine flood hazard areas and develop the FHM for fluvial floods is given in the Methodology for the development of flood hazard maps and flood risk maps in the second planning cycle, attached as Annex 1 to the report.

A summary of the applied hydraulic modelling methodology is presented below, for the following stages:

1) Model building:
   a) 1D: schematisation of the river network, introducing cross-sections, determining roughness coefficients, introducing engineering structures, introducing water bodies;
   b) 2D: preparation of DTM, determination of the roughness coefficient values;
   c) 1D/2D: construction of components of 1D and 2D models, combination of 1D and 2D models;
2) Determining boundary conditions;
3) Calibration and verification;
4) Performing model calculations of flood scenarios.

8.2.1.1 ONE-DIMENSIONAL MODELLING (1D)

SCHEMATISATION OF THE RIVER NETWORK

The river network was identified and the impact of individual tributaries on flood flows was analysed. Vectorisation was made on the basis of Maps of Hydrographic Division of Poland at 1:10,000 scale, geodetic measurements, DTM and orthophotomaps.

For flood terraces, the vectorisation was done according to the shape of the valley, in order to properly reflect the flow of floodwater across the entire width of the valley. In river valleys, where land topography causes the flow of floodwater to be separated, parallel floodwater flow routes were separated and links (connection channels) between them were defined.

INTRODUCTION OF CROSS-SECTIONS AND DETERMINATION OF THE ROUGHNESS COEFFICIENT

Cross-sections were imported into the models. For each of the cross-sections, the roughness coefficients were selected, based on the codes assigned to all cross-section sections (according to the code table in 3 point 5.1.1.2 of the Methodology). Orthophotomaps, BDOT10k and topographic maps were used to determine roughness coefficients on flood terraces. Two methods were used in the models to define the lateral variability of the roughness coefficient in cross-sections:

- medium roughness coefficient method with division into the main riverbed and floodplain (*High/Low flow zones*);
- method of variable roughness coefficient in the cross-section (*Distributed*).

The choice of the method representing roughness coefficients depended on the specificity of floodplains and variability of land use types.

INTRODUCTION OF ENGINEERING STRUCTURES (BRIDGES, CULVERTS, HYDROTECHNICAL STRUCTURES)

All engineering structures relevant to the flow of floodwater, such as bridges, culverts and hydrotechnical structures, were introduced into hydraulic models.

Depending on the type of structure and the degree of limitation of the flood water flow field, a method was used to implement bridge objects in a hydraulic model by means of two interlinked hydraulic elements (overflow and culvert), describing the water flow over and inside the bridge (through its clearance) or a dedicated module for bridges.

Non-controlled hydraulic facilities with constant damming were considered as overflows or modified cross-sections. Controlled hydraulic facilities were considered by using an appropriate control algorithm, depending on the known variables, e.g.: inflow size, water level at the upper or lower position, and sometimes also time (date). Such rules were implemented on the basis of information received from administrators or contained in the current water management manual (IGW).

Retaining walls and mobile flood protection systems were included in the models as devices that could affect the range of flood hazard areas.

INTRODUCTION OF WATER RESERVOIRS

The implementation of the water reservoir into the hydraulic model for the river network included:

1) Description of reservoir and dam geometry;

   The geometry of the bottom of reservoir was mapped using real cross-sections based on current bathymetric data. If bathymetric data was unavailable, artificial (so-called virtual) cross-sections were used. The geometry of the reservoir's head dam was mapped in the model as an overflow with a wide crest with parameters consistent with the current IGW.

2) Calibration of the reservoir's capacity curve;

   The basis for mapping the volume of the water reservoir was the reservoir's capacity curve. The reservoir's capacity curve was calibrated in the hydraulic model with the introduced geometry of the head dam closing the outflow from the reservoir, assuming a constant inflow to the reservoir. The calibration parameter was the storage area built by the reservoir's cross-sections between individual calculation levels (in Mike11 software from DHI, this parameter is called "additional retention area"). Reservoir capacity was calibrated for characteristic damming levels according to the current IGW.

3) Implementation of the principles of controlling the outflow from the reservoir;

   The control rules were mapped out by means of a system of logical conditions and tables linking the individual variables (e.g. damming ordinates on the reservoir, output of hydrotechnical structures, inflow to the reservoir). The module enabling this approach in DHI's Mike11 software is the "control structures" module included in the NWK11 river network file.

   Prior to implementing the control rules, data on the discharge of releases and overflows for all characteristic levels of the water level in the reservoir were prepared based on the information contained in the IGW.

   After introducing the outflow control principles in the model, the correctness of the individual procedures was checked. In particular, the maximum amount of the outflow was checked in relation to the maximum total output of the release devices for particular levels of water accumulation in the reservoir.

DETERMINING BOUNDARY CONDITIONS

The hydrodynamic model based on the Saint-Venanta equations takes into account upper and lower boundary conditions and optionally internal boundary conditions. Upper boundary conditions were defined in the form of flow hydrographs or water levels (water level ordinates). The lower boundary conditions closing the river channel network system, depending on the modelling assumptions, were the hydrograph of water level ordinates (in estuarial cross-sections), flow intensity curve or constant water level ordinate. For rivers entering the sea, the average sea level was taken as the lower boundary condition. Internal (concentrated and distributed) boundary conditions were given in the form of flow hydrographs or constant values.

Boundary conditions were prepared for calibration and verification of the model and calculations of probable water scenarios with probabilities of exceedance of p = 10%, p = 1%, p = 0.2%.

The basis for the flood scenarios were hypothetical waves, whose culmination corresponds to the value of flows with a certain probability of occurrence.

The boundary conditions for model calibration and verification for controlled watercourses were prepared using the hydrographs of selected historical surges.

Where a precipitation-drainage model was developed for the modelled catchment area, the results of this model for the relevant scenarios were used to develop boundary conditions.

CALIBRATION AND VERIFICATION

Calibration and verification were performed for controlled watercourses, i.e. those on which at least one water gauge post is located.

Calibration was performed by comparing the observed hydrograph (from the historical flood) with a calculative hydrograph (obtained from the model). The verification was carried out for a historical flood other than the flood for which calibration was performed.

For calibration and verification, flood waves from at least the two largest floods that have occurred in the last 30 years and that have complete and reliable hydrological data were used. Where floods were similar in size, more recent floods were preferred, especially if flow conditions in the river channel or valley have changed considerably.

PERFORMANCE OF MODEL CALCULATIONS

With a calibrated hydraulic model, model calculations were carried out for hypothetical waves with peaks corresponding to flows with a certain probability of exceedance for the assumed flood scenarios: 10, 1 and 0.2%.

Based on preliminary model calculations, the model correctness was reviewed in terms of e.g. length of cross-sections (valley cross-sections) in relation to the maximum water level obtained in the model, as well as the obtained water level layout and flow distribution in the longitudinal river profile.

8.2.1.2 TWO-DIMENSIONAL MODELLING (2D)

PREPARATION OF A DIGITAL TERRAIN MODEL

The basic element for the development of the two-dimensional model was to prepare computational bathymetry (DTM), correctly reflecting the topographic variability of the entire area, taking into account the factors influencing the flood hazard level (shape of the valley, tributaries, building development, coastal conditions). The range of the model was adjusted so that it is possible to carry out modelling for all flood scenarios of 10%, 1% and 0.2%. It was necessary to determine the optimum size of the model and its resolution, which was a compromise between the accuracy and the efficiency (time-consuming process) of calculations.

The size of the calculation cell was selected depending on the size of the area under consideration and its shape and was within the range of 2 to 10 m, and in justified cases above 10 m. a larger size of the calculation cell (15 m) was assumed for a large area of the calculation area and for high values of culminating flows, and thus the need to optimise the calculation time, and when it was required to maintain the digital stability of the simulation.

At the stage of preparing the 2D model, conversion of DTM (generalisation) to the resolution adopted in the given 2D model was performed, taking into account the correct mapping of linear structures (sometimes point structures – water structures, bridges), influencing the range of flood hazard areas.

Structures were considered in the 2D model using the following two solutions:

1) separation of buildings from the Digital Surface Model (DSM) or BDOT10k and implementing them into DTM;
2) recording the representation of buildings with BDOT10k in the form of appropriate values of coefficients on the raster of roughness coefficients (M=3.333 $m^{1/3} s^{-1}$).

DETERMINATION OF ROUGHNESS COEFFICIENT VALUE

The roughness coefficients value was determined in two-dimensional models in the same way as in one-dimensional modelling. Based on BDOT10k and DTM for the modelled area, zones/classes of land cover were determined and assigned coefficient values. In the first stage, the polygons with different roughness coefficient values were separated and then a raster file of roughness coefficients was created.

DETERMINATION OF BOUNDARY CONDITIONS

The boundary conditions in two-dimensional models were determined according to the procedures described for the construction of one-dimensional models.

Upper boundary conditions, distributed flows and concentrated inflows were introduced to the model using the options available in a two-dimensional model. The option to implement a flow for defined open limits of the model or a flow in the form of “source” point inflows was employed. The lower boundary condition closing the river channel network system, depending on the modelling assumptions, was a hydrograph or a constant value of water level ordinates for the receiver. For rivers entering the sea, an average sea level was assumed as the lower boundary condition.

CALIBRATION AND VERIFICATION

The calibration and verification of two-dimensional models was carried out according to the criteria described for the construction of one-dimensional model.

PERFORMANCE OF MODEL CALCULATIONS

Calculations with a two-dimensional model were made for hypothetical waves with culminations corresponding to flows with a certain probability of exceedance.

For the area of two-dimensional calculations, the result was a digital model of water level and flow velocity raster (applies to models for voivodeship cities and cities with poviat rights and other cities with more than 100 000 inhabitants).

8.2.1.3 HYBRID MODELLING (1D/2D)

PREPARATION OF 1D MODELS

The main assumption for preparing one-dimensional models for hybrid modelling was to limit the range of calculations to the riverbed (to the upper edge of the bank slopes) or to the crest of the embankments. In one-dimensional models, the distances between cross-sections usually did not exceed 50 m.

PREPARATION OF 2D MODELS

A two-dimensional model, being an element of a hybrid model, was created in a similar way as for the classical version of a two-dimensional model. An important element was to define the model's boundaries and exclude from calculations the area which was mapped in one-dimensional model.

COMBINATION OF 1D AND 2D MODELS

A two-dimensional model, which is part of a hybrid model, was combined with one-dimensional model. For this purpose, parallel (lateral) connections were used, operating on the principle of side overflows with a wide crest with an ordinate determined at the height of the banks (possibly a crest of embankments or similar structures). The area between the riverbank and the flood embankment was included in a two-dimensional model when it was possible to depict on a map at least a few symbols representing the directions of water flow, across the width of this area. In justified cases, standard connections were also used, based on the use of wide overflows located perpendicularly to the river valley, with ordinates consistent with the valley cross-section.

DETERMINATION OF BOUNDARY CONDITIONS

The boundary conditions in hybrid models were determined according to the procedures described for the construction of one-dimensional models.

CALIBRATION AND VERIFICATION

Hybrid models were calibrated and verified as per the criteria described for the calibration of one-dimensional models.

PERFORMANCE OF MODEL CALCULATIONS

Calculations with a hybrid model were performed for hypothetical waves with culminations corresponding to the flows with a certain probability of exceedance.

For hybrid models, the calculation results (in the axis of the watercourses covered by the one-dimensional model) are presented in .shp files containing water level ordinates – along the whole length of the model and flows – at the sections modelled only one-dimensionally. For the area of two-dimensional calculations, the result was a digital model of water level and flow velocity raster (applies to models for voivodeship cities and cities with poviat rights, as well as other cities with population over 100,000).

8.2.1.4 DETERMINATION OF FLOOD HAZARD AREAS

Flood hazard areas (OZP) and water depth zones were determined using GIS software, in the following stages:

1) Generating a Digital Water Surface Model (DWSM) and water depth raster;
2) Verifying water depth raster;
3) Determining OZP and depth zones;
4) Agreeing OZP at the connections of the modelling areas;
5) Final verification of water depth zones and OZP.

GENERATION OF DWSM RASTER AND WATER DEPTH RASTER

Flood hazard areas and water depth zones were determined on the basis of water level ordinates obtained from 1D and 2D hydraulic modelling.

In the case of 2D modelling, the results were in the form of DWSM raster, depth raster and water speed raster. In this form, they were further processed in GIS systems.

In the case of 1D modelling, the results were water level ordinates in the design sections (spatial linear layers with water level ordinate value assigned). Then, in order to obtain a two-dimensional plane with continuous information about the water level ordinate (DWSM raster), TIN interpolation was performed. In the process of DWSM generation, linear objects separating the main riverbed from floodplains were taken into account. In the next step, by subtracting the water level ordinates (DWSM) from digital terrain model (DTM), a water depth raster was generated. When reconciling the rasters at the interface of the inflow and the receiver, the DWSM rasters and the depth for the receiver were first developed. Next, the water level ordinates for the inflow were interpolated with considering the ordinates of the DWSM raster of the receiver from the accepted border (edge) of its zone range. If there was a need to combine the results of modelling developed in the first planning cycle with the results obtained in the second cycle, it was necessary to agree the contacts at the border of these studies by extending the recharge of the recipient upstream, assuming a constant ordinate. Details of these procedures are provided in chapter 6.2.4 Methodology for the development of FHM and FRM in the second planning cycle, attached as Annex 1 to this Report.

VERIFICATION OF WATER DEPTH RASTER

Initially, the verification of the water depth raster was carried out by analysing and eliminating the identified errors in the form of irregularities in DTM. In the next step the water depth grid was reclassified to four water depth classes (0-0.5 m; 0.5-2 m, 2-4 m; over 4 m). The result of the reclassification was automatically generalized in order to remove noise from the raster image using appropriate filters. Finally, the water depth raster was smoothed out twice (generalization in the range of raster data) by removing so called noise from the raster images after classification by means of majority filter.

DETERMINATION OF FLOOD HAZARD AREAS AND WATER DEPTH ZONES

By converting the water depth raster (at the external borders of individual depth classes) into a vector form, using the preliminary algorithm of edge smoothing, the working water depth fields were obtained. Their external envelope was the initial boundary of flood hazard areas. These polygons were subjected to further topographical verification, consisting in a visual check of the created flood zone and the process of rejection of areas which had no hydraulic connection with the main riverbed. The next step was to simplify the geometry of water depth and flood hazard areas in order to eliminate "teeth" and "loops" structures and the effect of sharp line breaks. Subsequently, the depth zones were generalised. The generalisation of water depth polygons was carried out in order to reduce the size of files and the number of vertexes. It was performed using the ET Geowizard – Generalize Polygons tool with the parameter 0.5 or with the Simplify Polygons tool. The roundness of the depth polygons is maintained at a scale of 1:1000, and the maximum deviation from similar polygons in the first cycle is no more than 0.5 m. In the process of generalisation of vector water depth classes, the polygons with an area of less than 400m² were aggregated to adjacent, larger polygons. If there was no neighbouring one, the polygon not meeting the surface criterion was removed. An analogous approach was used for small (less than 400 m^2) "holes" and "islands" within the depth classes. Next, the area of the riverbed was cut out of the smoothed water depth polygons with a mask representing the range of still and flowing waters during normal hydrological conditions (surface water layer with BDOT10k). Finally, as an outer perimeter of the depth zones in the given scenario, a flood hazard area was generated. In addition, flood hazard areas were removed in sections including artificial reservoirs.

ARRANGING THE OZP AT THE INTERFACES OF MODELLING AREAS

The compatibility at the interfaces of the modelling areas was primarily ensured by the results of hydraulic modelling, through the correct and consistent adoption of water level ordinates at the model boundaries as boundary conditions and the transfer of these ordinates between models. This approach ensured that the developed DWSM rasters and water depths were initially consistent, which was finally determined during the contact alignment phase. After conversion of the rasters into vector form of flood hazard areas and water depths, additionally, the resulting polygons were verified.

FINAL VERIFICATION OF WATER DEPTH ZONES AND OZP

The final verification of water depth zones and OZP were checked for topology and consistency between the different scenarios.

8.2.2 SUMMARY OF THE METHODOLOGY FOR FLUVIAL FLOODS (DESTRUCTION OF FLOOD EMBANKMENTS)

The scenario of total destruction of the flood embankment was performed for all embanked rivers indicated in the preliminary flood risk assessment. According to the Regulation, the flood hazard areas for this scenario were determined for a flow with a 1% probability of occurrence.

The scenario of total destruction of the flood embankment was developed using one of the two methods described below. The choice of the method depended on specific topographical, hydrographic and hydrological conditions of river valleys.

FIRST METHOD

The first method consisted in using the results of hydraulic modelling for Scenario II – areas with a medium probability of flooding of 1% (once every 100 years). For this purpose, the maximum water level ordinates resulting from modelling were used to determine the OZP. The ordinates of the water level calculated for the riverbed zone were transferred to the parallel area of the dam. For this purpose, sets of extended riverbed cross-sections were prepared to match the shape of the river valley. The further development of the results is in line with the methodological description for the other fluvial flood scenarios.

SECOND METHOD

In the case of "flat" and vast river valleys or rivers, whose area on the embankment was significantly below the embankment, additional hydraulic modelling was used. The models developed for this scenario were built in accordance with the guidelines for models developed under the baseline scenarios described in section 7.2.1.

The flood hazard area is determined by removing one-sided embankments (separately for each bank). In the first stage, the left-hand embankment is removed and hydraulic modelling is performed, and the calculations are repeated after the right-hand embankment is removed.

The process of determining the flood hazard areas is the same as for the other river scenarios.

8.2.3 SUMMARY OF THE METHODOLOGY FOR SEA WATER FLOODS (NATURAL EXCEEDANCE)

The FHM from the sea water, including internal marine waters, made in the first planning cycle, were developed based on the results of mathematical calculations of hydrodynamic models in unsteady flow. The models developed at that time served as a basis for verifying, updating or creating new maps in the second planning cycle.

Two-dimensional (2D) and hybrid (1D/2D) models were developed to determine the flood hazard areas from the sea water. The calculations were made using unsteady flow conditions. Modelling was carried out using DHI's MIKE software (Mike21, Mike Flood, Mike FM).

For each area, a careful analysis of its hydromorphological conditions was carried out and; on this basis, an appropriate type of modelling was selected so that the range of the model could be obtained in the shortest possible time, while maintaining the reliability of the results and the precision of mapping. Due to the specificity of the modelling of flood hazard from the sea water (large spatial character of the marine coastal condition), it was advisable to use two-dimensional or hybrid models.

According to the Regulation for floods from the sea water, including internal sea waters, no FHM was carried out at the speed and direction of water flow.

A detailed description of the methodology for modelling flood risk from the side of the sea and internal sea waters is included in the Methodology for developing FHM and FRM from the sea water in the second planning cycle, attached as Annex 2 to the report.

A summary of the applied hydraulic modelling methodology is presented below, in the following steps:

1) Preparing computational bathymetry;
2) Identifying important hydrotechnical structures;
3) Establishing the initial conditions;
4) Determining the roughness coefficient value;
5) Determining boundary conditions;
6) Calibration and verification;
7) Performing model calculations of flood scenarios.

In the case of hybrid modelling, in addition to those mentioned above, the following steps of model preparation are distinguished: schematisation of the river network in 1D model, introduction of cross-sections into 1D model, definition of connections at the interface between 1D and 2D models.

8.2.3.1 TWO-DIMENSIONAL MODELLING (2D)

PREPARATION OF COMPUTATIONAL BATHYMETRY

The most important element in the development of the two-dimensional model was to prepare the computational bathymetry in such a way that it correctly reflects the topographical variability of the entire area. The range of the model was determined in such a way as to ensure correct modelling for all flood scenarios.

The determination of the optimal size of the model and its resolution (the size of the grid element) was determined by the lay of the land and the degree of complexity of the river network designated for analysis, the location of the water level gauge stations, the possibilities of available hardware and software and constituted a compromise between the accuracy and time-consuming calculations.

Two types of grids were used in two-dimensional models: regular and irregular ones. The maximum size of the orthogonal grid did not exceed 200 m^2 and ensured the depth precision of +/- 10 cm. In models with irregular computational grids, the places of compaction (narrow riverbed) or dilution of grid elements (sea fragment, large lake) were determined manually. In land areas, the size of the grid element ranged from 10 m^2 to 200 m^2, and in large basins from 1000 m^2 to 3000 m^2.

The generalisation process of the digital terrain model consisted in averaging the ordinates to the resolution adopted in a given 2D model. It was thus possible to lose or distort some important altitude data, hence preparatory actions appropriate for the selected type of the grid were taken in prior.

The buildings were considered using two solutions:

1) extracting buildings from the Digital Surface Model (DSM) or BDOT10k and implementing them into the DTM developed for modelling purposes;
2) recording the representation of buildings with BDOT10k in the form of appropriate values of coefficients on the roughness gradient ($M=3.333\ m^{1/3}\ s^{-1}$).

The complete terrain model was obtained by adding information on important hydrotechnical structures and the shape of the seabed and riverbed based on available sources.

The so developed DTM was prepared in the form of files *. xyz or *. asc, in the National Geodetic Coordinate System (PUWG 1992) and the Kronstadt 86 geodetic height system (PL-KRON86-NH).

IDENTIFICATION OF IMPORTANT HYDROTECHNICAL STRUCTURES

Natural and technical facilities protecting areas against flood and structures allowing THE free flow of flood water in field (culverts, viaducts, etc.) were identified and included in the model by analysing the available data.

Two methods were applied:

1) DTM update by GIS processing;
2) entering objects directly into a hydrodynamic model, using the dedicated Structures module.

DETERMINATION OF INITIAL CONDITIONS

The initial hydrological and wind conditions were assumed in the form of variable or constant conditions depending on the area where the given model was located. The time of initial calculations depended on the stabilisation of levels and flows in watercourses and in the sea water body in question. The aim was to make the transition to calculations on a hypothetical wave for a given flood scenario as smoothly as possible. This ensured that the model was stable and the calculations presented were correct.

DETERMINATION OF ROUGHNESS COEFFICIENT

The basic parameter describing the flow resistance is the roughness coefficient. This coefficient was presented two-dimensionally for the modelling area. For inland watercourses in their wet cross-sections, it was determined on the basis of land cover codes, recorded by field crews performing river cross-section measurements. In other cases (land areas), roughness coefficients were taken from the Topographical Object Database or own studies if BDOT for the area in question was not available. The classes were assigned the appropriate value of Manning coefficient M [$m^{1/3}/s$] according to Ven Te Chow tables. The roughness coefficients' raster was adjusted in terms of resolution and ranges to the calculation bathymetry. Verification and possible correction of the roughness coefficient was made at the model calibration stage.

DETERMINATION OF BOUNDARY CONDITIONS

The boundary conditions in two-dimensional models were introduced globally (wind speed and direction) or with location indication (water level or flow).

In the first stage of introducing the boundary conditions, the model limits were set. In places where no water transfer was to take place, closed borders were established, i.e. cells were blocked by giving them high ordinate values. In the sections where water flow was to occur, open borders were introduced, i.e. the value of cells was determined according to the calculation bathymetry. At open borders, the boundary conditions of the model were placed. For the sea and internal sea waters, the coastline condition was a time variable sea level determined for the nearest water indicators (directly or by interpolation). For watercourses, a boundary condition was introduced as a constant flow value.

Boundary conditions for model calibration and verification were prepared based on hydrographs of the largest historical storm floods over the last 15 years.

The basis for the construction of flood scenarios were hypothetical waves, the culmination of which corresponded to levels with a probability of exceedance of 1% and 0.2%, calculated using statistical methods on the basis of data on maximum annual water levels for the last 30 years (1987-2016).

A boundary condition for the side of the rivers that had to be taken into account in the second planning cycle was located to exclude the effect of backwater from the time-varying sea level with a probability of exceedance of 0.2% and to represent a constant medium flow of SSQ in estuarial river sections (calculated over the last 30 years).

Sea levels with a certain probability of exceedance were determined taking into account the impact of the sea (wave) and the increase in the sea level along the Polish Baltic coast caused by climate change according to A2emission scenario.

A detailed description of the preparation and development of hydrological data for hydraulic modelling is provided in Chapter VII of the Methodology for the development of FHM and FRM from the sea water in the second planning cycle, attached as Annex 2 to the report.

Statistical methods relied upon on the recorded maximum annual water levels, without any relation to the actual cross-sectional shape of the riverbed and the adjacent valley. Therefore, for such complex areas exposed to flooding in terms of terrain morphology, such as the Żuławy, the result obtained from the hydraulic model had to be taken for water indicators.

The wind parameter was taken into account in the model with two solutions:

1) as a value of direction and speed constant over time (from the beginning to the top of the exceedance), where the direction was defined perpendicularly to the bank line and the speed was 10 m/s;
2) as the waving component taken into account in the calculation of levels with a certain probability of exceedance.

CALIBRATION AND VERIFICATION

The model was calibrated by iterative adjustment of the roughness coefficient using bank line conditions in the form of levels recorded for storm floods at selected mareograms and/or water level gauges in estuarial river sections. For the rivers entering the sea, a boundary condition was introduced in the form of recorded flow (calculated according to the flow intensity curve) for a selected water level gauge (with possible correction of the flow depending on the distance from the water level gauge). Additionally, a boundary condition was applied in the form of a time variable: direction and speed of the wind (alternatively, atmospheric pressure variable over time and space). The same method was applied for model verification, however, on the basis of a different storm surge than the one used for calibration.

For the part of the coast administered by the Maritime Office in Gdynia, due to the specificity of the coastline and location of the mareographers, a two-dimensional large-area model with an irregular grid was built. By obtaining the correct calibration results, it was possible to apply the same coefficients for models with smaller dimensions of regular grid elements, for which it was not possible to perform calibration calculations due to the lack of at least 2 mareographers in their area.

For the part of the coastline administered by the Maritime Office in Szczecin and the Maritime Office in Słupsk, due to the specificity of the models and the type of input data taken into account, the so-called “expert calibration” was carried out, consisting in iterative selection of roughness coefficients, in order to obtain results that will describe the character of the area being modelled as closely as possible to reality. The assessment was made by comparing water ranges in the model with possible probable water ranges caused by water with registered level ordinates. Moreover, depending on the results obtained, irregular calculation grids were modified, including their detail level; fragments of the grid were zoomed in our out (e.g. in the place of the riverbed, embankment, lakes) and the time step was changed to obtain comparable results due to small changes of input data, with the first planning cycle.

Two-dimensional models were calibrated and verified in line with the criteria described in the FHM methodology, attached as Annex 1 to the report.

PERFORMANCE OF MODEL CALCULATIONS

Calculations with the two-dimensional model were made for hypothetical waves with the culminations corresponding to levels with a probability of exceedance of 0.2% and 1%. If there was a river boundary condition, it was the value of medium flow from the last 30 years (SSQ) for the section starting the model.

The result of calculations in a regular grid was a *.dfs2 file containing information about maximum water level ordinates and depths in each cell of the grid. These were *.dfsu files in an irregular grid, which contained information about the maximum depth and speed of water and the ordinate of flood zone in each element of the calculation grid.

If discrepancies arose for the obtained digital water surface models in adjacent areas, it was necessary to change the boundary conditions of the models and to perform calculations again. In cases particularly difficult to agree on a digital water surface model at the interface between the results of two models, the acceptable margin of ordinate difference up to 10 cm was assumed.

8.2.3.2 1D/2D HYBRID MODELS

The decision to use a hybrid model, consisting of a one-dimensional model for watercourse riverbeds and a two-dimensional model for a body of water and floodplains, was taken when:

1) the resolution of the two-dimensional model did not allow for precise characterisation of the bottom of the watercourse;
2) the section of the river that goes into the sea required the area of the two-dimensional model to be enlarged in a way that significantly lengthens the calculation time;
3) inland coastal areas were identified to which there has been a transfer of flood hazard from the sea or internal sea water via the river mouth.

PREPARATION OF 1D MODELS

The stages of building a standard one-dimensional model, considering the introduction of important hydrotechnical structures, are described in detail in chapter 7.2.1.1.

The preparation of a 1D model for hybrid modelling required limiting the range of calculations to the riverbed (to the upper edge of the bank slopes) or to the top of the embankment and the correspondingly dense distribution of cross-sections. The distances between the cross-sections usually did not exceed 50 m. It was allowed to locate the cross-sections more rarely if it did not affect the correctness of model calculations. The river network was schematised on the assumption that the model area had to cover the maximum range of backwater.

PREPARATION OF 2D MODELS

A two-dimensional model, which is an element of the 1D/2D model, was prepared in the same way as for the standard version of the two-dimensional model. For the purpose of hybrid modelling, the model boundaries were properly defined and the calculation bathymetry was modified, by excluding from calculations the area which was mapped in the one-dimensional model (to avoid the duplication of calculations).

COMBINATION OF 1D AND 2D MODELS

Two types of connections were used:

1) lateral – connections parallel to the riverbed, operating as side overflows with a wide top, with the ordinate determined at the height of the banks (possibly the top of embankments or similar structures);
2) standard – connections perpendicular to the riverbed (frontal), based on the use of wide overflows with ordinates consistent with the valley cross-section.

DETERMINATION OF BOUNDARY CONDITIONS

The boundary conditions for the one-dimensional model (in the form of variable or constant flows over time) were placed at such a distance from the connection with the two-dimensional model that there was no backwater effect on the set flow. The method of determining the boundary conditions for one-dimensional models is described in detail in Chapter 7.2.1.1. Boundary conditions for a two-dimensional model in the form of sea levels variable over time or internal sea waters were determined by analogy with the standard 2D model.

CALIBRATION AND VERIFICATION

The calibration and verification of the hybrid models was carried out as described in section 7.2.3.1. in accordance with the criteria described in the methodology of the FHM, attached as Annex 1 to the report.

PERFORMANCE OF MODEL CALCULATIONS

Calculations with a hybrid model were performed for hypothetical waves with peaks corresponding to levels with a probability of exceedance of 0.2% and 1% according to the rules described in chapter 7.2.3.1. The upper boundary condition is defined as a hydrograph of medium water flows. As the lower boundary condition, a hypothetical storm flood wave (hydrograph of water level ordinates), was assumed. For the area of two-dimensional calculations, the result is a *.dfs2 file containing information about maximum water level ordinates and depths. For one-dimensional calculation area, the result are *.res11 files containing information about maximum water level ordinates and flows in calculation sections. 1D results, after transferring appropriately to a linear layer of cross-sections in a *. shp file, were the basis for developing a digital water surface model.

8.2.3.3 DETERMINATION OF FLOOD HAZARD AREAS

Flood hazard areas (OZP) and depth zones were determined using GIS software in the following steps:

1) Generating a digital water surface model (DWSM) and water depth raster from 2D modelling results as *.dfs2 or * file. dfsu and, in case of hybrid models, based on a previously created linear *. shp layer containing the results of 1D modelling;
2) Verifying a water depth raster;
3) Determining the OZP and depth zones;
4) Determining the OZP at the connections of the modelling areas;
5) Final verification of water depth zones and OZP.

For a detailed description of the procedure, see Chapter 7.2.1.4.

The spatially adjacent rasters of the digital water surface model contained a sufficiently large common part to obtain comparable results at the boundaries of the areas, but in cases particularly difficult to agree on, a margin of ordinate difference of up to 10 cm was accepted.

All the activities carried out within the framework of the OZP from the sea water, including internal sea waters, were described in the reports for the areas administered by the Maritime Office in Gdynia, Słupsk and Szczecin respectively, provided as Annexes 7-9.

8.2.4 SUMMARY OF THE METHODOLOGY FOR SEA WATER FLOODS (DESTRUCTION OF FLOOD OR STORM EMBANKMENTS)

After obtaining the calculations for the natural flooding scenarios, a scenario of destruction or significant damage to the elements forming the bank protection system (beaches, dunes, cliffs, storm embankments, wharves, etc.) was prepared.

The OZP, due to the complete destruction of the mentioned structures, were determined by modelling in unsteady flow for levels with a 1% probability of occurrence after the completely removing the flood protection objects, independently for left and right embanked area of the river or body of water. Hydraulic simulation was carried out with the use of models with parameters such as those in the natural flooding scenario. If there was a river boundary condition, it was the value of medium flow from the last 30 years (SSQ) for the section starting the model.

8.2.5 SUMMARY OF THE METHODOLOGY FOR FLOODS FROM DAMMING STRUCTURES

The basis for determining the areas exposed to flooding in the event of damage or destruction of damming structures were hydraulic models based on unsteady flow, i.e. based on hydrographs of flood waves with a certain probability of maximum flow. Only for the section of the Oder River affected by the failure of the Turawa, Nysa and Otmuchów reservoirs, was this model based on steady flow. In most cases, models developed for the FHM and FRM for fluvial flooding were used. Calculations were based on a 1D model (Mike 11) or, in some cases, a combination of 1D and 2D models (hybrid model, Mike Flood). A water reservoir model was an integral part of the hydraulic model.

8.2.5.1 HYDRODYNAMIC MODEL OF DAM DISASTER

MAPPING OF THE RESERVOIR BOTTOM AND DAM SHAPE

The description of the geometry of the bottom of the reservoir was based in most cases on the reservoir's capacity curve, and in some cases on the cross-sections derived from bathymetric measurements (Mietków, Chańcza). The reservoir's capacity was calibrated for at least the characteristic damming levels: NPP, MaxPP and for the level corresponding to the ordinate of the dam top, taking the current reservoir capacity curve as the reference.

The reservoir's head dam was implemented as an overflow with a wide top, with parameters corresponding to the facility's real characteristics.

RULES FOR CONTROLLING THE OUTFLOW FROM THE RESERVOIR

The reservoir's operation was described in line with the flood management manual and the assumptions made about the failure of the release equipment. The control rules were introduced to the 1D model using the CONTROL STRUCTURE function.

DAM DISASTER MODEL

For particular variants of the disaster, assumptions were made about hydrological conditions, the initial filling of the reservoir and parameters of the simulated dam failure. Damage parameters of the dam were implemented in the calculation structure responsible for disaster mapping (DAMBREAK STRUCTURE in 1D model). The implementation consisted in introducing the calculation parameters concerning:

- the location of the damage in relation to the body, i.e. location of the break (for an earth dam) or a damaged section of the dam (for a concrete dam);
- damage geometry (maximum width in the bottom, target bottom ordinate of the break, gradient of side walls);
- resistance coefficients for water flow through the damaged part of the dam body;
- the moment or conditions determining the start of the dam disaster process (e.g. a disaster when the reservoir reaches a certain level of accumulation);

– the way of describing the phenomenon of formation and spatial development of the damage (time series – for concrete dam damage, erosion formulas – for earth dam damage);
– the cause inducing the disaster (overflowing through the top, hydraulic puncture).

For the simulation of an earth dam's disaster using erosion formulas, the basic physical and mechanical characteristics of the soil of the dam body were also determined.

In addition, because of the need to define the initial boundary conditions for the calculation of the formation of the breakthrough or hydraulic puncture line over time, the initial parameters of these structures, i.e. the initial width and the ordinate of the breakthrough bottom in the dam body or the initial diameter of the puncture line and its ordinate, were defined.

Detailed information on the considered variants of the disaster for particular damming structures is included in the report for the development of FHM and FRM for damming structures (2021), provided as Annex 10.

8.2.5.2 HYDRODYNAMIC MODEL OF THE VALLEY BELOW THE DAM

PATTERN OF THE VALLEY

Schematisation in a one-dimensional model is intended to take into account in the model those characteristics of the river valley impacting the transformation of extreme flows, with omitting the insignificant details such as small embankments, meanders and bends. This process was carried out for the reservoirs from the first phase of the works. In the second phase, models developed for the FHM and FRM for fluvial flooding were used.

CROSS-SECTIONS

Cross-sections of the riverbed and adjacent areas were obtained by means of geodetic measurements. A DTM was used to obtain valley cross-sections. The cross-sections were located perpendicularly to the main direction of the valley, i.e. perpendicular to the course of contours on the main slopes delimiting the river valley. In hybrid models, combining the elements of one-dimensional and two-dimensional modelling, the cross-sections from the 1D model were agreed with the calculation grid of the two-dimensional model. Cross-sections prepared for river flood simulations supplemented by DTM as necessary were used.

IDENTIFICATION OF HYDRAULIC PARAMETERS

The basis for determining the roughness coefficients were land cover classes, determined at the stage of surveying or such separated on the basis of BDOT10k, orthophotomaps and other available materials. The land cover classes were assigned appropriate values according to Ven Te Chow. In some cases, due to high flow and velocity values directly below the dam, the Manning roughness coefficient of n = 0.1 was assumed for the 10 km distance directly below the dam.

Roughness coefficients implemented in the model were verified during the calibration process.

ENGINEERING STRUCTURES

The impact of hydrotechnical structures such as weirs, steps, bridges or culverts, especially those located near the dam, on the catastrophic flows resulting from the dam disaster is not significant. However, due to the calibration and verification of the model on historical waves, these structures were introduced into the model. For the purpose of building a hydraulic model, information on engineering structures inventoried during surveying works was used.

BOUNDARY CONDITIONS

In the developed models, the upper boundary condition was the hydrograph of inflow to the reservoir, usually a wave with the culmination equal to the control flow of the dam. The lower boundary condition, closing the model, depending on the modelling assumptions, was the water level hydrograph or flow intensity curve. Internal boundary conditions (concentrated and distributed inflows) were assumed to be mostly identical to the $Q_{0.2\%}$scenario. In some cases, lateral inflows were assumed on the receiving watercourse where the analysed damming structure was located as in the $Q_{10\%}$ scenario (lateral inflows of the Oder River in steady flow models for reservoirs: Nysa, Otmuchów and Turawa).

CALIBRATION AND VERIFICATION

For hydraulic models built for the analysis of the transformation of the flood wave caused by the dam disaster, the process of calibration and verification of the model is performed only to check the general principles of its operation, i.e. to determine whether the model properly transforms the flows down the valley and whether the relations between the values of levels and flows at individual control points (water gauges) is maintained. The flows caused by the dam disaster are many times higher than the flows associated with typical floods, caused by precipitation, hence calibration of the model for such high flows is impossible, due to the lack of appropriate historical waves.

Due to the use of the models developed for the FHM and FRM for fluvial flooding, in most cases the calibration process was carried out as part of work relating to fluvial flows. The models were calibrated and verified for large historical exceedances, selecting 2 exceedances for each reservoir.

8.2.5.3 DETERMINATION OF FLOOD HAZARD AREAS

Maps presenting flood hazard areas with water depth are the final result of calculations simulating the disaster of a damming structure.

Flood hazard areas were determined by creating a Digital Water Surface Model (DWSM) based on the results of hydraulic modelling. Flood hazard areas and the distribution of water depth can be determined by combining a Digital Water Surface Model with a Digital Terrain Model in GIS systems.

8.3 METHODOLOGY FOR THE DEVELOPMENT OF FLOOD RISK MAPS

The flood risk maps present the potential negative impacts associated with flooding by determining:

1) adverse consequences for human life and health;
2) types of economic activities;
3) protected areas;
4) objects that pose a threat to the environment in the event of flooding, including those that may negatively affect human health;
5) cultural heritage areas and sites;
6) values of potential flood damages.

The methodology for presenting flood risk is uniform for all types of floods. A detailed description of the methodology for the development of flood risk maps is given in the Methodology for the development of flood hazard maps and flood risk maps in the second planning cycle, attached as Annex 1 to the report.

8.3.1 POTENTIAL NEGATIVE EFFECTS ON HUMAN LIFE AND HEALTH

Adverse consequences for the population were identified by presenting the following on the maps:

– estimated number of inhabitants likely to be affected by the flood;
– residential buildings and facilities of social importance, together with the water depth determining the degree of hazard to the population.

The FRM presents an estimated number of people living in buildings located in a flood hazard area in a given locality.

The number of people inhabiting a given building was estimated with GUS statistics, i.e. the average number of people per dwelling in the municipality and the Address Identification of Streets, Real Estates, Buildings and Dwellings (NOBC) register from which tabular information on the number of dwellings located at a given address was obtained.

The FRM also presents facilities of particular social importance, whose operation may be difficult or impossible due to the occurrence of floods, i.e.: hospitals, sanatoriums, schools, kindergartens, nurseries, police and fire protection units, Border Guard units, social care centres, nursing homes, hospices, shopping and service centres, market halls, hypermarkets, penitentiary, correctional or custodial facilities, hotels, motels, inns, guest houses, holiday homes and children's homes, care facilities, boarding schools, school dormitories, student houses, workers' homes, houses for the homeless, monasteries, parish houses.

Information on the nature of the facility was obtained from BDOT10k and relevant institutions dealing with the issue.

For each residential building and facility of particular social importance, the average water depth was determined separately for each of the flood scenarios, classified in two ranges:

– water depth less than or equal to 2 m,

– water depth greater than 2 m.

The limit value of the water depth of 2 m was established in connection with the adopted water depth ranges and their influence on the degree of hazard to the population and the buildings.

8.3.2 TYPE OF ECONOMIC ACTIVITY

In order to determine the types of economic activities, the land use classes were indicated in the Regulation, i.e.:

1) residential areas;
2) industrial areas;
3) transport areas;
4) forests;
5) recreational areas;
6) arable land and permanent crops;
7) grassland;
8) other areas;
9) surface water.

The land use classes were developed on the basis of relevant classes of objects from the topographic objects database.

The FRM also presents buildings with a specific function, from which the type of economic activity also derives.

Additionally, industrial plants were divided into categories of activity: energy, production and processing of metals, mineral, chemical, waste management and other activities (production and processing of paper and wood, intensive rearing of poultry and pigs, production and processing of plant and animal raw materials), according to the division from Annex 1 to Directive 2010/75/EU on industrial emissions - IED.

8.3.3 PROTECTED AREAS

The FRM presents the protected areas listed in the Regulation, including the areas indicated in Annex IV, point 1 (i), (iii) and (v) to Directive 2000/60/EC (Water Framework Directive - WFD), i.e.:

1) surface water and groundwater abstractions – including those for human consumption (designated under Article 7 of WFD);
2) water abstraction protection zones;
3) bathing waters included in the list referred to in Article 44, paragraph 2 of the Water Law Act;
4) forms of nature protection: national parks, nature reserves, Natura 2000 areas divided into special areas of habitat protection (SACs) and special bird protection areas (SPAs);

5) zoos.

Information about these objects was obtained from the Topographical Object Database or relevant institutions dealing with the issue.

8.3.4 FACILITIES THAT POSE AN ENVIRONMENTAL THREAT IN THE EVENT OF FLOOD, INCLUDING THOSE THAT MAY NEGATIVELY AFFECT HUMAN HEALTH

In accordance with the Water Law Act (Article 170, paragraph 2, point 3), the FRM shows installations which in the event of flooding may cause significant pollution of individual natural elements or the environment as a whole.

These are installations for which an integrated permit is required to be obtained within the meaning of the Act – Environmental protection law (in accordance with the division from Annex 1 to Directive 2010/75/EU on industrial emissions – IED) in the following categories of industrial activity:

1) energy industry;
2) production and processing of metals;
3) mineral industry;
4) chemical industry;
5) waste management;
6) other activities including
   - production and processing of paper and wood,
   - intensive rearing of poultry and pigs,
   - production and processing of plant and animal raw materials.

An integrated permit is required to operate an installation whose operation, due to the type and scale of its activity, may cause significant pollution of individual natural elements or the environment as a whole. Types of these installations are specified in the Regulation of the Minister of Environment on the types of installations which may cause significant pollution of particular natural elements or the environment as a whole.

Moreover, the FRM presents industrial plants whose installations do not require an integrated permit and which may pose a hazard, including plants posing a threat of a serious industrial accident within the meaning of the Act – Environmental protection law (in accordance with Directive 2012/18/EU on the control of major accident hazards involving dangerous substances, also called the Seveso III Directive), i.e.:

1) plants with a higher risk of a major industrial accident and
2) plants with a high risk of a major industrial accident.

Additionally, the FRM presents, in accordance with the Regulation, potential water pollution sources, i.e.:

1) wastewater treatment plants;

2) wastewater pumping stations;
3) landfills;
4) cemeteries.

Information about the objects was obtained from the Topographic Objects Database and relevant institutions dealing with the issue.

8.3.5 CULTURAL HERITAGE AREAS AND SITES

In accordance with the Regulation, the following cultural heritage sites are presented on the FRM:

1) immovable heritage areas and sites, in particular those covered by forms of protection of the monuments in the Act on Protection and Care of Monuments;
2) monuments included in the World Heritage List, referred to in the Convention for the Protection of the World Cultural and Natural Heritage;
3) extermination monuments referred to in Article 2 of the Act on the Protection of the Grounds of Former Nazi Death Camps;
4) open-air museums and museums entered in the National Register of Museums referred to in the Act on Museums;
5) libraries with collections constituting the national library resource referred to in the Library Act;
6) archives with collections constituting the national archival resource referred to in the Act on National Archival Resource.

The source material for identification of the above-mentioned objects were mainly the resources of the National Heritage Institute including, in particular, immovable monuments, as well as additionally:

1) UNESCO World Cultural and Natural Heritage List;
2) list of libraries indicated in the Regulation of the Minister of Culture and National Heritage of 4 July, 2012 on the national library resource;
3) list of state archives;
4) list of extermination monuments indicated in the Act on the Protection of the Territories of Former Nazi Death Camps;
5) National Register of Museums.

8.3.6 VALUES OF POTENTIAL FLOOD DAMAGES

The calculations of potential flood damages were made for seven land use classes:

1) Class 1 – residential areas;
2) Class 2 – industrial areas;
3) Class 3 – transport areas;

4) Class 4 – forests;
5) Class 5 – recreational areas;
6) Class 6 – arable land and permanent crops;
7) Class 7 – grassland.

For other areas and surface waters, potential flood damages are not calculated due to lack of use or small land use. A detailed description of the methodology for calculating the value of potential unit losses and the method of estimating the potential losses for particular land use classes was included in the Methodology for the development of FHM and FRM in the second planning cycle, provided as Appendix 1 to the report.

CLASS 1 – RESIDENTIAL AREAS

Depending on how the floods affect, potential flood damages in class 1 were divided into two types:

– direct damages – including damage to real estate, loss of or damage to property, destruction or damage to technical infrastructure around buildings (yards, playgrounds, pavements, squares, livestock buildings);
– indirect damages – including expenditure on the clean-up of the damage.

Potential flood damages in class 1 are the sum of direct and indirect damages.

The value of potential direct unit damages in PLN/m^2 was calculated on the basis of the value of assets in housing estates and the value of the loss function, determining the degree of impairment of assets, depending on the water depth. To determine the value of potential direct unit damages for class 1, the data of the National Bank of Poland (NBP) from 2016 and the Central Statistical Office (GUS) were used. The calculation was made using the method proposed by I. Godyń [2016] to determine the indices of property values in residential areas for individual voivodeships.

The value of indirect damages estimated according to J. Chojnacki [2000] as a percentage of direct loss was added to the direct loss calculated above. The division was made because the value of damages varied depending on the density of residential buildings. The following values of indirect damages were assumed for class 1:

– for dense housing – 80% of direct damage;
– for dispersed housing – 40% of direct damage.

CLASS 2 – INDUSTRIAL AREAS

Depending on how the floods affect, potential flood damages in class 2 were divided into two types:

– direct damages – including damage and/or loss of fixed assets and current assets, loss of documentation, archives;
– indirect damages – including expenditure on clean-up, expenditure relating to the transfer of movable property, damages in production/interruption of the production process.

Potential flood damages in class 2 are the sum of direct and indirect damages.

Individual direct damages were calculated on the basis of the value of assets for industrial areas and the value of the loss function determining the degree of impairment of assets, depending on the water depth.

The value of assets for industrial areas was calculated by dividing the gross value of fixed assets for industry by the area of industrial areas. The calculations were made by voivodeship, using GUS data from 2016 on the area of industrial areas and the gross value of fixed assets. Due to the lack of uniform spatial data on the type of industry and the lack of possibility to determine the value of current assets as a measure of direct damages, the gross value of fixed assets in individual voivodeships was assumed to be related to the area of industrial areas.

According to A. Symonowicz [Chojnacki 2000 for Symonowicz 1969], the number of indirect damages in individual sectors of the economy can be estimated in the range of 50-100% of direct damages. An additional surcharge was accepted by agreement for industrial areas as an indirect loss in the form of 80% of the direct damages value.

CLASS 3 – COMMUNICATION AREAS

The value of communication areas was calculated on the basis of indexation of the value of assets in transport areas, valid in the first planning cycle, specified in the regulation on the development of FHM and FRM of 2012.[6] The value of the potential unit loss in 2008 was 436 PLN/m^2. The indexation was made with the index of the increase in the value of fixed assets in Poland in the current registered prices (GUS). It was calculated in percentages in relation to 2008 (to which the value of assets in the 2012 regulation referred to) and is 64%. The value of transport areas from 2008 was indexed by the amount of the index and is 717 PLN/m^2 for 2016.

Individual direct damages were calculated on the basis of the value of assets in the traffic areas and the value of the loss function determining the degree of impairment of assets depending on the water depth.

CLASS 4 – FORESTS

The potential unit damage for this class is difficult to determine. Flood damages depend primarily on the duration of the flood, the age of the tree stand, the type of natural habitat, the condition of the tree stands before the occurrence of the flood phenomenon and many other factors. In addition, undergrowth and forest infrastructure may also be damaged. Flooding also has a negative impact on fauna living in forest areas. It is extremely difficult to identify intangible damages – in non-productive assets, e.g. damages in public functions of the forest, e.g. protective role of forests.

For the purpose of developing the FRM, the potential unit damages for this class was determined on the basis of data from the General Directorate of State Forests and the German LTV publication [2003].

[6]The regulation from 21 December, 2012 of Minister of the Environment, Minister of Transport, Construction and Maritime Economy, Minister of Administration and Digitization and Minister of the Interior on the development of FHM and FRM (Journal of Laws 2013, item 104) expired on the date of entry into force of the Regulation of the Minister of Maritime Economy and Inland Navigation of 4 October, 2018 on the development of FHM and FRM (Journal of Laws 2018, item 2031).

Using the "State Treasury Property Report as of 31.12.2016", the average value of 1 ha of forest (wood stock) was calculated. For 2016, it amounted to 40,807 PLN/ha. Based on the "National Flood Damage Evaluation Methods" publication, which estimates the damage of the property value for forests in the event of flooding at 1% [2003], the potential unit loss was calculated at 0.04 PLN/m^2. The value determines the average loss of wood.

For class 4, fixed damages values for the whole country were adopted, independent of water depth.

CLASS 5 – RECREATIONAL AREAS

The value of potential unit loss for recreational areas was calculated on the basis of indexation of the unit value of the potential loss, valid in the first planning cycle, specified in the regulation on the development of FHM and FRM of 2012[7]. The value of the potential unit loss in 2008 was 5.1 PLN/m^2. The indexation was made with the index of the increase in the value of fixed assets in Poland in the current registered prices (GUS). It was calculated in percentages in relation to 2008 (to which the value of assets in the 2012 regulation referred) and is 64%. The value of recreational areas from 2008 was indexed by the value of the index and is 8 PLN/m^2.

For class 5, constant loss values for the whole country were adopted, independent of water depth.

CLASS 6 – ARABLE LAND AND PERMANENT CROPS

Depending on the way the floods affect, potential flood damages in class 6 are divided into two types:

- direct damages – including crop damages, soil destruction, e.g. by flushing processes, erosion, disruption of water relations in the soil, soil contamination;
- indirect damages - including expenditure on cleaning up the damage, damages in animal production, e.g. a reduction in yields has an impact on additional expenditure or a reduction in breeding.

Potential flood damages in class 6 are the sum of direct and indirect damages.

The largest part of direct damages are crop damages. The analysis of damages from historical floods shows that there is a regional variation in the number of damages in agricultural crops in Poland, so the agricultural production index was calculated by voivodeship.

The value of agricultural production was calculated in the following steps using data from the Central Statistical Office (GUS) (2013-2014):

1) determining agricultural output for crop production less meadow hay;
2) calculating crop production for voivodeships on the basis of the agricultural output structure;

[7]The regulation from 21 December, 2012 of Minister of the Environment, Minister of Transport, Construction and Maritime Economy, Minister of Administration and Digitization and Minister of the Interior on the development of FHM and FRM (Journal of Laws 2013, item 104) expired on the date of entry into force of the Regulation of the Minister of Maritime Economy and Inland Navigation of 4 October, 2018 on the development of FHM and FRM (Journal of Laws 2018, item 2031).

3) calculating the index of the value of agricultural production in voivodeships with the use of selected agricultural land areas (land under sowing, permanent crops, house gardens, other agricultural land) characteristic for class 6.

The amount of unit damages was calculated by assuming data for individual crops, depending on the month in which flooding may occur [Penning-Rowsell et al. 2013, for RISC-KIT 2015]. The potential direct loss to crops for the whole year was 52%.

According to A. Symonowicz [Chojnacki 2009, after Symonowicz 1969] the number of indirect damages in agriculture does not exceed 20% of direct damages.

CLASS 7 – GRASSLAND

Depending on the way the floods affect, the potential flood damages in class 7 are divided into two types:

– direct damages – including damages in biomass, soil destruction, e.g. by flushing processes, erosion, disruption of water relations in the soil, soil contamination;
– indirect damages - including expenditure on cleaning up the damage, damages in animal production, e.g. a reduction in yields has an impact on additional expenditure or a reduction in breeding.

Potential flood damages in class 7 are the sum of direct and indirect damages.

For arable land, the largest part of direct damages are damages in biomass. In order to estimate the value of grassland, an average yield of 1 ha of meadows and pastures in decitonnes by voivodeship was assumed and compared to the value of the average price in PLN/decitonne from the last 3 or 5 years (in the case of analysis, 5 years after the highest and lowest values were rejected). The GUS data for 2016 were used.

For the calculation of flood damages, similar to the calculation for arable land and permanent crops, data are used depending on the month in which flooding may occur [Penning-Rowsell et al. 2013, for RISC-KIT 2015]. The potential direct loss for meadows for the whole year was 30% and for pastures - 25%. The number of indirect damages was assumed to account for 30% of direct damages.

RANGES OF POTENTIAL FLOOD DAMAGES

Thew FRM in the cartographic version presents values of potential unit damages using a coloured scale in the following ranges in PLN/m^2:

– areas for which no damages are calculated;
– ≤ 1;
– 1-50;
– 50-150;
– 150-300;
– 300-600;
– > 600.

The values of potential damages for particular areas of land use should be rounded off to the nearest PLN. If areas are separated for which the potential loss in PLN is below 1 PLN, such area should be included in the adjacent area.

TOTAL VALUES OF POTENTIAL FLOOD DAMAGES

It is possible to calculate the total values of potential flood damages for any chosen area on the basis of the digital FRM (spatial databases). However, the total values of potential flood damages are not presented on maps in the cartographic version.

The sum of potential damages for classes 1 and 2 is expressed by the equation:

$$Sp_i = \sum_{j=1}^{4} Sp_{ij} \cdot A_i \; dla \; i = 1 \; lub \; 2$$

where: Sp_i – means the total value of potential damages for a given class and (PLN); Sp_{ij} – means the value of potential unit damages for class and depth range j (PLN/m^2); A_i – means the area occupied by a given class and (m^2).

The total value of potential damages for class 3 is expressed by the equation:

$$Sp_i = \sum_{j=1}^{2} Sp_{ij} \cdot A_i \; dla \; i = 3$$

where: Sp_i – means the total value of potential damages for a given class and (PLN); Sp_{ij} – means the value of potential unit damages for class and depth range j (PLN/m^2); A_i – means the area occupied by a given class and (m^2).

The total value of potential damages for classes 4-7 is expressed by the equation:

$$Sp_i = St_i \cdot A_i \qquad for \; i = 4 \ldots 7$$

where: Sp_i – means the total value of potential damages for a given class and (PLN); St_i – means the value of potential unit damages for a given class and (PLN/m^2); A_i – means the area occupied by a given class and (m^2).

The method of calculating the potential damages **aims only to spatially differentiate between the areas in terms of the value of potential damages** and thus to identify areas where flood risk reduction measures should be specifically continued or taken.

8.4 METHODOLOGICAL CHANGES VERSUS THE FIRST PLANNING CYCLE

The methodological changes introduced in the development of flood hazard maps and flood risk maps in the second planning cycle were aimed at improving the process of developing the maps, their publication and reporting to the European Commission, taking into account the timeliness and quality of available data. They result from the experience in creating the maps and in publishing them in the first planning cycle.

The changes concern in particular:

1) developing the flood scenarios;
2) updating the input data for the development of the FHM and FRM;
3) hydraulic modelling methodologies;
4) method of determining the flood hazard areas;

5) attribute structure of FHM and FRM layers;
6) elements of the cartographic version of FHM and FRM.

A detailed description of the changes introduced is provided in Chapter 10 of the Methodology for the development of the FHM and FRM in the second planning cycle, attached as Annex 1 to the Report.

8.5 ACCURACY OF DEVELOPMENT OF FHM AND FRM

The most important factors influencing the accuracy of the FHM and the FRM, including the determined flood hazard areas (OPZ), include:

1) accuracy and timeliness of input data, in particular:
    a) digital terrain model;
    b) geodetic measurements of wet riverbed cross-sections and engineering objects;
    c) hydrological data for the needs of hydraulic modelling;
2) hydraulic modelling methodology – modelling type, flow conditions (steady/unsteady flow), calibration and verification;
3) methodology for the designation and verification of OZP;
4) accuracy of the FHM and FRM database;
5) form of presentation of cartographic versions.

Each of these factors impacts the accuracy of FHM and FRM. Bearing in mind the objectives and uses of the FHM and FRM, the main assumptions of the methodology of creating the maps are set forth in the Regulation.

DIGITAL TERRAIN MODEL

In accordance with the Regulation, the Digital Terrain Model (DTM) is used to prepare flood hazard maps, made using the airborne laser scanning method (LIDAR) with a spatial resolution of 1 m and height accuracy of up to 0.2 m. Taking into account the purposes for which the maps are used, the above-mentioned resolution and altitude accuracy of DTM is very good. The parameters of the DTM used meet and even exceed the requirements of the Handbook on good practices for flood mapping in Europe (2004).

For the development of FHM and FRM, DTM was used, which was obtained in the years of 2010-2020, depending on the area of the country. The most recent DTM available was acquired for a given area.
In the case of the DTM acquired in the years of 2011-2013, which was used for the development of maps in the first planning cycle, it was updated by incorporating data on investments affecting the extent of flood hazard areas created until 2019.

The DTM provides the basis for the creation of computational structures used in hydraulic modelling, as a result of which flood hazard areas are determined. On the basis of DTM, valley cross-sections were generated, used in the process of one-dimensional hydraulic modelling, calculation rasters (grids) of two-dimensional models were prepared, watercourse routes and the course of flood and storm embankments were verified. It is also a necessary input element for determining the depth of flooding during the process of processing the results of hydraulic modelling.

In 2D models, DTM is used directly in the calculation. Therefore, it is necessary to select the appropriate resolution of the model, with particular emphasis on important topographical elements, i.e. objects influencing floodwater flow conditions.

The high accuracy of DTM allows to optimise the calculation grid size. Determining the optimum model size and its resolution is usually a compromise between the accuracy and efficiency of the model and time-consuming calculations. The size of the model and the size of the grid element is determined by the terrain, the complexity of the river network, the location of the water level gauge stations, the possibilities of available hardware and software. For rivers with wide valleys, with small denivelations, the resolution of the calculation grid was from 2x2 m to 12x12 m, maximum 15x15 m. It should be stressed, however, that for the generalisation of the calculation grid, all flood protection structures and others influencing the range of flood hazard areas, their location and parameters, were taken into account in the model bathymetry with the highest accuracy. Moreover, buildings influencing the flow resistance were taken into account in the DTM using two solutions:

1) recording the representation of buildings from BDOT10k in the form of appropriate values of coefficients on the roughness gradient (M=3.333 m1/3 s-1);
2) extracting buildings from the Digital Surface Model (DSM) or BDOT10k and implementing them into the DTM developed for modelling purposes.

GEODETIC MEASUREMENTS

The accuracy of the designated flood hazard areas is influenced by the accuracy of the geodetic measurements themselves, as well as the density of the distribution of the cross-sections and their timeliness.

Riverbed measurements and measurements of engineering objects were made with the use of geodetic instruments with:

1) GNSS methods (RTK or RTN kinematics) with reference to ASG-EUPOS reference stations (horizontal accuracy up to 0.03 m; vertical accuracy up to 0.05 m);
2) Tachometric method using electronic total stations with automatic recording of measurement results (horizontal accuracy of measurement up to 0.02 m; vertical accuracy of measurement up to 0.02 m).

In the first planning cycle, the cross-sections made in the years if 2011-2012, were located at distances not exceeding 500 m in a mountainous area and not exceeding 1500 m in a lowland area. As per the Methodology of developing the FHM and FRM in the second planning cycle (Annex 1), the riverbed sections made in the years of 2018-2021 were located at distances not exceeding 500 m, counting according to the length of the watercourse, and for measurements for valley sections for 2D modelling, at a distance not exceeding 250 m, which significantly increased the accuracy of mapping the watercourse riverbed and valley. Thanks to the higher density of cross-sections, a more faithful representation of the shape of the riverbed is obtained and the roughness coefficients can be more precisely determined.

As a part of the geodetic works, detailed measurements were also made of engineering objects located in the watercourses covered by the study, i.e.: bridges (including bridges and footbridges); hydrotechnical objects (including dams, weirs and steps).

Cross-sections from other sources were also used to develop the FHM and FRM. A detailed list of data used is included in the chapter concerning input data.

HYDROLOGICAL DATA

Hydrological data for the purpose of hydraulic modelling was developed for hydrologically controlled and uncontrolled catchments. The choice of the calculation method of maximum annual flows with a certain probability of exceedance for a given cross-section on the river depended on the availability of hydrological data and on the position of the calculative cross-section in relation to the water level gauge, having a sufficiently long sequence of homogeneous flows.

The calculations of maximum annual flows with a certain probability of exceedance for controlled rivers in gauge cross-sections were performed using a statistical method. The basis for the calculation of the maximum annual flows with a certain probability of exceedance was the homogeneous distribution sequences of the maximum annual flows from the hydrological year, covering at least 30 years until 2016. If data were not available until that year, e.g. due to decommissioning of the station, the available data series were used.

In uncontrolled catchments, the method of extrapolation within the hydrological similarity, the territorial regression equation, the precipitation formula or the precipitation-drainage model taking into account the linear conceptual Nash model were applied. The input data were maximum annual precipitation with a certain probability of exceedance for different durations calculated from the Bogdanowicz, Stachý formulas (1998).

For both, controlled and uncontrolled catchments, in which reservoirs are located and for which wave transformations through the reservoir are carried out, maximum annual flows with a certain probability of exceedance in accordance with the current water management manuals are assumed in the dam profiles.

As in the first cycle, sea-level hydrological data from the last 30 years, including data up to and including 2016, were used to map the flood risk from the sea water. The hydrological data were developed in accordance with the principles laid down in the Methodology for the development of the FHM and FRM from the sea water in the second planning cycle, provided as Annex 2. The calculation of water levels with a certain probability of exceedance took into account the impact of the sea and the increase in sea level along the Polish Baltic coast caused by climate change under the A2 emission scenario.

Taking into account all hydrological factors influencing the quality of the calculations, the highest reliability of the results was achieved on controlled rivers, for which it was possible to calibrate and verify on waves from the years following the latest investments on the river.

HYDRAULIC MODELLING

In accordance with the Regulation, the following hydraulic modelling methods are used to determine flood hazard areas:

- One-dimensional (1D) modelling – obtaining results in the form of water level ordinates in cross sections;
- Two-dimensional (2D) modelling – obtaining results in the form of a digital water level model and water velocity raster;
- hybrid modelling (1D/2D) – a combination of one-dimensional modelling for watercourse trays with two-dimensional modelling for floodplains.

Two-dimensional modelling was performed for cities with poviat rights and other cities with more than 100,000 inhabitants. By applying 2D models, it was possible to present the velocity and directions of water flow on flood hazard maps. For areas other than the cities mentioned above, one-dimensional or hybrid modelling was performed. This type of modelling was also performed for flood areas from the sea water, including internal sea waters, also due to the possibility of including wind impact in the models. The selection of the modelling type was preceded by a detailed analysis of the river network layout, valley shape and possible water flow paths, location and layout of hydrotechnical and transport structures.

For one-dimensional models, the calculation results (water level ordinates and flows) are presented at the points of the calculative cross-sections. For two-dimensional models, the result is a raster of the digital water level model and a raster of velocity and direction of flow, which allows for detailed representation of the complex hydrographic system of rivers, the direction and method of water outflow and its volume on the complicated relief of the floodplain.

The calculations were made mainly for the conditions of unsteady flow, i.e. based on flood waves (variable in time) with a certain probability of maximum flow. The adoption of such solutions is characterised by the highest degree of representing the real conditions and correctness of the assumptions made, because the unsteady flow in its nature is close to the actual course of the flood wave or storm flood in the function of time. In justified cases, calculations were used in steady flow conditions, where - as upper, internal and lower boundary conditions for baseline scenarios - steady values of flows or water levels were given.

Another important element impacting the quality of the results is the calibration and verification of the models according to the criteria described for all types of models in the methodology. This was performed for controlled watercourses, i.e. those on which at least one water level gauge station is located in the cross-section covered by the hydraulic model. The criteria analysed during calibration and verification of the hydraulic model:

- Correlation coefficient (R);
- Special correlation coefficient (Rs);
- Total square error (CBK);
- Culmination state error (ΔHmax);
- Peak flow error (ΔQmax);

- Culmination offset (Δtmax);
- Flood wave volume error (ΔVmax).

The calibration was performed by comparing the hydrograph observed from the historical flood with the calculation hydrograph obtained from the model. The verification was made for a historical flood other than the exceedance for which calibration was performed.

For calibration and verification, flood waves from at least two of the largest floods that had taken place in the last 30 years and have complete and reliable hydrological data were used. For exceedances with the similar size, more recent ones were preferred, especially if flow conditions in the riverbed or valley have changed significantly. The data for the floods older than 10 years were treated with caution or as auxiliary for evaluating the model operation.

In order to ensure a high quality of calculations, it is assumed that for calibration for each criterion, the model must be rated “excellent”, “very good” or “good”. However, when verifying, for each criterion the model must be rated “excellent”, “very good”, “good” or “fairly good”. The ranges for each criterion are presented in the methodology. They were used in order to obtain the most accurate, precisely defined consistency of hydrographs.

DETERMINATION OF FLOOD HAZARD AREAS

The results of 1D hydraulic modelling in the form of water level ordinates are the basis for generating, using DTM, a digital water surface model raster (DWSM) and water depth raster. In the case of 2D modelling, the results of modelling are provided in the form of the DWSM raster, depth raster and flow velocity raster.

In order to increase the accuracy and readability of the final product and to eliminate possible errors, a few steps were taken to verify the results obtained. The substantive correctness of the determined flood hazard areas was checked, as well as the geometric and topological correctness of spatial layers. The procedure described in section 6.2 of the Methodology has contributed to diminishing the uncertainty in the designation of OZP.

SPATIAL DATABASE

The spatial database of FHM and FRM comprises elements obtained from external institutions and made for the purpose of developing FHM and FRM. We can distinguish the following elements of the database:

1) flood hazard maps data;
2) flood risk maps data;
3) reference data.

Data of flood hazard maps are one of the most important products and were produced based on the results of hydraulic modelling according to the Methodology, in line with a strictly defined procedure, and the factors influencing their accuracy are described in the previous chapters.

The key element of the FHM are flood hazard areas, which together with their complementary layers (water depths, water ordinates, water velocities and flow directions) constitute a precise tool for other activities, i.e. flood protection planning and spatial management in flood hazard areas. The accuracy of flood hazard maps is appropriate both for the needs of individual users as well as for administration authorities for the purpose of comprehensive environmental, economic, spatial planning and crisis management analyses. It also allows to determine - at the scale of the plot - whether a given property is located in a flood hazard area with a certain probability of occurrence.

The data of flood risk maps are based on the data obtained from the institutions responsible for the individual thematic data, in accordance with the Regulation. The timeliness, completeness and quality of the data presented in the flood risk maps depends on the registers from which they are obtained. The specification of the individual data sets and the methodology of their extraction is the subject of relevant institutions' independent studies. Some of the data for the purpose of flood risk maps were implemented in a form similar to the original, while some were processed as per the Methodology for the development of FHM and FRM in the second planning cycle.

The reference data sourced from external institutions are complementary to flood hazard maps and flood risk maps for the purpose of their presentation.

The spatial database enables to present graphically data in GIS software in any way, with the spatial range chosen by the user, by means of various conventional signs and at any scale. Keep in mind however the input accuracy of the data set that was imported into the database.

CARTOGRAPHIC VERSIONS

The standardised graphic version of the spatial database is the cartographic version, prepared with division into sheets (emblems) corresponding to the sheets of topographic maps at the scale of 1:10,000. The scale of cartographic versions of FHM and FRM should not be associated with their accuracy. The accuracy of FHM elements depends on the accuracy of input data and modelling results, while the accuracy of the FRM elements depends on the accuracy of registers from which they were obtained. The scale of 1:10,000 was chosen as appropriate because of the detail of the elements of the FHM and the FRM and because the level of flood hazard and risk for a large area of the country can be clearly presented at this scale. This was possible by applying the appropriately selected symbolisations of the content elements of the FHM and FRM, the topographic background (orthophotomap) and by editing the maps cartographically.

SUMMARY

The following was considered when preparing the FHM and FRM: their strategic importance, their use in flood risk planning and management, national spatial planning and management, crisis management and in informing the public about potential flood hazards and risks. Hence, an effort was made to achieve products with the highest quality. The factors described above to a certain degree influence the accuracy of the FHM and FRM, in particular the designated flood hazard areas.

9 COORDINATION WITH THE FRAMEWORK WATER DIRECTIVE

The need for coordinating and integrating the sectoral plans in order to reduce conflicts, ensure synergies and achieve territorial cohesion was highlighted, inter alia, in the document titled "Blueprint to Safeguard Europe's Water Resources" (2012). This document outlines the activities of the European Commission and the EU Member States in improving water policy implementation. Each policy has its own planning rules and the application of Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment can actively support coordination and integration processes between different policies. The document underlines the need to link water policy objectives with integrated disaster management.

The Water Law Act stipulates issues related to ensuring coordination of works carried out within the framework of flood risk management (including the development of FHM and FRM), resulting from the implementation of the Floods Directive (FD), with works resulting from the Water Framework Directive (WFD).

Article 326, paragraph 2 of the Act provides that the information presented in flood hazard maps and flood risk maps should be consistent with the information in the river basin management plans and the drought management plan.

The flood hazard maps and flood risk maps are created and reviewed in coordination with the elements of the water management plans, namely:

- characterisation of bodies of water, indicating artificial and heavily modified bodies of water and bodies of water threatened with failure to meet environmental objectives;
- identification of significant anthropogenic impacts and assessments of their impact on the status of surface water and groundwater;
- economic analyses related to water use.

The FRM contains data resulting from Annex VI (i), (iii) and (v) of WFD:

- areas intended for the abstraction of water intended for human consumption (i);
- water bodies intended for recreational purposes, including areas designated as bathing waters (iii) and
- areas designated for the protection of habitats or species, including Natura 2000 sites (V).

The above documents and planning documents are either indirectly (drought prevention plan, economic analyses related to water use) or directly (characteristics of water bodies indicating artificial and heavily modified water bodies and water bodies at a risk of failing to meet environmental objectives, identification of significant anthropogenic impacts and assessment of their impact on the status of surface water and groundwater) related to the implementation of works under the WFD aimed at achieving the environmental objectives set forth in Article 4 of WFD.

The above provisions refer to Article 9 of the Floods Directive.

There are three main areas of coordinating the review and updating of the FHM and FRM with the works resulting from WFD:

1) Ensuring hydrographic cohesion, taking into account the division into catchment management units in Poland.

   When developing the FHM and FRM, the hydrographic structure of water resources management in Poland (river basin areas and water regions) was considered, used also in works resulting from the WFD. It is important to underline that while the primary reference areas for the WFD and the Floods Directive are river basin areas, the more detailed divisions of basins depend on the specificities of EU Member States. Consistency with regard to the division into water regions ensures that planning works under the Floods Directive and WFD are pursued.

2) Information provided in FHM and FRM.

   The consistency of the input data used for implementing the works resulting from the Floods Directive and the works resulting from WFD was assumed when creating the FHM and the FRM. Information from the identification of significant anthropogenic impacts was used when creating the FHM for flood embankments and other water facilities. When creating the FRM, information was utilised on areas designated for the protection of habitats or species (Natura 2000 sites), surface water abstractions and groundwater abstractions, protection zones of abstractions, industrial plants, bathing waters, i.e. the information and data that are used for the works resulting from the WFD. It was further assumed that the results of creating the FHM and the FRM could provide a source of data for preparing the water management plans (aPGW) and drought prevention plans (PPSS). The detailed scope of exchange of the data considered in the FHM and the FRM and the data considered in aPGW and PPSS is presented in the Methodology attached as Annex 1 to the report.

3) Ensuring the consultation process.

   The provisions of the Water Law Act define that the draft FHM and FRM were subject to consultations and agreements with competent government administration authorities (voivodes). The flood hazard areas designated as a result of hydraulic modelling were consulted at an intermediate stage, which allowed to introduce appropriate corrections in justified cases. Comments submitted in writing by local government units were also considered.

10 EXCHANGE OF INFORMATION WITH NEIGHBOURING COUNTRIES IN TERMS OF FHM AND FRM PREPARATION

In accordance with the Floods Directive (Article 6, paragraph 2) and the Water Law Act (Article 171, paragraph 6 and 7), actions to exchange respective information with the competent authorities of the relevant countries are taken prior to preparing flood hazard maps and flood risk maps for areas situated in river basin areas, some of which are at the territory of other countries.

Information with Poland's neighbouring countries on the preparation of the FHM and the FRM was exchanged under the existing international and cross-border bilateral commissions established under international agreements and arrangements. This cooperation concerned both countries belonging to the European Union: Germany, the Czech Republic, Slovakia, Lithuania, as well as those outside the EU: Belarus and Ukraine.

The only country where no specific rules of cooperation were established is Russia (outside the EU, for the Pregola river basin). Formally, the cooperation with the Russian Federation in the field of water management is based on the Agreement between the Government of the People's Republic of Poland and the Government of the Union of Soviet Socialist Republics concerning the use of water resources in frontier waters of July 17, 1964. The Agreement is valid by succession and is subject to automatic extension for subsequent five-year periods, while the Russian party shows no practical interest in its implementation.

Information on the forms and basis of cooperation is presented in Table 15.

Table 16. Forms of cooperation and exchanging information with neighbouring countries in terms of preparing the FHM and the FRM.

<table>
<tr><th>River basin area</th><th>Neighbouring country</th><th>Form of cooperation</th><th>Basis for cooperation</th></tr>
<tr><td rowspan="4">Oder</td><td rowspan="2">Germany</td><td>German-Polish Border Water Commission</td><td>Agreement between 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.</td></tr>
<tr><td>International Commission for Protection of the Oder River against Pollution</td><td rowspan="2">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</td></tr>
<tr><td rowspan="2">Czech Republic</td><td>International Commission for Protection of the Oder River against Pollution</td></tr>
<tr><td>Czech-Polish Border Waters Commission</td><td rowspan="2">Agreement between the Government of the Republic of Poland and the Government of the Czech Republic on cooperation in border waters in the field of water management of
20 April, 2015</td></tr>
<tr><td rowspan="2">Elbe</td><td rowspan="2">Czech Republic</td><td>Czech-Polish Border Waters Commission</td></tr>
<tr><td>International Commission for the Protection of the Elbe River</td><td>Agreement of 8 October, 1990 between the Federal Republic of Germany, the Czech and Slovak Federal Republics and the European Economic Community.</td></tr>
<tr><td rowspan="2">Vistula</td><td>Belarus</td><td>Polish-Belarusian Border Waters Commission</td><td>Agreement on cooperation in the protection and rational use of transboundary waters signed on 7 February, 2020.</td></tr>
<tr><td>Ukraine</td><td>Polish-Ukrainian Commission for Border Waters</td><td>Agreement between the Government of the Republic of Poland and the Government of Ukraine on cooperation</td></tr>
</table>

River basin area	Neighbouring country	Form of cooperation	Basis for cooperation
			in the field of water management on border waters of 10 October, 1996.
	Slovakia	Polish-Slovakian Commission for Border Waters	Agreement between the Government of the Republic of Poland and the Government of the Slovak Republic on water management in border waters of 14 May, 1997.
Danube	Slovakia	Polish-Slovakian Commission for Border Waters	Agreement between the Government of the Republic of Poland and the Government of the Slovak Republic on water management in border waters of 14 May, 1997.
Neman	Lithuania	Polish-Lithuanian Commission for Border Waters	Agreement between the Government of the Republic of Poland and the Government of the Republic of Lithuania on cooperation in the field of use and protection of border waters of 7 June, 2005.

The type and scope of cooperation for the development of flood hazard maps and flood risk maps depends on the location of border rivers. Specific cooperation and exchange of information is required where a river forms a common border between countries and it is advisable to exchange data on both sides of the river to determine flood hazard areas. The Oder, Lausitzer Neisse and the Bug are the border rivers (constituting a state border) identified as flood-prone areas and for which FHM and FRM are set up.

Apart from the activities described below for each river basin area, the neighbouring countries have been informed about the scope of the review and update of the FHM and FRM in Poland by mail in the form of a memo on the works conducted in Poland on the FHM and FRM. The memo contained information on:

- FHM and FRM developed so far;
- the area of the FHM and FRM in the first planning cycle for a given river basin area (common for Poland and a neighbouring country);
- works performed in scope of the review of the FHM and FRM and the scope of update;
- territorial coverage of the FHM and the FRM in the second planning cycle for the river basin area with a view to finalising the works over the review and updating of the preliminary flood risk assessment;
- the expected completion date of the works.

THE ODER BASIN AREA

In the Oder River basin area, information on the development of flood hazard maps and flood risk maps is exchanged under the International Commission for the Protection of the Oder River against Pollution (ICPO). All three countries in the Oder catchment area participate in the works, i.e.: Poland, Czech Republic and Germany. The topic of floods under the ICPO ai led by the G2 Floods Working Group whose task is, notably, to coordinate tasks related to the implementation of the Floods Directive, including the exchange of information when verifying and updating the FHM and FRM.

There is also an expert group within the Flood Working Group of ICPO, which works on developing a common hydraulic model for the Lausitzer Neisse. The need for such work is a consequence of the use of different hydraulic modelling platforms by different Member States for the development of the FHM and for the design of hydrotechnical structures, which leads to significant differences in results and problems in achieving consistency in this area. A common model could be used in the third planning cycle as a planning and simulation model, not as a predictive model. The existing models developed so far for the Lausitzer Neisse catchment area have been discussed under the works, a pilot section (Ostritz – Zgorzelec) was selected as a test section to test the entire hydraulic modelling and the scope of topographic, hydraulic and hydrological input data and the possibilities of their acquisition and exchange for the entire section of the Lausitzer Neisse was agreed. The creation of a coherent, up-to-date and complete database is an important element of the undertaken cooperation, because until now only hydrological data has been agreed upon. The results of the works are described in the document titled "Concept for the implementation of the common hydraulic model for the Lausitzer Neisse".

The Polish-Czech Border Water Commission cooperates and exchanges data within the framework of the HyP Working Group on Hydrology, Hydrogeology and Flood Protection.

THE ELBE BASIN AREA

The International Commission for the Protection of the Elbe River (ICPER) operates in the area of the Oder River basin, where Poland acts as an observer.

THE VISTULA RIVER BASIN AREA

International cooperation in the Vistula River basin area is conducted between Slovakia, Belarus and Ukraine.

The cooperation and exchange of information with Slovakia is carried out by the HyP Working Group on Hydrology and Flood Protection, operating within the framework of the Polish-Slovakian Commission for Border Waters. This group mainly deals with issues of cooperation in a wide scope of hydrology, with particular emphasis on the phenomenon of floods, including the exchange of hydrological data, consultations and cooperation in verifying the results of the works in terms of hydrological conditions.

Since 7 February, 2020, the exchange of information with Belarus is based on a cooperation agreement on the protection and rational use of transboundary waters. The agreement provides for multi-faceted cooperation in the field of protection and use of transboundary waters, including hydrological observations and protection against floods.

Earlier, when negotiating the above agreement, steps were taken to start cooperation on flood risk management for the Bug River basin. The Belarusian party submitted a proposal for a Polish-Belarusian-Ukrainian project for the joint development of planning documents under the Floods Directive, including FHM and FRM. The Polish party has presented the scope, method and legal conditions for the development of these documents in Poland. It also pointed out the need to make arrangements for the availability of data and the possibility of their exchange between the countries, in order to develop a hydraulic model allowing to identify flood hazard areas. The Belarusian party has agreed with the solutions proposed by Poland, taking into account a certain specificity of the legislation of the Republic of Belarus.

In 2019, together with the Belarusian party, the principles of cooperation on hydrometric measurements in the Bug and Narew rivers were set tup:

- joint measurements in the profiles of Włodawa and Krzyczew;
- joint measurements in the profiles of Niemierża and Bondary on the Narew;
- establishment of a working group to make full cross-sections of the Bug River valley in the Włodawa and Krzyczew water signalling profiles.

In November 2019, a set of surveying cross-sections and a set of hydrometric measurements in two profiles, Krzyczew/Terebuń and Włodawa/Tomaszówka, was prepared, together with control profiles, measurements were made altogether in 8 cross-sections. The measurements were made both in the Republic of Belarus and the Republic of Poland.

The cooperation and exchange of information with Ukraine in the field of floods is pursued by the OP Working Group on Flood Protection, Regulation and Remediation, acting within the framework of the Polish-Ukrainian Border Water Commission. This group mainly deals with the exchange of hydrological and meteorological data, with agreeing on materials for the development of and the use of hydrological models.

THE DANUBE BASIN AREA

Cooperation and information exchange with Slovakia in the Danube River basin area is carried out by the HyP Working Group on Hydrology and Flood Protection, operating under the Polish-Slovakian Commission for Boundary Waters.

THE NEMAN BASIN AREA

Cooperation and information exchange with Lithuania in the Neman River basin area in the field of, notably, flood risk management, is carried out by Working Group No. 1, operating under the framework of the Polish-Lithuanian Border Water Commission.

11 PUBLICATION AND CONVEYANCE OF FHM AND FRM TO ADMINISTRATION AUTHORITIES

11.1 CONVEYANCE OF FHM AND FRM TO ADMINISTRATION AUTHORITIES

Pursuant to Article 171 of the Water Law Act, the minister competent for water management approves and submits the FHM and FRM prepared by the Polish Waters in electronic form to the following authorities:

1) The Chief National Surveyor,
2) competent Environmental Inspection Authority: Chief Inspector of Environmental Protection, voivodeship environmental protection inspectors,
3) Director of the Government Centre for Security,
4) Chief Commander of the State Fire Service,
5) Polish Waters (National Water Management Board, Regional Water Management Boards),
6) competent voivodes,
7) competent provincial marshals,
8) competent starosts,
9) competent aldermen, mayors, city presidents,
10) competent provinicial and municipal (city) commanders of the State Fire Service,
11) competent directors of inland navigation authorities and competent directors of maritime offices,
12) competent railway infrastructure managers and competent public road managers.

FHM and FRM are provided in electronic format, as a spatial database and as cartographic maps. The spatial scope of FHM and FRM submitted depends on the competence of the specific administration body.

11.2 PUBLICATION OF FHM AND FRM

Pursuant to Article 171, paragraph 5 of the Water Law Act, the minister in charge of water management makes the FHM and the FRM public by posting them in the Public Information Bulletin of the office in charge. The subsequent updates of the FHM and FRM are made public via the website of the Public Information Bulletin of:

- the Ministry of Maritime Economy and Inland Navigation on 19 September, 2018.
- the Ministry of Climate and Environment on 22 October, 2020.
- the Ministry of Infrastructure on 7 September, 2022.

Maps in cartographic version, in pdf format, are available at: http://mapy.isok.gov.pl

The digital version of the maps is available at: https://isok.gov.pl/hydroportal.html.

The digital version of the flood hazard maps is available at:

https://wody.isok.gov.pl/imap_kzgw/?gpmap=gpMZP

The digital version of the flood risk maps is available at:

https://wody.isok.gov.pl/imap_kzgw/?gpmap=gpMRP

FHM and FRM are published in the form of functioning map services, raster services, INSPIRE data and metadata browsing and downloading services. The main services include:

1) FHM and FRM Hydroportal in pdf format;
2) Hydroportal;
    a) Orientation map;
    b) FHM and FRM services;
3) INSPIRE services.

FHM AND FRM HYDROPORTAL IN PDF FORMAT

The FHM and FRM Hydroportal in pdf format (Figure 9) allows to download pdf files containing cartographic versions of FHM and FRM, divided into sheets at a scale of 1:10,000, in the rectangular PL-1992 coordinate system. It contains current (valid) and archival (replaced by updated versions) versions of FHM and FRM.

The PDF Hydroportal contains background data for user orientation. It is possible to switch from a topographic background map to an orthophotomap, enabling the recipient to better orientate himself in the field. The service also allows to connect external wms/wmts, wfs data sources and to upload of objects from .kml, .gml, .shp files.

The service enables to search data by locating any plot, river, locality, Polish Waters units (RZGW, catchment area management, catchment area supervision), the emblem number of the FHM or FRM sheet. It provides tools to support the selection of objects by selection on the map (point, line polygon and buffer), as well as tools to sketch one's own objects (e.g. lines, points, areas, labels). In addition, the service allows to measure coordinates, lengths, areas.

The map view can be exported to graphic files – .jpg, .png, or georeferential .pdf document. It is possible to print the map at a given scale and to generate a link to the map view.

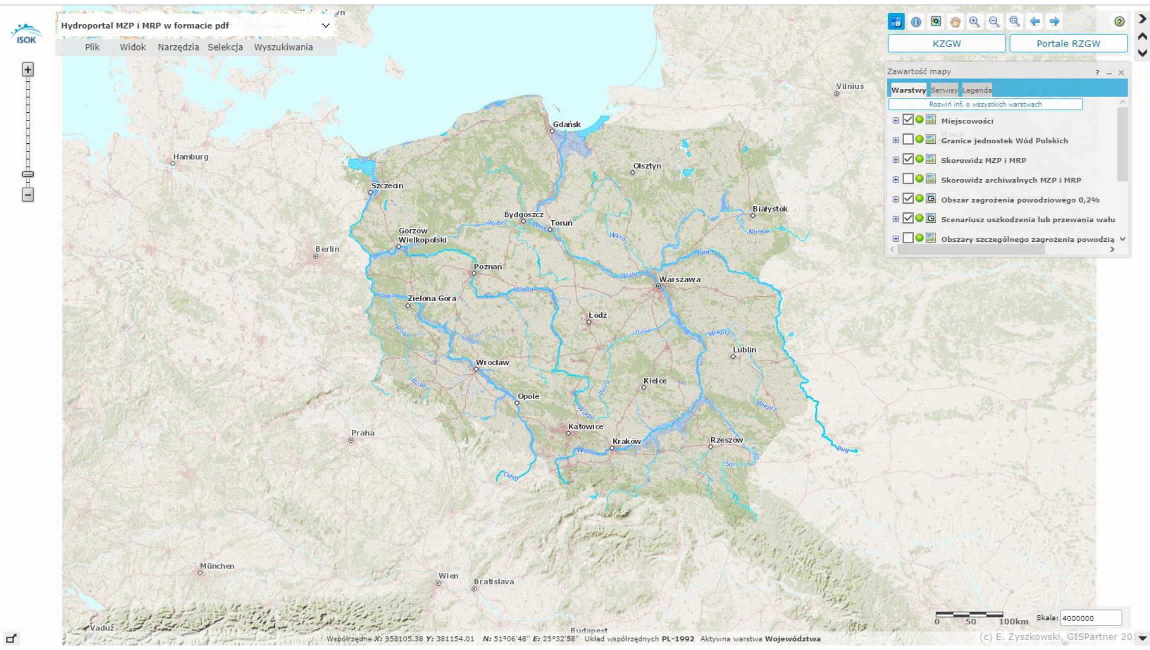

Figure 9. General view of the FHM and FRM Hydroportal in PDF format.

The map is downloaded (Figure 10) after indicating the selected map emblem, then selecting the map type (FHM or FRM) and the flood scenario (0.2%, 1%, 10% or destruction of flood embankments – WZ).

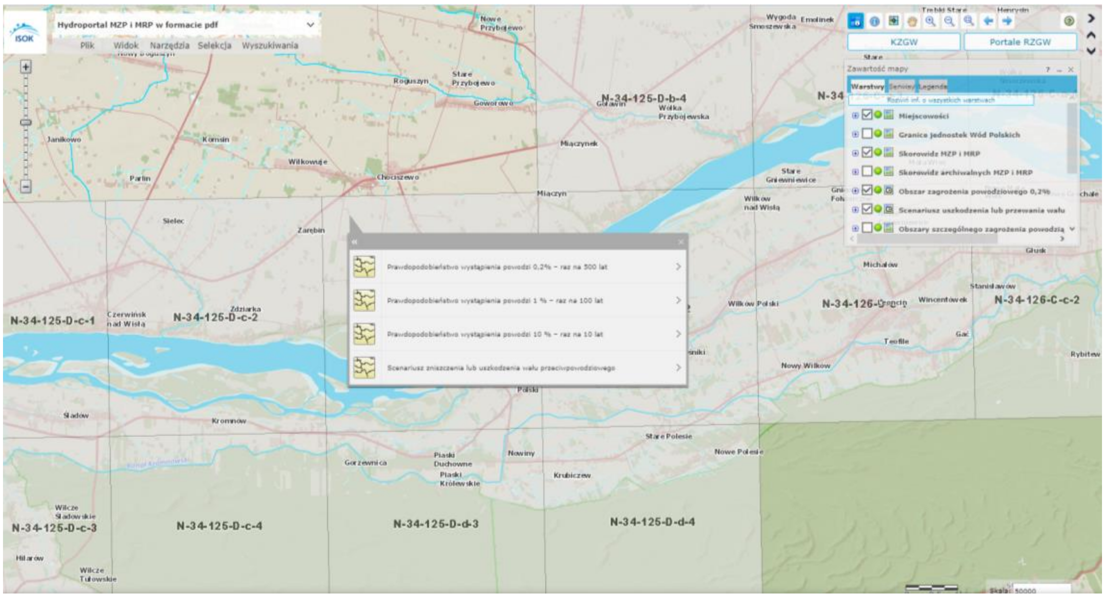

Figure 10. Downloading a map from FHM and FRM Hydroportal in pdf format.

HYDROPORTAL

Hydroportal is a public portal addressing the broadly understood water issues in Poland. It provides an overview of data on flood hazard and risk, drought mitigation or water management plans.

The Hydroportal offers map services presenting FHM and FRM in a dynamic form, i.e. as services generated based on the FHM and FRM database with appropriate resymbolisation. The services present FHM and FRM in a continuous manner (without dividing into sheet frames). It is possible to browse maps at different scales, connect to the view of various background data, as well as sectoral data. FHM and FRM within the services are presented in a division into particular types of maps and flood scenarios.

In addition, the FHM and FRM services offer an orientation map showing the ranges of all flood hazard areas for all flood scenarios and types of floods. The orientation map allows the user to easily obtain information whether the area of interest is exposed to flooding and to determine the source and degree of this hazard.

FHM AND FRM SERVICES

They are the main source of information on flood hazard and risk (Figure 11). They contain the full content of the information provided in the cartographic version of FHM and FRM. The symbolisation in the services is identical to the pdf versions. The user can control the visibility of individual layers, to adjust the content as needed.

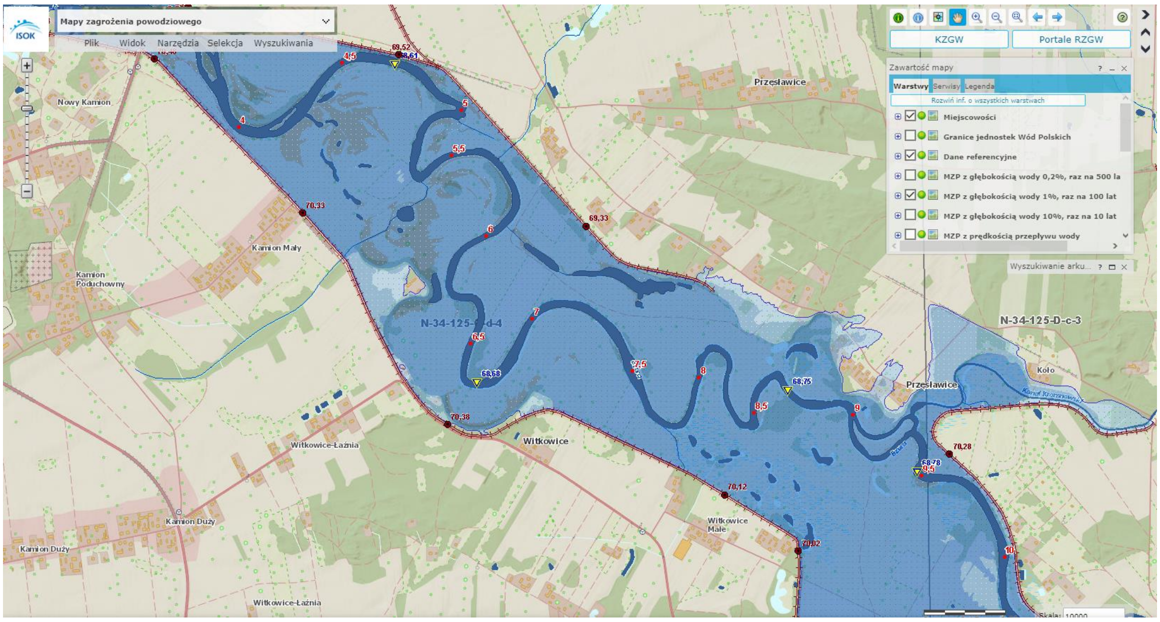

Figure 11. FHM and FRM service – vector version of maps.

There are following services for presenting the FHM and FRM data: FHM and FRM. Each of them presents data for each available flood scenario on a topographic base or orthophotomap using reference layers used for FHM and FRM, i.e. watercourse axes, chainage, administrative boundaries, embankments, coastal technical belt boundaries and others.

FHM and FRM services, similarly to PDF Hydroportal, offers many options to search data by locating any plot, river, locality, Polish Waters units (RZGW, catchment area management, catchment area supervision). Objects can also be selected on the map. The selection tools are point, polygonal line and buffer.

There are also tools for sketching your own objects. It is possible, for example, to sketch lines, points, areas, labels. Sketched objects can be exported to vector formats, such as shp or raster, .jpg, .tif. It is also possible to measure coordinates, length, area and download objects from .kml, .gml, .shp files. The view can be exported to graphic formats – .jpg, .png, or georeferential .pdf document.

The service also allows you to connect external data sources from wms/wmts, wfs, print the map on a given scale and generate a link to the map view.

ORIENTATION MAP

The orientation map is a new service created in order to present information about the FHM and FRM available in a given area for particular types of floods and their range (Figure 12). It presents data on the range of flood hazard areas at scales from the whole area of Poland (ca. 1:10,000,000) to detailed scales – covering a specific plot of 1:200. The map service is designed to quickly present whether an area is exposed to flooding and its source. The map covers all types of floods for which the maps have been developed: i.e. fluvial floods, floods from the sea water and floods from damming structures. Each flood scenario and type is marked with a different colour.

The service enables to change the base from a topographic map to an orthophotomap and to control the transparency of layers in order to better adjust the displayed data content to the user's needs. The orientation map complements the main FHM and FRM services and contains selected data only.

Figure 12. Orientation map.

INSPIRE SERVICES

INSPIRE services are available at https://www.isok.gov.pl/inspire.html

There are currently 3 types of INSPIRE services:

- viewing services;
- download services;
- search services.

Browsing services are provided through WMTS (Web Map Tile Service) and WMS (Web Map Service) services. These services can be connected to any GIS and CAD applications supporting WMS and WMTS services.

12 NON-TECHNICAL DESCRIPTION OF READING, SCOPE AND CONTENT OF FHM AND FRM

LEGAL GROUNDS

Directive 2007/60/EC of the European Parliament and of the European Council of 23 October, 2007 on the assessment and management of flood risks, known as the "Floods Directive", introduced the obligation for the Member States of the European Union to develop planning documents as a basis for taking action to reduce the adverse consequences of floods on human health and life, economic activities, the environment and cultural heritage.

Flood hazard maps and flood risk maps in Poland have been prepared in accordance with the Water Law Act and the Regulation of the Minister of Maritime Economy and Inland Navigation of 2018 on the development of flood hazard maps and flood risk maps. According to the Act, FHM and FRM are reviewed every 6 years and updated, if necessary.

The draft flood hazard maps and flood risk maps created by the State Water Holding – Polish Waters in agreement with the relevant voivodes have been approved by the minister (Minister of Maritime Economy and Inland Navigation).

DEFINITIONS

The Floods Directive introduced a new definition of floods, according to which **flooding** means the temporary covering of land that is not normally covered by water. This phenomenon is caused in particular by the accumulation of water in natural watercourses, bodies of water, canals and the sea water.

Flood hazard is the possibility of flooding with a certain probability.

Flood risk means the combination of the possibility of flooding and its potential adverse consequences for human life and health, environment, cultural heritage and economic activities.

Hazard and risk are interconnected, no risk is present without hazard, a high hazard dictates a significant risk. In addition, the degree of risk is influenced by population density, land use, technical and transport infrastructure in the hazard area.

Flood hazard areas are those areas where floods may occur, as shown on the flood hazard maps.

Historical flood is a flood that occurred in the past at a certain place and time.

OBJECTIVES AND USE OF FHM AND FRM

Human activity and climate change contribute to changes in the frequency and intensity of floods. Floods have adverse consequences for population, environment and economy. A prior evaluation of the hazard and risk is required for the proper risk management and for the planning of measures to prevent damages from floods. For this purpose, a preliminary flood risk assessment (CORP), identifying areas of significant flood risk, is undertaken. Detailed flood hazard maps and flood risk maps are then developed for those areas. The FRM and the FRM form the basis for developing flood risk management plans aimed at identifying technical and non-technical measures to reduce the adverse consequences of floods on human health and life, economic activity, the environment and cultural heritage.

In order to ensure protection against flooding and to limit the potential adverse consequences of floods, the areas at particular hazard of flooding presented on the maps are comprised in the spatial planning documents.

Informed decisions concerning the location of investments are made by residents and local authorities where information is provided on flood-prone areas and the flood hazard level and where risks associated with the occurrence of floods in a given area are highlighted. Every citizen can check whether they live in a flood-prone area and if so, how much they are at risk.

Maps can provide a starting point for further analyses necessary for launching the activities of different administrations, including crisis management when flood occurs.

INFORMATION PRESENTED IN FLOOD HAZARD MAPS

Flood hazard maps are created for the areas and types of floods identified as a result of reviewing and updating the preliminary flood risk assessment, i.e.:

1) fluvial flood – in two scenarios:
   - natural flood;
   - destruction of flood embankments;
2) flood from the sea – in two scenarios:
   - natural flood;
   - destruction of flood or storm embankments;
3) flood associated with flooding for damming structures' damage or destruction.

The FHM shows areas with a certain probability of flood occurrence:

- areas where the probability of flood occurrence is low, 0.2% (once every 500 years) – for river and sea water floods;
- areas where the probability of flood occurrence is medium, 1% (once every 100 years) – for river and sea water floods;
- areas where the probability of flood occurrence is high, 10% (once every 10 years) – for fluvial floods.

A damming structure's destruction or damage is considered to be an extreme event scenario with a very low probability of occurrence. These maps provide information for residents and authorities on the potential risk of flooding in case of a dam disaster. However, it should be remembered that the maps for this scenario refer to an extreme situation in which the occurrence of a flood wave coincides with a technical failure of the discharge equipment or failure to the dam. The result is the destruction of the dam and the rapid emptying of the reservoir, hence the range of flood hazard areas for this scenario is highly extensive. Therefore, the areas presented in the FHM for the scenario of destruction or damage to damming structures are not areas of the special flood hazard within the meaning of the Water Law Act, so they do not constitute the basis for agreeing the spatial planning and development documents.

The areas of special flood hazard within the meaning of the Water Law Act, which constitute the basis for agreeing upon the spatial planning and development documents, are areas where the probability of flood occurrence is:

– medium and is 1% (once every 100 years) and;
– high and is 10% (once every 10 years).

Particular attention should be paid to the fact that flood hazard maps do not show the range of historical floods that have occurred in the past at a particular place and time. The maps show floods with a certain probability of occurrence, the range of which is based on accepted statistical calculations.

In fact, at least one flood may occur each year. In the Kłodzko Valley, catastrophic floods occurred in the consecutive years of 1997 and 1998. In the summer of 2010, the so-called 100-year-old water appeared twice in the Carpathian Mountains, and there were two more smaller floods.

It is seen when comparing areas exposed to high, medium and low probability of flood occurrence with historical flood areas that the range of these areas varies. The highest number of historical floods is close in terms of the range to a flood with a 10% probability, the lower number is close to 1% and the lowest to 0.2%.

Flood hazard maps are prepared in two sets of topics:

1) flood hazard map with water depth;
2) flood hazard map with water flow velocity.

The depths of water in flood hazard areas are presented in classes determining the degree of hazard to people and the way water impacts the building structures:

– $h \leq 0.5$ m – indicating a low hazard to people and building structures;
– 0.5 m < $h \leq 2$ m – indicating a medium hazard to humans, due to the possibility of evacuation to higher floors, but high due to material damages;
– 2 m < $h \leq 4$ m – indicating a high hazard to people but very high due to material damages; not only the ground floors but also the first floors of buildings may be flooded;
– $h > 4$ m – indicating a very high hazard to people and very high risk of total damages.

For areas of voivodeship cities and cities with poviat rights, and other cities with population over 100,000 people, a similar classification is applied for water velocity:

– $v \leq 0.5$ m/s – low velocity – the water has small capacity to impact the structures;
– 0.5 m/s < $v \leq 1$ m/s – medium velocity – water has a moderate impact on structures and is able to move objects of small size and mass, poses a danger to people;
– 1 m/s < $v \leq 2$ m/s – high velocity – water has a strong impact on structures and is able to move objects of relatively large size and mass; poses a serious risk to people;
– $v > 2.0$ m/s – very high velocity – water has a very strong impact on structures and is able to move objects of very large size and weight and to disturb the structure of static objects; it poses a very serious threat to people.

A description of the legend for the FHM is available in the annexes to the methodologies for a given type of flood.

INFORMATION PRESENTED IN FLOOD RISK MAPS

Flood risk maps are created for the areas shown in the flood hazard maps. The FRM determine the values of potential flood damages and present objects exposed to flooding in the case of flood occurrence. These are objects allowing to evaluate flood risks to human health and life, the environment, cultural heritage and economic activities.

Flood risk maps show the following:

1) Estimated number of inhabitants who may be affected by the flood;
2) Residential buildings and facilities of social importance whose operation may be impeded or prevented due to flood, i.e.: hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, social welfare homes, nursing homes, hospices, penitentiaries, correctional facilities, custodial facilities, police units, fire protection units, Border Guard units.

   For residential buildings and facilities of social importance, the average flood depth is determined separately for each flood scenario, then classified in two ranges, i.e. depth less than or equal to 2 m, water depth greater than 2 m.
3) Types of economic activities conducted in flood hazard areas, in the form of land use classes:
   - residential areas,
   - industrial areas,
   - transport areas,
   - forests,
   - recreational areas,
   - arable land and permanent crops,
   - grassland,
   - surface water,
   - other areas;
4) Cultural heritage areas and sites;
5) Installations which may, in the case of flood, cause significant pollution of individual natural elements or the environment as a whole;
6) Protected areas:
   - water abstractions (surface and groundwater) – including those intended for human consumption,
   - water abstraction protection zones,
   - bathing waters;
   - Natura 2000 sites,

- national parks and nature reserves,
- zoos;

7) Potential sources of water pollution in case of flood, i.e. industrial plants, wastewater treatment plants, wastewater pumping stations, landfills, cemeteries;
8) Values of potential damages for individual land use classes.

Flood risk maps are prepared in two thematic sets:

1) potential adverse consequences for human life and health, and the value of potential flood damages;
2) potential adverse consequences for the environment, cultural heritage and economic activity.

A description of the legend for FRM is available in the annexes to the methodologies for a given type of flooding.

SCALE AND FORM OF FHM AND FRM DEVELOPMENT

The FHM and the FRM were created in electronic form as:

1) spatial databases, and
2) a cartographic version (in the form of pdf and geotiff files), divided into sheets corresponding to sheets of topographic maps at a scale of 1:10,000.

A spatial database consists of **vector layers** in shapefile format, on the basis of which any spatial analysis in geographical information systems can be carried out.

The cartographic version of the maps in **pdf format** is a complete map containing the legend.

The cartographic version of maps in **geotiff format** contains only the content of the map with a specific spatial reference, enabling to use them in spatial information systems.

Information on FHM and FRM can be found on the website: www.powodz.gov.pl.

Maps in cartographic version, in pdf format are available at: http://mapy.isok.gov.pl

Maps in digital (vector) version are available at:
https://isok.gov.pl/hydroportal.html.

The digital version of the flood hazard maps is available at:

https://wody.isok.gov.pl/imap_kzgw/?gpmap=gpMZP.

The digital version of the flood risk maps is available at:

https://wody.isok.gov.pl/imap_kzgw/?gpmap=gpMRP.

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Annex 1. Methodology for the development of flood hazard maps and flood risk maps in the second planning cycle (2020);

Annex 2. Methodology for the development of flood hazard maps and flood risk maps from the sea water in the second planning cycle (2019);

Annex 3. Methodology for the development of flood hazard maps and flood risk maps for areas exposed to flooding for embankment damage or destruction (2021);

Annex 4. Report on the development of hydrological data for hydraulic modelling (2022);

Annex 5. Report on the review of flood hazard maps and flood risk maps (2019);

Annex 6. Scope of flood hazard maps and flood risk maps for different types of floods:

6.1. The scope of flood hazard maps and flood risk maps – for fluvial floods;

6.1a. The scope of flood hazard maps and flood risk maps for fluvial floods updated in 2022 as a result of the review, together with a description of the reasons for the update;

6.2. The scope of flood hazard maps and flood risk maps – the scenario of total destruction of flood embankments;

6.3. The scope of flood hazard maps and flood risk maps – for sea water floods, including internal marine waters;

6.4. The scope of flood hazard maps and flood risk maps – destruction or damage scenario for damming structures;

Annex 7. Report for floods from the sea water, including internal sea waters – for the area of the Maritime Office in Gdynia (2020);

Annex 8. Report for floods from the sea water, including internal sea waters – for the area of the Maritime Office in Słupsk (2020);

Annex 9. Report for floods from the sea water, including internal sea waters – for the area of the Maritime Office in Szczecin (2020);

Annex 10. Report on the implementation of the FHM and FRM for flood-prone areas in the event of damage or destruction of damming structures (2021).

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