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METHODOLOGY FOR THE DEVELOPMENT OF FLOOD HAZARD MAPS AND FLOOD RISK MAPS IN THE 2nd PLANNING CYCLE

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LIST OF ABBREVIATIONS

BDOT	Topographic Objects Database
CODGiK	Main Geodetic and Cartographic Documentation Centre
CZSW	Central Administration of the Prison Service
DPP	Drought Prevention Plan (Polish abbreviation “PPSS”)
DRA	District Road Authorities
DSTM	Digital Surface Terrain Model
DTM	Digital Terrain Model
DWSM	Digital Water Surface Model
FHM	Flood Hazard Maps (Polish abbreviation “MZP”)
FRM	Flood Risk Maps (Polish abbreviation “MRP”)
FRMP	Flood Risk Management Plan (Polish abbreviation “PZRP”)
GDDKiA	General Directorate for National Roads and Motorways
GDOŚ	General Directorate for Environmental Protection
GIOŚ	Chief Inspectorate of Environmental Protection
GIS	Geographic Information System
GUGiK	Head Office of Geodesy and Cartography
GUS	Central Statistical Office
MPHP10k	Hydrographic Map of Poland at a 1:10,000 scale
IMGW-PIB	Institute of Meteorology and Water Management – National Research Institute
ISOK	Project: IT System of the Country's Protection Against Extraordinary Threats
KG PSP	National Headquarters of the State Fire Service
MKiDN	Ministry of Culture and National Heritage
UM	Maritime Offices
MS	Ministry of Justice
MŚ	Ministry of Environment
NFZ	National Health Fund
NID	National Heritage Board
NOBC	System of Address Identification of Streets, Real Estates, Buildings and Dwellings
PFRA	Preliminary Flood Risk Assessment (Polish abbreviation “WORP”)
PGW WP	State Water Holding Polish Waters
PIG-PIB	Polish Geological Institute – National Research Institute
PIS-GIS	State Sanitary Inspection – Chief Sanitary Inspectorate
PRA	Provincial Road Authorities
PSHM	National Hydrological and Meteorological Service
PZGiK	National Geodetic and Cartographic Database
RBMP	River Basin Management Plan (Polish abbreviation “PGW”)
RZGW	Regional Water Management Authorities
UW	Voivodeship Offices
WIOŚ	Voivodeship Inspectorate for Environmental Protection
WWS	Wroclaw Water System

1. INTRODUCTION

1.1. LEGAL BASIS FOR THE METHODOLOGY

In order to properly assess flood risk and develop ways of managing it, as well as to limit the negative effects of flooding in the European Union, the Directive 2007/60/EC of the European Parliament and the Council of October 23, 2007 on the assessment of flood risk and its management, hereinafter referred to as the "Floods Directive", was concluded. The directive introduced the obligation for member countries to develop planning documents, which constitute the basis for undertaking measures, aimed at limiting the negative consequences of floods for human health and life, economic activity, the environment and cultural heritage.

The provisions of the Floods Directive have been implemented into the Polish legal system by the Act amending the Water Law Act and some other acts of January 5, 2011 (Journal of Laws of 2011 No. 32, item 159), which entered into force on March 18, 2011.

According to article 11, paragraph 1, point 1 of the abovementioned of the Act, the Floods Directive was implemented in the first planning cycle (in 2010-2015) by drawing up:

- preliminary flood risk assessment (PFRA) by December 22, 2011,
- flood hazard maps (FHM) and flood risk maps (FRM) by December 22, 2013 (publication and submission of maps to administrative bodies took place on April 15, 2015),
- flood risk management plans (FRMP) for river basin districts by December 22, 2015 (Regulation on flood risk management plans of October 18, 2016).

The Act of 20 July, 2017 – Water Law (Journal of Laws of 2020, item 310), hereinafter referred to as the "Water Act", which entered into force on January 1, 2018, retains the validity of the above-mentioned planning documents (article 555, paragraph 2, points 4, 5, 7 and 9) and orders them to be reviewed every six years and updated, if necessary. The deadlines for performing reviews and updates are as follows:

- preliminary flood risk assessment by 22 December, 2018,
- flood hazard maps and flood risk maps by 22 December, 2019,
- flood risk management plans for river basin areas by 22 December, 2021.

Based on article 171, paragraph 9 of the Water Law Act, flood hazard maps and flood risk maps may be reviewed and, if necessary, updated more often than every 6 years, except that if such an update is made, it should be repeated in accordance with the principle set out in paragraph 8, i.e. on the dates resulting from the Floods Directive.

The Water Law Act (in articles 169-171) also defines the general scope and method of drawing up flood hazard maps and flood risk maps, as well as the procedure for their opinions and agreeing.

Detailed requirements for the development of maps are contained in 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 development of flood hazard maps and flood risk maps (Journal of Laws of 2013, item 104).

This regulation was replaced by the regulation of the Minister of Maritime Economy and Inland Navigation of October 4, 2018 on the development of flood hazard maps and flood risk maps (Journal of Laws of 2018, item 2031), hereinafter referred to as the "Regulation".

The aforementioned legal provisions (Floods Directive, Water Law Act and Regulation) are the basis for the preparation of a methodology which presents the method of developing flood hazard maps and flood risk maps, including reviewing and updating them.

Based on article 171, section 1 and article 240, paragraph 2, point 6 of the Water Law Act, draft flood hazard maps and flood risk maps shall be prepared by Polish Waters in consultation with the relevant voivodes. Whereas, under article 171, paragraph 2 draft flood hazard maps and flood risk maps from the sea water, including inland marine waters shall be prepared by directors of maritime offices. Projects of flood hazard maps and flood risk maps from the sea water, including inland marine waters, are an integral part of the draft of flood hazard maps and flood risk maps.

In accordance with the requirements of the Floods Directive, flood hazard maps and flood risk maps are prepared for areas and types of floods indicated in the preliminary flood risk assessment. As a result of the review and update of PFRA in 2018, areas exposed to the risk of flooding were identified, i.e. areas where significant risk of flooding exists or is likely to occur, including the following types of floods:

1) fluvial flood – related to the flooding of land by waters originating from rivers, streams, mountain streams, canals, lakes – in two scenarios:
    a) a natural exceedance,
    b) destruction of flood embankments;
2) flood from the sea water – related to flooding of the area by sea waters, including estuary river sections and coastal lakes – in two scenarios:
    a) a natural exceedance,
    b) destruction of storm embankment;
3) flooding from artificial water bearing infrastructure – related to flooding of the area in the event of dam failures.

This methodology concerns the development of flood hazard maps and flood risk maps for fluvial floods.

Flood hazard maps and flood risk maps for sea water floods are drawn up by directors of maritime offices based on a separate methodology.

The methodology for the development of flood hazard maps and flood risk maps from artificial water bearing infrastructure, including the scenario of damage or destruction of damming structures, is a separate document.

1.2. SCOPE OF THE METHODOLOGY

The methodology for the development of flood hazard maps and flood risk maps in the second planning cycle determines the scope and implementation of works at different stages of the review, followed by updating and developing new FHM and FRM for fluvial floods. However, due to the need of integrating maps in the scope of other types of floods, the methodology also includes how they are taken into account.

The methodology therefore provides guidance for tasks related to, inter alia, the following:

- preparation of data for the review and update of the FHM and FRM (including inventory of investments affecting the extent of flood hazard areas, development of hydrological and meteorological data and geodetic measurements),
- review of FHM and FRM developed in the first planning cycle,
- development of FHM (including hydraulic modelling),
- development of FRM (including data preparation),
- preparing a spatial database,
- preparing a cartographic version of maps.

Due to the considerable size of the parts related to hydrology, cartography of maps and attribute structure of the prepared vector layers, they are included as annexes to this methodology.

1.3. PRODUCT QUALITY CONTROL

Product control is carried out in accordance with the “Procedure and criteria for product quality control” adopted in the project: “Review and update of flood hazard maps and flood risk maps”.

2. FHM AND FRM CONTENT

Flood hazard maps and flood risk maps shall be prepared for areas of potential significant flood risk identified in the preliminary flood risk assessment, i.e. areas where a significant flood risk exists or is likely to occur.

According to the Water Law Act, the flood hazard maps are presented as follows in particular:

1) areas with a low probability of flooding of 0.2%;
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%,
   c) areas between the shoreline and the embankment or natural high bank with built-in flood embankment, as well as islands and alluvials, which constitute cadastral parcels,
   d) *technical belt (only applicable on maps from the sea water)*;
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 *the storm embankment (only applicable on maps from the sea water);*
5) *areas exposed to flooding in case of damage or destruction of dams (this methodology does not apply to this scenario)*.

According to the Regulation, the flood hazard maps show, among others, the following elements:

1) flood hazard areas;
2) water depths;
3) the maximum ordinates of water level, corresponding to flows with a certain probability of exceedance;
4) flow velocity and direction of water flow (in case of two-dimensional modelling);
5) flood embankments;
6) top of flood embankments ordinates in cross-sections that have been used for hydraulic modelling.

The flow velocity and directions of water flow are taken into account only on flood hazard maps from rivers – in towns with the seat of the voivodeship self-government authorities or voivode, towns with district rights and other towns with more than 100,000 inhabitants.

On flood hazard maps for other types of floods, i.e. from the sea water, from damming structures, as well as in case of damage or destruction of the embankment, flow velocity and directions are not shown.

Flood hazard maps show the depths of water and flow velocities in the intervals determining the degree of danger to people and the way they affect the construction objects, according to the Regulation:

1) water depth:
   – $h \leq 0.5$ m – low hazard to people and buildings;
   – $0.5 < h \leq 2.0$ m – medium hazard to people, due to the possibility of evacuation to the higher floors of buildings, but high due to material damages;

- 2.0 < h ≤ 4.0 m – 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;
- h > 4 m – very high hazard to people and very high hazard of total material damages;

2) flow velocity:
   - v ≤ 0,5 m/s – low velocity, water has a small impact on buildings;
   - 0.5 m/s < v ≤ 1 m/s – medium velocity, water has moderate impact on buildings and is able to move objects of small size and weight, it is hazardous to people;
   - 1 m/s < v ≤ 2 m/s – high velocity, water has strong impact on buildings and is able to move objects of relatively large size and weight, it is a serious threat to people;
   - v > 2 m/s – very high velocity, the water has very strong impact on buildings and is able to move objects of very large size and weight, as well as disturb the structure of static objects, it is a very serious threat to people.

For flood hazard areas, for which flood hazards maps were made, the flood risk maps are prepared, in accordance with article 170 of the Water Law Act.

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

Flood risk maps specify the values of potential flood damages and show objects exposed to flooding with a certain probability of occurrence. These are objects that will allow the assessment of flood risk to human health and life, the environment, cultural heritage and economic activity, i.e. groups for which the adverse effects of floods should be limited in accordance with the objectives of the Floods Directive.

For this purpose, flood risk maps show:
1) the estimated number of inhabitants likely to be affected by the flood;
2) types of economic activities carried out in flood hazard areas;
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) in justified cases:
   a) areas where floods may occur, accompanied by the transport of large quantities of sediment and debris,
   b) 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 set out in the Regulation. A detailed description of the map contents is also provided later in this methodology.

3. DESCRIPTION OF FLOOD SCENARIOS

3.1. SCENARIOS IN THE 1st PLANNING CYCLE

In the first planning cycle, under the Water Law Act of 18 July 2001 (Journal of Laws of 2012, item 145, as amended, and Journal of Laws of 2014, item 850), the following flood scenarios were developed:

1) Scenario I – low probability of flooding once every 500 years (0.2%);
2) Scenario II – medium probability of flooding once every 100 years (1%);
3) Scenario III – high probability of flooding once in 10 years (10%);
4) Scenario IV – destruction or damage of the flood embankment, in two variants:
   a) destruction or damage of embankment on a selected section (for a flow with a 1% probability of occurrence),
   b) total destruction of the flood embankment (for flow with 1% probability of occurrence);
5) Scenario V – destruction or damage of the storm embankment (protective structures of the technical belt).

The flood embankment damage locations were selected on the basis of the overflow locations above the embankment top with a probability of exceeding 0.2% and 1%.

The scenario of total destruction of the flood embankment determines the flood hazard resulting from the possibility of failure of any section of the embankment. The scenario was performed for all river embankments indicated in the preliminary flood risk assessment.

3.2. SCENARIOS IN THE 2nd PLANNING CYCLE

In the second planning cycle, according to the Water Law Act, the following flood scenarios are performed:

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 in case of damage or destruction of the embankment (determined for a flow with a 1% probability of occurrence) – scenario of total destruction of the embankment;
   – areas exposed to flooding in case of damage or destruction of the storm embankment – scenario of total destruction of the storm embankment (only applies to maps from the sea water);
5) Scenario V – areas exposed to flooding in the event of dam failure (this methodology is not applicable to this scenario).

Scenario of flood embankment damage in a selected section, developed within the first planning cycle did not allow a comprehensive presentation of the risk associated with embankment failure – as it is not possible to analyse all potential embankment destruction sites. In addition to this scenario, a scenario of total destruction of the embankment was created in the first cycle.

Therefore, in the second cycle, only the scenario of total destruction of the embankment was taken into account, which allows to determine the flood hazard in any location. The scope of work necessary to develop this scenario is described in subsection 3.3 below.

3.3. DEVELOPING THE SCENARIO OF TOTAL DESTRUCTION OF THE EMBANKMENT

Flood hazard maps for areas exposed to flooding due to destruction or damage of embankments result from the possibility of embankment failure at any location, which has been repeatedly confirmed by the facts during flooding e.g. in 1997 and 2010.

Areas exposed to flooding in case of total destruction of the embankment shall be developed as follows:

1) The scenario is performed for all embanked rivers indicated in the preliminary flood risk assessment.
2) Flood hazard areas should be determined for a medium flood probability of 1% (once every 100 years).
3) The scenario of total destruction of the embankment shall be developed using one of the two methods described below. The choice of the method depends on the specific topographical, hydrographic and hydrological conditions of the river valleys.

METHOD I

The first method is to use the modelling results for scenario II. For this purpose, the maximum water level ordinates resulting from the modelling under scenario II are used to designate flood hazard areas. The ordinates of the water level calculated for the riverbed zone are transferred to a parallel area behind the flood embankment. For this purpose, sets of extended riverbed cross-sections are prepared to match the shape of the river valley (Figure 1). The further processing of the results is in accordance with the methodological description for the other flood scenarios. An example of the result is shown in Figure 2. The result of this method is similar to the results developed using hydraulic modelling in the first planning cycle. The flood hazard areas for scenarios II and IV do not show significant discrepancies.

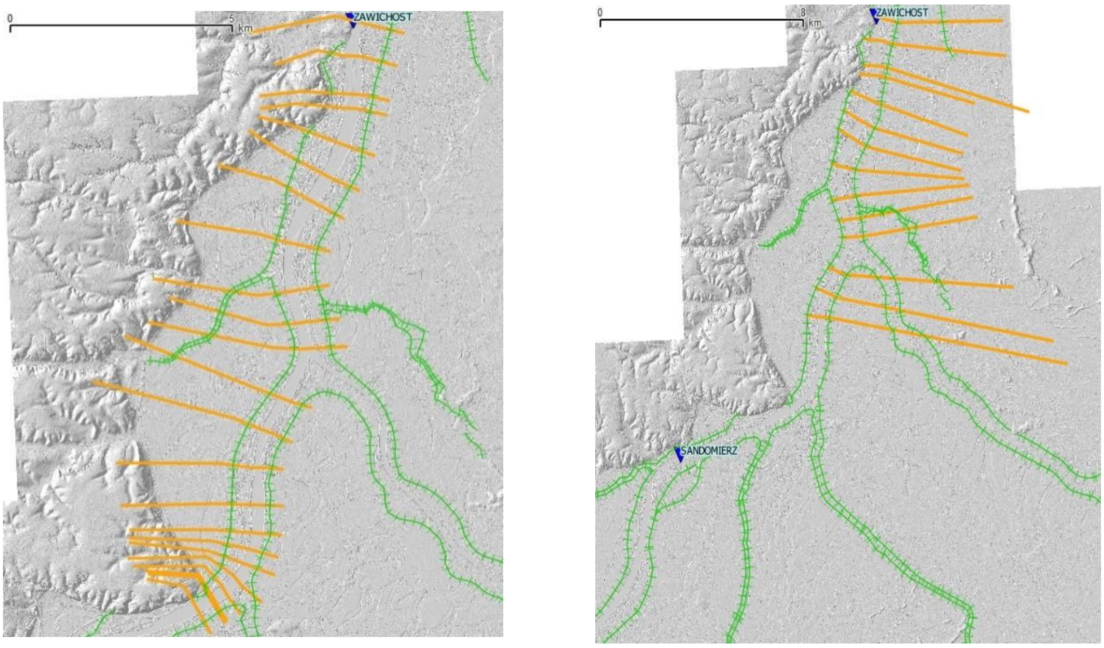


Fig.1. Example of a set of cross-sections to transfer the results from the Vistula riverbed to the area behind the flood embankment.

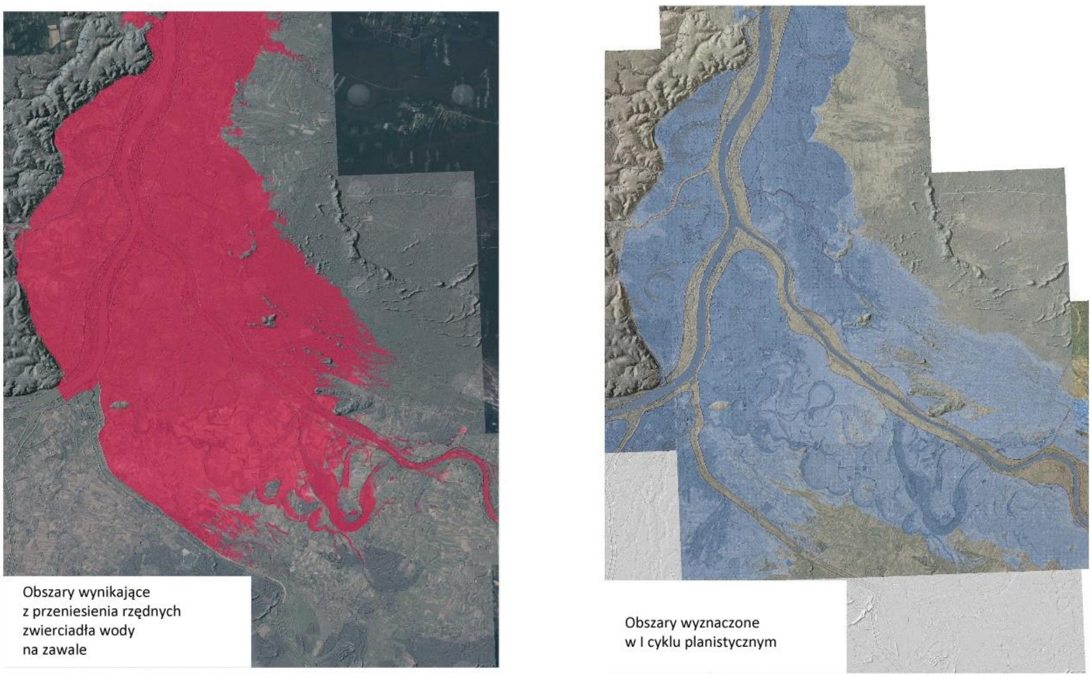


Fig. 2 Results of scenario IV development according to the first method

In case the water level ordinates calculated in scenario II significantly exceed the top of embankment ordinates (> 0,2 m), the reduction of the water level ordinate transferred to the floodplain to the top of embankment ordinate should be considered. This is to prevent possible excessive depths and ranges of water in floodplains, which participate in conducting flooding waters, not being only a retention area, which occurs e.g. in valleys often crossed by communication routes in embankments.

Flood hazard areas designated in accordance with the above approach reflect the effects of embankment failures at any location.

METHOD II

In case of "flat" and extensive river valleys or rivers, whose area behind the flood embankment is significantly below the embankment, a second method may be necessary, i.e. additional hydraulic modelling. The choice of this method is made by the hydraulic modelling specialist. The volume of the wave and the duration of its culmination is also an important indication for such a decision. Their high values are a premise for using the first method. However, an unambiguous criterion for determining the applicability of both methods is difficult to determine due to the diversity of river valleys.

An example of using the second method is the area of the Żuławy Wiślane (Fig. 3 and 4). In this case, it is possible to show significant discrepancies between the flood hazard areas determined by first method and those determined using hydraulic modelling within the first planning cycle.

Area of RW DW (Vistula River in the vicinity of Żuławy Wiślane)

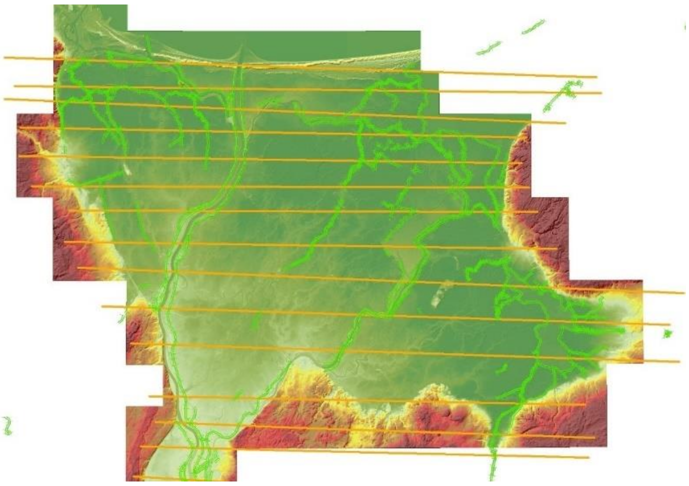


Fig. 3 A set of sections for transferring the results from the Vistula riverbed

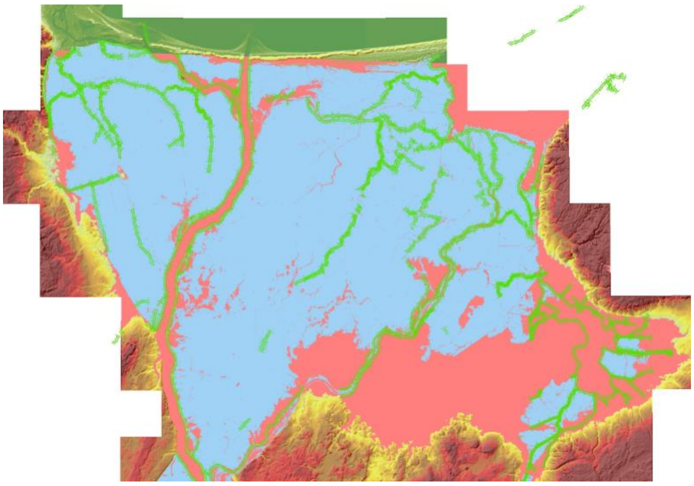


Fig. 4 Results of scenario IV development according to the first method

The application of the second method is based on the following principles:

1) The mathematical modelling of the flow with a 1% probability of exceeding is carried out using hydrodynamic models built under scenario II, which should be adapted to the assumptions of the total embankment destruction scenario.
2) The flood hazard area is determined by removing unilateral embankments (separately for each bank). This process is carried out in two stages: in the first stage, the left-hand embankment must be removed and hydraulic modelling must be carried out, and then the calculations for the removed right-hand embankment must be repeated.
3) Mathematical modelling should be performed for unsteady flow.
4) For unsteady flow conditions, the simultaneous removal of the embankment over a long section is excluded. Several models should be made, in which subsequent parts of the embankments will be removed. The sections of the embankment to be removed (example shown in Fig. 5) should be selected based on the topography of the terrain (beginning and end of the section linked to naturally or artificially occurring hills).

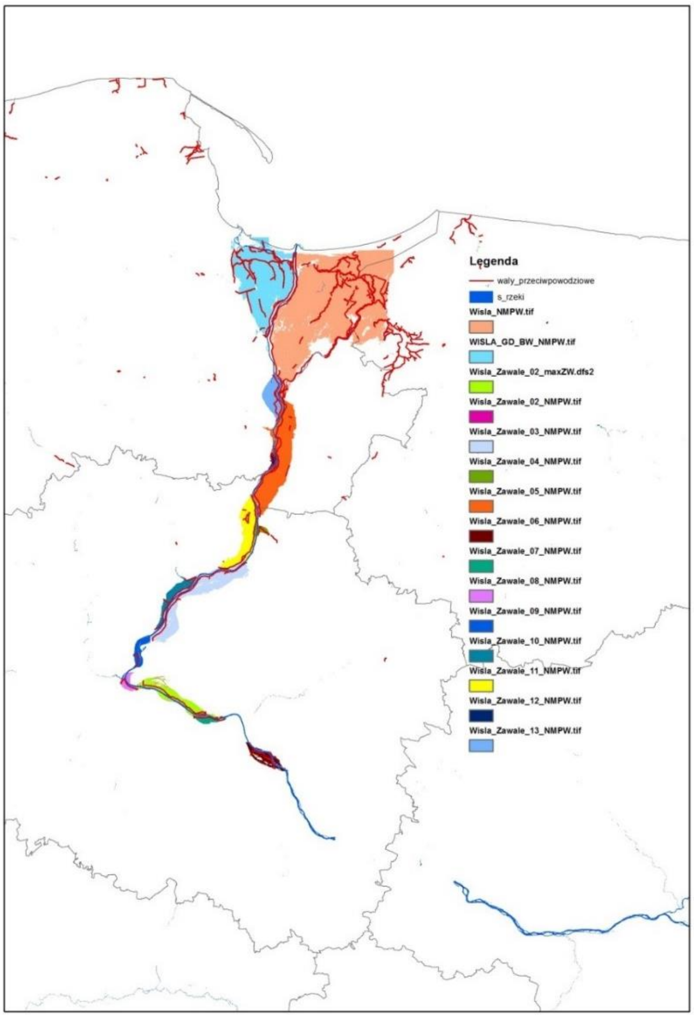


Fig. 5. Lower Vistula – sections of embankments to be removed when modelling in scenario IV

5) If the shape of the valley of the analysed section requires it, the river network of models will be extended accordingly.

6) In justified cases other solutions than those described above may be used. Any deviations will be described in the documentation with the indication of their spatial extent and justification.

The steps to identify flood hazard areas in an embankment protected area are as follows:

1) Actual state – marking all embankments in black (Fig. 6 on the example of the Vistula river).

Fig. 6. Existing state of embankments

2) Determining the flood hazard area on the left embankment (Fig. 7; the dashed red line marks the embankments removed from the model, the black line marks the embankments left).

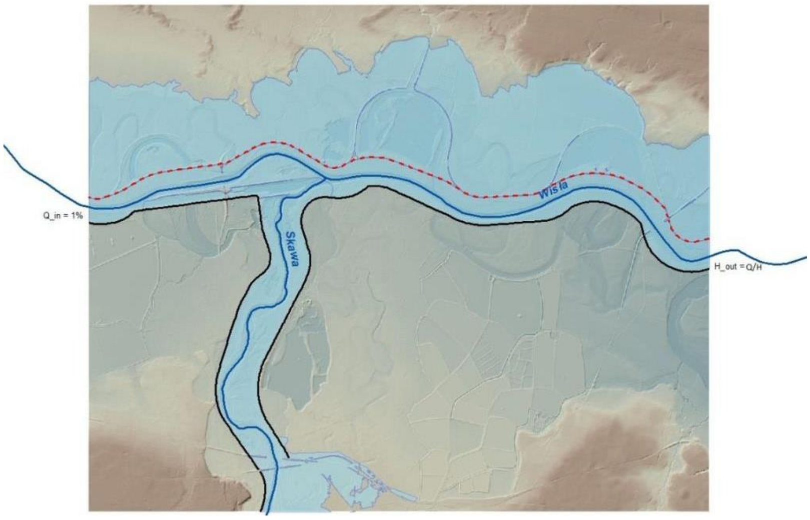


Figure 7: Removed left-hand embankment for the main river

3) Determining the flood hazard area on the right-hand embankment (Fig. 8; line colours as above).

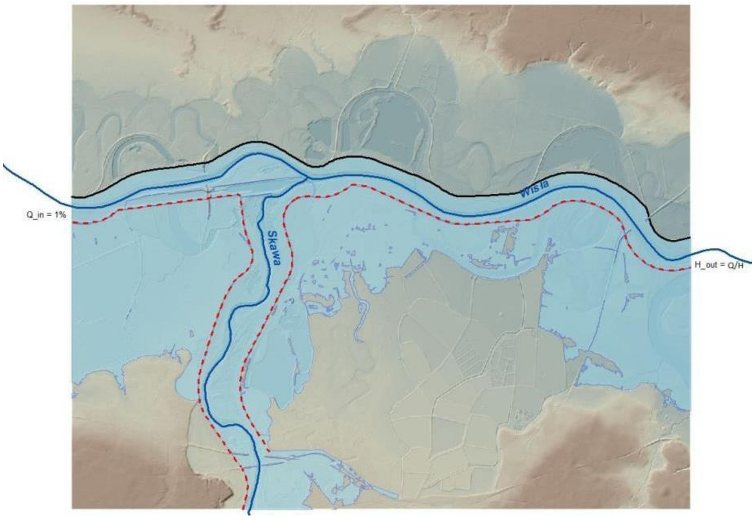


Figure 8: Removed right-hand embankment for the main river

4. METHOD AND SCOPE OF REVIEW AND UPDATE OF FHM AND FRM

4.1. INTRODUCTION

The purpose of this chapter is to indicate a uniform methodology for the review of flood hazard maps and flood risk maps drawn up in the first planning cycle and to indicate the rivers or river sections for which the maps should be updated.

The aim of the methodology is also to define the concept of "significant changes", which will guide the updating of flood hazard and risk maps and to find criteria to assess the validity and correctness of the FRM and the FRM.

4.2. PURPOSE AND SCOPE OF THE REVIEW

The purpose of the FHM and the FRM review is to identify significant changes in flood hazard and risk and to determine the scope for the FRM and the FRM update.

The review of FHM and FRM carried out in the first planning cycle concerns 255 rivers or river sections with a total length of about 14.4 thousand km.

The review analyses the flood scenarios of the FHM and the FRM and identifies significant changes in flood hazard (to the FHM) and flood risk (to the FRM). The following scenarios are reviewed:

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 high probability of flooding of 10% (once every 10 years);
4) Scenario IV – areas exposed to flooding in case of damage or destruction of the embankment (determined for flow with 1% probability of occurrence) – scenario of total destruction of the embankment.

The process of reviewing the FHM and FRM is schematically presented in Fig. 9. The need for review for particular rivers may result from the necessity to take into account the completed or planned investments, data indicating e.g. change of hydrological regime, the need to improve/adjust the hydraulic model, but also from consultations and comments made so far by institutional recipients (at the voivodeship, possibly district and commune, as well as social levels).

Figure 9: Diagram of FHM and FRM review

4.3. DEFINING THE ASSUMPTIONS AND SCOPE OF THE FHM REVIEW

Flood hazard maps developed in the first planning cycle shall be updated for areas where there significant changes in the flood hazard have occurred, including significant changes of input data, taking into account their availability, as well as in cases where there is a justified need to change the methodological assumptions adopted in the first planning cycle.

The following factors/criteria should be taken into account when identifying **significant changes in** flood hazard and risk:

1) changes in topography, as well as flood protection investments and other investments that change the flood hazard;
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 from administrative authorities to the FHM submitted in the first planning cycle.

Changes in topography, as well as flood protection investments and other investments that affect the change of the flood hazard

The review should include an analysis of topographical changes and their impact on changes in the level of flood hazard and risk:

1) checking the availability of newer digital terrain models, in order to determine its changes with respect to the digital terrain model used for the first planning cycle, and to determine the impact of these changes on the level of flood hazard and risk;
2) inventory of flood protection and other investments that may potentially affect the extent of flood hazard areas, including the impact of mining activities on changes in the topography and the course of riverbeds;
3) impact of felling of trees and shrubs in special flood hazard areas – implementation of programmes or similar activities, about which information should be obtained, which may affect the capacity of rivers, and thus the water level ordinates of the various scenarios of probable waters and floodplains. However, this impact can be temporary, depending on the future maintenance of the riverbeds. The assessment should provide an answer as to whether and to what extent an update should be made.

In order to carry out the stocktaking of the investments, information on the implementation of the investments obtained from the following institutions and administrative bodies should be used:

- Regional Water Management Authorities (RZGW);
- Regional Boards of Land Facilities and Water Management (ZMiUW);
- Maritime Offices (UM);
- Provincial Road Authorities (PRA);
- District Road Authorities (DRA);
- General Directorate for National Roads and Motorways (GDDKiA);
- Railway Authorities.

The source of data on investments affecting the change in the level of flood hazard and risk is also the information collected during the survey conducted under the project "Review and update of the preliminary flood risk assessment", as well as information obtained from the administrators of water courses and water facilities.

The stocktaking of investments should take into account investments arising since obtaining input data for maps developed in the first planning cycle and investments planned for implementation by 2019. The analyses should also include the investments that have been taken into account in the development of flood risk management plans in the first planning cycle (in the so-called zero variant W0).

For investments which have been pre-qualified as having a potential impact on the change in the level of flood hazard, their impact on the change in the level of flood hazard and risk should be determined.

Verification of the input data to the FHM used in the first planning cycle

As a part of the verification of the input data for the FHM used in the first planning cycle, analyses of hydrological data and riverbed geometry (riverbed cross-sections) should be carried out.

In the case of hydrological data, it should be verified for correctness and timeliness. Changes in hydrological data may result from the extension of hydrological databases/information and changes in methodological assumptions for calculation of hydrological data. For water gauges located on the rivers covered by modelling in the first planning cycle, the maximum annual flows with a defined probability of exceeding shall be calculated, taking into account the data until 2016, and then analyse the changes of these data, compared to those calculated during the first planning cycle.

Verification of the input data also includes an analysis of the riverbed cross-sections for their timeliness. The analysis includes:

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

Changes in methodological assumptions of hydraulic modelling

Where FHM is indicated for updating, the methodology for developing FHM and FRM in the second planning cycle shall be used, whereby changes to the methodological assumptions for hydraulic modelling (compared to those used in the first planning cycle) shall only be taken into account if they change the level of flood hazard.

The analysis of changes in methodological assumptions of hydraulic modelling should be carried out on the basis of verification of their impact on the change of flood hazard and risk level. The assessment of the impact of changes in methodological assumptions of hydraulic modelling on the change of flood hazard level should be carried out according to the scale of significance of changes, according to the procedure below.

Important elements of methodological changes in the field of hydraulic modelling that are subject to verification include:

1) The use of unsteady flow solutions. The adoption of such solutions is in some cases necessary and leads to adjustments in flood hazard areas. The decision to update is preceded by an assessment of the need and effectiveness of this solution, taking into account topographical conditions (valley retention size) and hydrological data (in particular the maximum flow rate and duration of the flood wave), as well as the potential effect on the extent of the flood hazard area.

2) Removing the limitation of the active cross-sectional area to the width of the embankment spacing and including the area of the embankment as a calculative cross-section in sections where necessary. This methodological change concerns in particular those river sections where the level of the water level on the FHM in the first cycle exceeded the ordinate of the embankment top and the modelling was performed using the conditions of limiting the active cross-section to the width of the embankment spacing.

3) The influence of retention reservoirs on the hydrological regime of the river. For this purpose, a verification of flows with a certain probability of occurrence is carried out for the sections below the reservoirs, taking into account the transformation and reduction of the wave by the reservoir. An assessment shall be made as to whether it is necessary to simulate the flood wave transformation for the reservoirs. The criterion also indicates the reservoirs (river sections within the area of flood protection reservoirs) for which flood hazard areas shall be removed.

4) Change of modelling type in order to obtain the highest quality product. It is recommended to update the FHM for those flood hazard areas at that have been determined in accordance with the methodology of the first cycle, while the current analysis indicates the need for a new or alternative solution that guarantees the expected higher quality of results, especially for areas with a complex topography and significant flood risk potential.

Comments of the institutions and administration bodies to the FHM

An analysis of the comments regarding the level of flood hazard identified in the FHM, submitted by the authorities in the first planning cycle, as well as during the survey conducted by the "Review and update of the preliminary flood risk assessment" project should be carried out.

A tabular summary (in an xlsx file) of all submitted comments should be prepared, as well as their impact on the change in the flood hazard level and their relevance, together with justification and information whether the comment will be taken into account in the map update.

Determining the impact of the above factors/criteria on the change in the flood hazard level is based on the significance scale (Table 1). **Significant changes in flood hazard** should be understood as changes resulting from the impact of one (major) or combined impact of several (less important) factors on the flood hazard level in a given area. These changes are expressed as significant changes in the level of the water level and/or the extent of flood hazard areas. They involve a specific change in hydrological data (relative or expressed in absolute values), a change in the methodological assumptions of hydraulic modelling, natural changes in the morphology of the riverbed and valley, as well as resulting from the implementation of investments and other human activities. Apart from significant changes and their absence, less important – moderate and small – changes should also be assumed.

Table 1. Significance scale of changes in flood hazard and risk

Significance of changes	Description
Significant	Major or important changes that have a significant impact on the hazard and risk of flooding – these changes form the basis for updating the maps
Moderate	Less important changes having a moderate impact on the hazard and risk of flooding – these changes may form the basis for updating the maps
A small	Small changes with small impact on the hazard and risk of flooding – these changes do not form the basis for updating the maps
None	No impact on flood hazard and risk

The assessment of the significance of individual factors/criteria is based on an analysis of the impact of individual criteria (indicated in Table 2) on the flood hazard level:

1) based on an expert evaluation;
2) in specific cases, for selected moderate or small changes, the significance of which is difficult to determine in the first stage of the review, on the basis of a detailed, usable analysis:
   a) GIS analysis,
   b) the results of modelling from the first planning cycle,
   c) hydraulic calculations,
   d) other analyses.

Table 2. Criteria for assessing the impact of changes to the level of flood hazard within the review of the FHM and the FRM

STAGE	Criterion code	Description of the criterion	Evaluation parameters	Significance/Measurement
I	**Implementation of investment, topographical changes in the river valley, changes in riverbed cross-sections**			
	I1	Hydraulic engineering investments (embankments, weirs, bridges, polders, reservoirs) and other investments	The impact of investment on the change in the level of flood hazard. Evaluation based on expert analysis	Impact: significant/moderate/ small/none
	I2	Changes in route and riverbed cross-section (natural and regulatory)	The impact of investment on the change in the level of flood hazard. Evaluation based on expert analysis	Impact: significant/moderate/ small/none
	I3	Changes in the river valley as a result of construction development and changes of use	The impact of investment on the change in the level of flood hazard. Evaluation based on expert analysis	Impact: significant/moderate small/none
	Hydrology			
	H1	Change in the value of probable flows with a specified probability of exceeding Q10%, Q1%, Q0.2% between the values calculated in the I and II planning cycle	The impact of a change in the value of probable flows calculated for water gauges on the change in flood hazard level	Percentage change (%) Effect: significant: >20 (**>15) moderate: 10-20 (**10-15) small: 5-10 (*0-10) none: 0-5 (*0)
	H2	Change of water level ordinates and water levels corresponding to the probability of exceedance for water gauges estimated in accordance with effective methodology in the first planning cycle	The impact of a change in water level values at water gauges corresponding to probable flows on the change in flood hazard level	Absolute value (cm) Impact: significant: >40 moderate: 20-40 small: 10-20 none: 0-10
	Change of methodological assumptions			
	M1	Use of unsteady flow	Influence of the application of unsteady flow conditions in models where the steady flow conditions established in the first planning cycle were applied to the change of flood hazard level	Impact: significant/moderate/ small/none
	M2	Removing the limitation of the active cross-section to the width of the embankment spacing	Changes in the level of flood hazard resulting from a change in the approach to modelling in embanked river sections (rejection of the active cross-section up to the width of the embankment spacing). In the case of overflow of water through the embankment, with simultaneous cutting off the flood hazard area on the embankment, the relevant sections were qualified for updating.	Absolute value (cm) Effect: significant: >30 cm moderate: 20-30 cm small: 10-20 cm none: <10 cm
	M3	Impact of the operation of retention reservoirs (flood protection)	The change in the level of flood hazard resulting from the implementation of water management rules in models for river sections with retention (flood protection) reservoirs, for which simplified water management rules were applied. Removal of flood hazard areas from the zones around reservoirs	Impact: significant/moderate/ small/none
	M4	Modelling change	The change of the approach to modelling a given river section, in order to obtain a top quality product	Impact: significant/moderate/ small/none

STAGE	Criterion code	Description of the criterion	Evaluation parameters	Significance/Measurement
	Comments from the administration bodies to the FHM			
	U1	Comments of the institutions and administration bodies	Analysis of the comments concerning the level of flood hazard submitted by institutions and administration bodies in the first planning cycle	Impact: significant/moderate/ small/none
II	**Detailed analysis (optional)**			
	ZP1	Change of the position of the water level	Change of the ordinate of the water level or change of the depth of flood hazard areas	Absolute value (cm) Effect: significant: >30 cm moderate: 20-30 cm small: 10-20 cm none: <10 cm
	ZP2	Change of the width of the water level	Change of the width of the water level (in cross-sections of the river section to be changed) and the flood hazard area	Absolute value (m) Effect: significant: >10 m, none: <10 m

The flow criterion measure (H1) is the change expressed as a percentage (relative measure), for the position of the water level (H2) the absolute measure is expressed in centimetres. Thresholds determining the significance of change take into account the specificity (river sections) of the rivers in a given water region: * the water region of the Central Oder, the water region of the Upper Oder, the water region of the Little Vistula, ** the water region of the Upper Vistula.

Due to the predominantly mountainous nature of watercourses in the Upper Vistula water region, the water region of the Central Oder, the water region of the Upper Oder and the water region of the Little Vistula, manifested by narrower, indented valleys, and thus by larger changes in the water ordinates with smaller changes in flows, the modified percentage limits of the ranges of changes in probable flows classifying the impact of changes on the update of the FHM were adopted.

Based on the criteria, a comprehensive assessment of changes in individual scenarios is prepared, and then the need for updating is indicated.

For each river or section of a river, the impact of the above factors/criteria on the change in flood hazard level shall be determined. The range of influence is given using a chainage.

On the basis of the assessment of individual factors/criteria under stage I or stage II (cf. Table 2), a comprehensive assessment of their impact on the level of flood hazard in individual scenarios is determined in a given river/river section.

A comprehensive assessment resulting in the need for updating on a given river or river section occurs for at least one important or several less important (e.g. moderate) factors/criteria. However, each case of update shall be considered individually, taking into account the specificities of the river or river section concerned.

A comprehensive assessment of changes applies to all flood scenarios. If a river or river section is indicated for updating, the update includes all flood scenarios.

The update range for a given river should be adapted to the type of change. For local changes, e.g. investments with a local impact, the update applies only to a short river section. In the case of several investments (or other changes) on the same river, in different locations, it will be reasonable to update the maps for a longer river section due to the possible overlapping impact of these investments and to maintain the continuity of the digital water surface model.

In the case of changes in flood hazard, a decision to update the FHM is also influenced by the vulnerability of the area to these changes. In the case of areas with higher vulnerability (built-up areas), updating the maps is more advisable than in the case of extensively used areas (e.g. grassland or wasteland).

As a result of the review, a list of the rivers indicated for updating is presented, for which, as a result of a comprehensive assessment, significant changes in factors influencing changes in flood hazard and risk have been identified.

The indication to update the FHM should be carried out in two steps.

In the first step, indications for updating the FHM are presented in three categories:

1) update required (WA) – for significant changes indicated in a comprehensive assessment;
2) update recommended (ZA) – for moderate changes indicated in a comprehensive assessment;
3) no need to update (BA) – for small changes and no impact on the flood hazard level.

The results of the analyses with indications to be updated in three categories are presented in PGW WP to decide which sections of the recommended update are finally included for map updates. These decisions shall take into account the results of consultations of the draft review of the FHM and the FRM with the competent authorities.

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

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

Updating the FHM takes into account changes in the factors/criteria indicated in the review for a given river or section of river, as described in Table 3. Each case of indicated update shall be considered individually, taking into account local specificities.

Table 3 How the factors/criteria analysed in the revision of the FHM are taken into account in the update of the FHM

Criterion code	Description of the criterion	The approach takes into account the criterion when updating the FHM and FRM
Implementation of investments, topographical changes in the river valley, changes in riverbed cross-sections		
I1	Hydraulic engineering investments (embankments, weirs, bridges, polders, reservoirs) and other investments	Implementation into the hydraulic model for the investment identified in the review as necessary for the update of the FHM
I2	Changes in route and riverbed cross-section (natural and regulatory)	Implementation into a hydraulic model for an investment/change of a river or section of a river identified in the review as necessary to update the FHM
I3	Changes in the river valley as a result of construction development and changes in use	Implementation into the hydraulic model for an investment/ topographical changes identified in the review as necessary to update the FHM
Hydrology		
H1	Change in the value of probable flows with a specified probability of exceeding Q10%, Q1%, Q0.2% between the values calculated in the I and II planning cycle	Implementation into the hydraulic model for the hydrological changes identified in the review as significant and/or moderate in the river or river section to be updated, with continuity of development
H2	Change of water level ordinates and water levels corresponding to the probability of exceedance for water gauges, estimated according to the project methodology in the first planning cycle	Implementation into a hydraulic model for a given river or river section identified in the review as significant and/or moderate hydrological changes for the update, while maintaining the methodological correctness of the study
Change of methodological assumptions		
M1	Use of unsteady flow	Implementation into the hydraulic model for a river or river section identified in the review as having a significant and/or moderate impact on the change of flood hazard level, where justified
M2	Removing the limitation of the active cross-section to the width of the embankment spacing	Implementation into the hydraulic model for the changes in the active section limitation indicated for the update of a river or river section
M3	Impact of the operation of retention reservoirs (flood protection)	Implementation into the hydraulic model for the river or river section identified in the survey as necessary for the update of the retention (flood) control rules
M4	Modelling change	Implementation of the required modelling changes identified in the review as affecting significantly and/or moderately the level of flood hazard, while maintaining the methodological correctness of the study into the hydraulic model for the river or river section to be updated
Comments from administration bodies to the FHM		
U1	Comments of the institutions and administration bodies	Implementation into the hydraulic model for the river or section of the river indicated for the update of the river or river section changes indicated in the remarks identified in the review as significantly changing the level of flood hazard, while maintaining the methodological correctness of the study

4.4. DEFINING THE ASSUMPTIONS AND SCOPE OF FRM REVIEW

All FRM developed in the first planning cycle are subject to updating. This is not only due to specific changes in flood hazard areas to the FHM, for which the FRM should always be changed, but also due to changes in other input data determining flood risk. Therefore, in addition to the changes of flood hazard described above, in the review of the FRM the account shall be particularly taken of:

1) updating the data on the values of potential flood damages, taking into account the depth of flooding;
2) updating the data on the estimated number of inhabitants likely to be affected by the flood;
3) verification and updating:
   a) land use classes (based on BDOT10k data),
   b) residential buildings and buildings of social importance (hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, police and fire protection units, Border Guard units, nursing homes, hospices, social care centre, educational care facility, penitentiary, correctional or custodial facility), based on BDOT10k data, using data from NFZ, MS, CZSW, voivodeship offices,
   c) zoos (based on BDOT10k data),
   d) surface water abstractions, groundwater abstractions, protection zones for abstractions, based on PGW WP and PIG-PIB data,
   e) bathing waters based on PIS-GIS data,
   f) Natura 2000 areas, national parks and nature reserves based on GDOŚ data,
   g) historic real estate areas and objects, based on NID data,
   h) other cultural heritage sites, based on MKiDN data,
   i) industrial plants, based on MŚ, GIOŚ, WIOŚ and KG PSP data,
   j) potential water pollution sources, i.e. wastewater treatment plants (based on data from WIOŚ and PGW WP), wastewater pumping stations (based on data from BDOT10k), landfills (based on data from BDOT10k, PGW WP and WIOŚ) and cemeteries (based on data from BDOT10k),
   k) cities (based on BDOT10k data).

5. PREPARATION OF INPUT DATA FOR FHM AND FRM

5.1. PERFORMANCE AND DEVELOPMENT OF GEODETIC MEASUREMENTS

5.1.1. Execution and development of river valley cross-sections

5.1.1.1. Determining the location and surveying of valley cross-sections (transverse)

Valley cross-sections should cover the entire river valley, i.e. the riverbed (riverbed cross-section) and both floodplain terraces (left and right) – the section through terraces. The part of the measurement concerning the riverbed should be carried out directly in the field (typical riverbed cross-section), while the part of the valley cross-section including floodplain terraces – based on the latest available digital terrain model (DTM).

Valley cross-sections should be developed with the following cumulative assumptions in mind:

a) Valley cross-sections (riverbed cross-section with terraces) should be located in characteristic and representative locations, in such way that ensures proper reproduction of the valley.
b) For the location of riverbed cross-sections, characteristic locations should be selected, i.e. representative of the riverbed section below and above the cross-section (variability in riverbed shape, slope and bottom material should be taken into account). The location of cross-sections should be avoided in places of sudden changes in the direction of water flow (sharp curves, meanderings, etc.) – in such situation it is recommended to carry out two cross-sections – above and below such place.
c) In the case of valley cross-sections on a watercourse where measurements have already been carried out in other studies, the measurements should be located in the same locations, taking into account all the principles contained in the methodology.
d) Riverbed cross-sections should be located perpendicularly to the axis of the watercourse and the part of the valley cross-section related to flood terraces should be located perpendicularly to the course of the valley, and then height information based on DTM should be generated. In the case of embanked watercourses, the cross-sections through flood terraces should be lengthened to the base of the vent slope. It is not allowed to cross the adjacent valley transverse cross-sections.
e) Both riverbed and valley cross-sections should be located at distances of not more than 500 m, counting along the length of the watercourse, and in the case of measurements for valley cross-sections for 2D modelling (for voivodeship cities, towns with district rights and other towns with more than 100,000 inhabitants) at distances of not more than 250 m.
f) Distances between valley cross-sections are determined by the course of watercourses from the Map of Hydrographic Division of Poland at the 1:10,000 scale (MPHP10k), verified on the basis of DTM (LiDAR) and orthophotomap.
g) If there is an active water gauge station on the measured watercourse, a valley cross-section should also be at this point.
h) The location of valley cross-sections (riverbed and floodplain terraces) is first determined by a hydraulic modelling specialist, which is a necessary condition to proceed with geodetic measurements.

i) For valley cross-sections, the forms of land cover shall be identified and the values of the Manning roughness coefficients shall be assigned, in accordance with the coding diagram in Table 4, and the codes for points/pickets in the cross-sections shall be specified, in accordance with the coding diagram in Table 5.

j) The source of data concerning forms of land cover for valley cross-sections on the flood terrace is the Topographic Objects Database, hereinafter referred to as BDOT10k, developed in accordance with the Regulation on the Topographic Objects Database and General Geographic Objects Database, as well as standard cartographic studies (MSWiA, 17.11.2011). Information for BDOT10k concerning the land cover was provided by registers kept by the Ministry of Agriculture, Environment and Land and Housing Management, as well as other state registers and data obtained as a result of the field interviews. This data is a reliable source for identifying forms of land cover.

k) The forms of land cover identified on the basis of BDOT10k are assigned the initial Manning roughness values.

l) In justified cases, the above mentioned initial values of roughness coefficients should be corrected, based on information obtained from orthophotomaps or topographic maps.

5.1.1.2. Geodetic measurements of riverbed cross-sections

Riverbed measurements are carried out with the use of geodetic instruments, using such methods as:

– measurement by GNSS (RTK or RTN kinematics) with reference to reference stations of the ASG-EUPOS or other reference systems, if the location data of these stations has been included in the National Geodetic and Cartographic Database (PZGiK);
– measurement using electronic total stations with automatic recording of measurement results.

In special cases other methods of measurement may be used.

Geodetic measurements of riverbed cross-sections should be made according to the following assumptions:

a) Riverbed cross-sections should be measured perpendicularly to the axis of the river and should include not only the part concerning the riverbed itself, but also a belt of land approximately 20 m wide on each side of the river. Riverbed sections will be measured in the location of the previously indicated valley section.

b) Riverbed cross-sections located in a line above the uppermost position of the bridge facilities should be measured at a distance of approximately the width of the bridge light, in a place representative for the riverbed in this section.

c) Riverbed cross-sections should also be measured on flowing reservoirs and flowing lakes perpendicularly to the river axis. In this case, it is also necessary to take into account the measurement of the cross-sections on the stream before the flow to the lake and after the outflow from the lake. The cross-section measurement should include, in addition to the reservoir or lake itself, a belt of land approximately 20 m wide, counting right and left of the bank. In the case of lakes or embankment reservoirs, the riverbed cross-section should end about 10 m beyond the embankment or side damming structure.

d) The riverbed cross-sections should faithfully reflect the shape of the riverbed. It is unacceptable to map the riverbed with three points (bank, bottom, edge), as well as to simplify its geometry to the trapezoidal section.

e) For each riverbed cross-section, the water level ordinate should be measured, noting the date and time of measurement in the measurement logs and plans (it also applies to bridge and hydrotechnical structures sections).

f) Geodetic measurements for riverbed cross-sections should be carried out from left to right, looking in the direction of the flow. The measured points are numbered during the measurement according to the order of measurement.

g) For typical riverbed cross-sections, as well as for cross-sections for engineering works, the forms of land cover shall be identified, and the value of the Manning roughness coefficients shall be assigned in accordance with the coding diagram in Tables 4 and 4a, while the codes for points/pickets in the cross-sections shall be specified in accordance with the coding diagram in Table 5.

h) The BDOT10k database should be used to determine the forms of land cover.

i) The coding sequence for individual points of geodetic measurements (pickets) must follow the direction of the cross-section, i.e. from left to right (looking in accordance with the direction of water flow in the watercourse), with the code value at a given measuring point being assigned to the section preceding it (according to the diagram below). It should be noted that for one section between successive measuring points only one code of the form of land cover can be defined (Fig. 10).

j) When taking measurements, site plans should be made and at least one photo per section should be taken, on which the field situation, point identifiers and the direction from which the photo was taken will be marked.

Table 4 Summary of land cover codes together with the initial values of Manning roughness coefficients and assigned land cover information from BDOT10k

CODE (land coverage)	The value of the roughness coefficient n	Description of land cover	BDOT10k code	Object name in BDOT10k
Riverbed part				
K01	0.035	earth, sludge	-	-
K02	0.032	sand	-	-
K03	0.035	fine gravel 2 cm	-	-
K04	0.038	thick gravel 2-4 cm	-	-
K05	0.040	stones (up to 20 cm)	-	-
K06	0.020	concrete	-	-
K07	0.050	boulders (over 20cm)	-	-
K09	0.070	riverbed with underwater vegetation	-	-
K10	0.100	riverbed with aquatic (emerging) vegetation, i.e. reeds	-	-
Flood terraces				
T01	0.025	concrete, asphalt	PTPLO1	square
			PTKM01	area under the road
			PTKM03	area under the road and the trackside
			PTKM04	area under the airport road

CODE (land coverage)	The value of the roughness coefficient n	Description of land cover	BDOT10k code	Object name in BDOT10k
T03	0.120	forest	PTLZO1	forest
			PTLZ02	grove
T04	0.080	woodland	PTLZ03	woodland
			PTUTO3	orchard
T06	0.12	bushes	PTRK01	mountain pine
			PTRK02	shrubs
			PTUTO4	nursery
			PTUTOS	ornamental plant nursery
T07	0.045	grass	PTTRO1	grassy vegetation
T08	0.090	wastelands	PTGN04	residual unused land
T09	0.200	allotment gardens	PTUTO1	allotment garden
T10	0.035	sand/gravel	PTGNO3	sandy or gravel ground
			PTWZO1	excavation
			PTWZO2	heap
T11	0.200	single-family buildings, enclosed areas	PTZB02	detached houses
T12	0.050	tillage on arable land	PTUTO2	plantation
			PTTRO2	tillage on arable land
T14	0.020	water	PTWPO1	seawater
			PTWP02	flowing water
			PTWP03	still water
T15	0.090	stones	PTKMO2	trackside
			PTGNO1	scree, landfill or rock rubble
			PTGNO2	stony area
T16	0.100	landfills	PTS001	municipal waste disposal site
			PTS002	industrial waste disposal site
			PTNZO1	land under technical equipment or construction
T17	0.300	large-size buildings, multi-family buildings, blocks of flats	PTZB01	multi-family buildings
			PTZB03	industrial and storage buildings
			PTZB04	commercial and service buildings
			PTZBOS	other build-up
			PTNZO2	industrial and storage site

Table 4a. Table with the classification of objects from BDOT10k and assigned land cover codes

Code	Name of the category of object classes	Code	Object class name	Code	Object name in BDOT10k	CODE (land cover)
PT	land cover	PTWP	surface water	PTWPO1	seawater	T14
				PTWP02	flowing water	T14
				PTWP03	still water	T14
		PTZB	buildings	PTZB01	multi-family buildings	T17
				PTZB02	detached houses	T11
				PTZB03	industrial and storage buildings	T17
				PTZB04	commercial and service buildings	T17
				PTZBOS	residual build-up	T17
		PTLZ	woodland and wooded area	PTLZO1	forest	T03
				PTLZ02	grove	T03
				PTLZ03	woodland	T04
		PTRK	shrubby vegetation	PTRK01	mountain pine	T06
				PTRK02	shrubs	T06
		PTUT	permanent crop	PTUTO1	allotment garden	T09
				PTUTO2	plantation	T12
				PTUTO3	orchard	T04
				PTUTO4	nursery	T06
				PTUTOS	ornamental plant nursery	T06
		PTTR	grassland and arable farming	PTTRO1	grassy vegetation	T07
				PTTRO2	tillage on arable land	T12
		PTKM	the area under roads, railways and airfields	PTKM01	roadside	T01
				PTKMO2	trackside	T15
				PTKM03	area under the road and the trackside	T01
				PTKM04	area under the airport road	T01
		PTGN	unused land	PTGNO1	scree, landfill or rock rubble	T15
				PTGNO2	stony	T15
				PTGNO3	sandy or gravel ground	T10
				PTGN04	other unused land	T08
		PTPL	square	PTPLO1	square	T01
		PISO	dump	PTS001	municipal waste disposal site	T16
				PTS002	industrial waste disposal site	T16
		PTWZ	pit and heap	PTWZO1	excavation	T10
				PTWZO2	heap	T10
		PTNZ	other unbuilt up land	PTNZO1	land under technical equipment or construction	T16
				PTNZO2	industrial and storage site	T17

Table 5 Code list for point/pickets in cross-sections

Point code	Description of point location	Point type
1	upper edge of the slope – left floodplain	riverbed section
7	bottom of the riverbed	riverbed section
12	upper edge of the slope – right floodplain	riverbed section
30	field point – dry	embankments, dams, walls
31	bottom edge – left side	embankments, dams, walls
32	top edge – left side	embankments, dams, walls
33	top – centre	embankments, dams, walls
34	top edge – right side	embankments, dams, walls
35	bottom edge – right side	embankments, dams, walls
36	upper edge of the mobile (movable) protective device	embankments, dams, walls
40	bottom edge of the construction	profile of construction
41	top edge of the construction	profile of construction
42	upper edge of the railing (including protective railings, etc.)	profile of construction
43	specific points of the building (e.g. roofing of the footbridge passage)	profile of construction
50	lower edge of the hydrotechnical structure top	single points of construction
51	upper edge of the hydrotechnical structure top	single points of construction
52	bottom of pipe, canal	single points of construction
53	upper edge of the channel cover	single points of construction
54	canal bottom	single points of construction
ZWW	water level	specific points

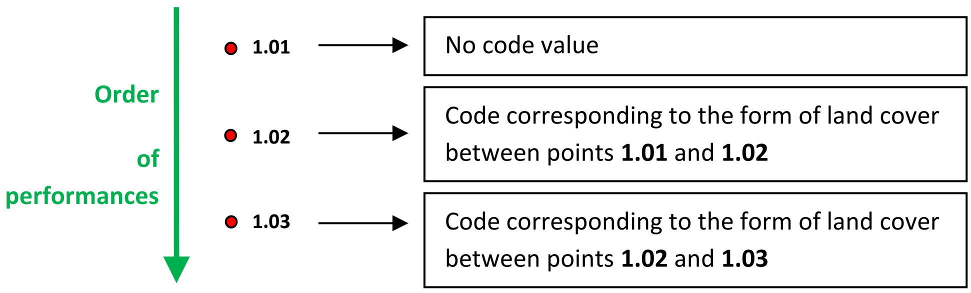


Fig. 10. Coding method for the forms of land cover in the sample cross-section

5.1.1.3. Development of a geodetic survey for valley cross-sections (riverbed cross-sections and cross-sections through floodplain terraces)

The geodetic survey for valley cross-sections should include:

a) table of riverbed cross-section measurements, according to the formula presented in Table 6;
b) tabular summary of valley cross-sections points (i.e. connected riverbed cross-sections with cross-sections through floodplain terraces), according to the formula presented in Table 7;
c) diagram of valley cross-section, according to Figure 11;

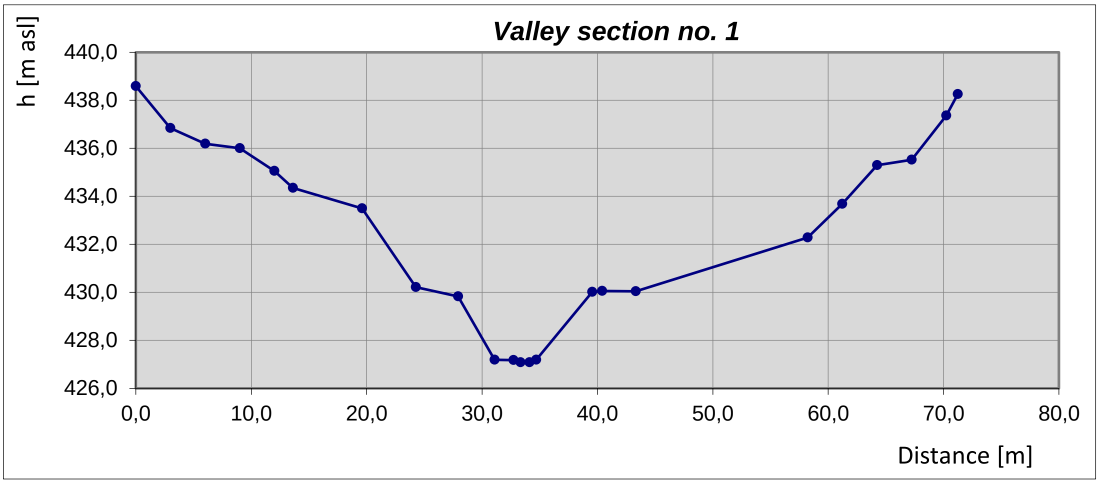


Fig. 11 An example of a valley cross-section graph in a spreadsheet

The cross-sections should be numbered according to the numbering of the riverbed cross-sections. The list must also take into account the valley cross-sections located in the measurement points of bridge and hydrotechnical structures.

d) site plans of riverbed cross-sections with picket numbers and the direction from which the photograph was taken, according to Figure 12 (PDF files)

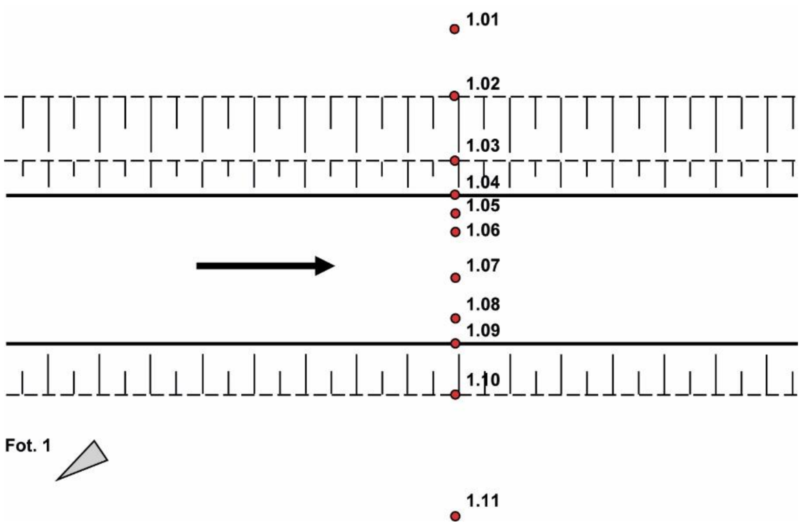


Fig. 12. The way of marking the direction of photography

Table 6 Tabular overview of riverbed cross-section measurements

Name of the watercourse	Number of cross-section and measurement point	X-coordinate [m]	Y-coordinate [m]	Z-ordinate [m.a.s.l.]	Distance [m]	Point code	Terrain cover form code	Water ordinate [m.a.s.l.]	Date of measurement	Photograph number	Comments
River name	1.101	187843.27	642904.02	434.35	0.00				2017.11.07	"River name"_1.JPG	
	1.102	187837.38	642902.96	433.50	5.98		T07				
	1.103	187832.79	642902.14	430.22	10.65		T07				
	1.104	187829.20	642901.49	429.83	14.30	1	T07				
	1.105	187826.08	642900.93	427.19	17.47	zww	T07	427,19			
	1.106	187824.48	642900.64	427.17	19.09		K04				
	1.107	187823.88	642900.54	427.08	19.70	7	K04				
	1.108	187823.10	642900.39	427.08	20.49		K04				
	1.109	187822.53	642900.29	427.19	21.07	zww	K04	427,19			
	1.110	187817.75	642899.43	430.01	25.93	12	T07				
	1.101	187816.91	642899.28	430.06	26.78		T01				
	1.112	187814.05	642898.77	430.04	29.69		T11				
	1.113	187799.37	642896.13	432.28	44.60		T07				

Table 7 Tabular overview of valley cross-section points

Name of the watercourse	Number of cross-section and measurement point	X-coordinate [m]	Y-coordinate [m]	Z-coordinate [m.a.s.l.]	Distance [m]	Point code	Terrain cover form code	Water ordinate [m.a.s.l.]	Date of measurement	Photograph number	Comments
River name	1.10000	187854.14	642895.8	438.59	0.00						
	1.10001	187851.75	642897.61	436.84	3.00						
	1.10002	187849.35	642899.42	436.19	6.00						
	1.10003	187846.96	642901.23	436	9.00						
	1.10004	187844.57	642903.04	435.06	12.00						
	1.101	187843.27	642904.02	434.35	13.63				2017.11.07	“River name”_3.JPG	
	1.102	187837.38	642902.96	433.5	19.61		T07				
	1.103	187832.79	642902.14	430.22	24.28		T07				
	1.104	187829.2	642901.49	429.83	27.92	1	T07				
	1.105	187826.08	642900.93	427.19	31.09	zww	T07	427.19			
	1.106	187824.48	642900.64	427.17	32.72		K04				
	1.107	187823.88	642900.54	427.08	33.33	7	K04				
	1.108	187823.1	642900.39	427.08	34.12		K04				
	1.109	187822.53	642900.29	427.19	34.70	zww	K04	427.19			
	1.110	187817.75	642899.43	430.01	39.56	12	T07				
	1.111	187816.91	642899.28	430.06	40.41		T01				
	1.112	187814.05	642898.77	430.04	43.32		T11				
	1.113	187799.37	642896.13	432.28	58.23		T07				
	1.20000	187796.53	642895.17	433.68	61.23						
	1.20001	187793.68	642894.22	435.3	64.23						
	1.20002	187790.84	642893.26	435.52	67.23						
	1.20003	187787.99	642892.31	437.36	70.24						
	1.20004	187787.04	642891.99	438.25	71.24						

e) photographs of riverbed cross-sections (minimum one photo for each cross-section) – in jpg format. The photo number should correspond to the cross-section number (in case of more than one photo for each cross-section – numbering: River_1A name, River_1B name, etc.);

f) drawings of riverbed cross-sections in the scale 1:100/500 (if it is necessary to ensure the legibility of the drawing, it is permissible to change the scale – it must be unambiguously described for each cross-section) prepared in the CAD environment, saved in dxf format and exported to PDF format (according to Figure 13).

The report must be prepared in an electronic version.

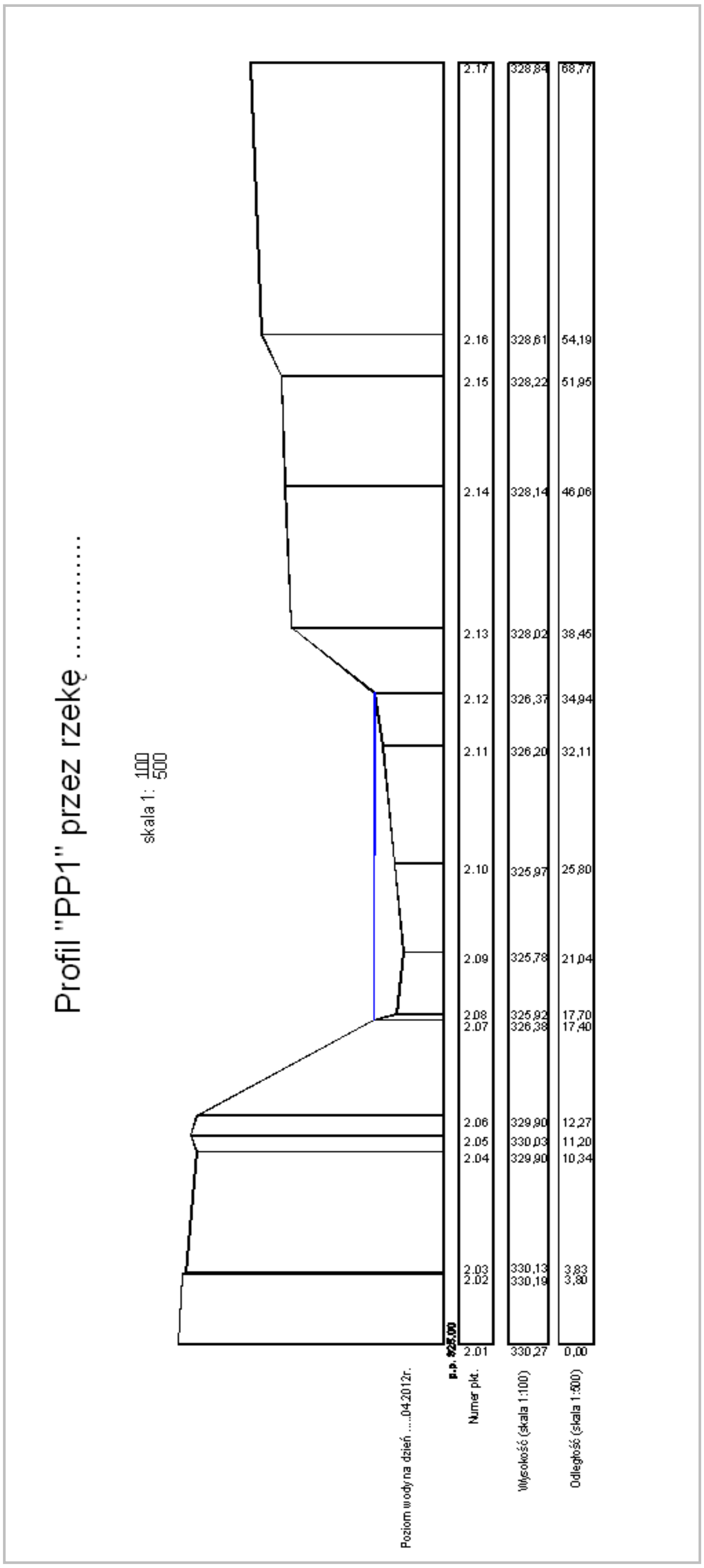


Figure 13: Example drawing of cross-section

5.1.1.4. Development of spatial layers of riverbed and valley cross-sections

The following spatial layers should be drawn up for surveying riverbed cross-sections:

a) RIVER_NAME_"cross-section_riverbed" – a point layer containing the location of individual measurement points together with assigned information about the name of the river, cross-section number, height ordinates, roughness coefficient, as well as codes of terrain cover forms and pickets;

b) RIVER_NAME_"cross-sections_terraces" – a point layer containing location of individual points of cross-sections through floodplain terraces generated on the basis of DTM together with assigned information about the name of the river, cross-section number, elevation ordinates, codes of land cover forms, roughness coefficient;

c) RIVER_NAME_"cut-off lines" – a linear layer containing the generated lines of valley cross-sections, i.e. the lines of riverbed cross-sections and lines of cross-sections through floodplain terraces.

These layers should be prepared in the rectangular flat coordinate system PL-1992 (National Geodetic Coordinate System, 1992), in shp file format.

All altitude geodetic measurements should be carried out in the Kronstadt 86 geodetic measurement system (PL-KRON86-NH). All horizontal geodetic measurements should be made in the rectangular flat coordinate system PL-1992. Accuracy of geodetic measurements – in accordance with the standards and guidelines in force in Poland.

5.1.2. Inventory and geodetic development of engineering objects

The measurement of engineering objects should be performed directly in the field with the use of geodetic instruments:

- measurement by GNSS method (RTK or RTN kinematics), with respect to reference stations of the ASG-EUPOS system or other reference station systems, if the location data of these stations has been included in the National Geodetic and Cartographic Database (PZGiK),
- measurement using electronic total stations with automatic recording of measurement results.

5.1.2.1. Inventory of engineering objects

As a part of geodetic works, a detailed inventory of engineering objects located in the watercourses covered by the study, i.e.:

- bridge structures (including bridges and footbridges);
- hydrotechnical facilities (including dams, weirs and thresholds).

The engineering inventory is to identify the actual locations of the facilities in the field and only those facilities that are to be used for the intended purpose of the hydraulic model, i.e. those that are located on the sections of watercourses to be modelled and meet at least one of the following criteria:

a) for bridge structures:
   - have pillars with a width (or diameter) of at least 0.5 m,

- have 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 edge slopes, with the thickness of their main horizontal structure exceeding 0.5 m,
- have abutments that are wholly or partly in the riverbed cross-section.

b) in the case of hydrotechnical facilities:
- are anti-flooding dams,
- are single objects with an overflow threshold of at least 0.8 m (except for the step-blades and ramps),
- are the initial and final objects of a systematic or segmented threshold or step correction and have an overflow threshold height of at least 0.8 m,
- are large hydrotechnical objects, such as steps and weirs with variable, controlled piling by lifting the closures.

As a part of the preparatory works, the spatial strata (shp) with location of bridge and hydro-technical structures for which measurements are planned to be made shall be prepared and associated attributes shall include in particular: object number, administrator, object type (road bridge, rail bridge, footbridge, anti-debris dam, single water stage, initial or final step correction, weir, etc.). In case of bridge objects, the angle of crossing of the main axis of the bridge with the river axis should be additionally specified, and for hydrotechnical object – the height of overflow threshold (damming).

5.1.2.2. Geodetic measurements of riverbed cross-sections at the location of bridge objects and measurements of object structures

The geodetic survey for bridge objects is to perform geodetic measurement in the line of the top position of objects of all elements of the objects' structure at characteristic points and the points of the riverbed, such as

- places where the geometry of the structure changes, as well as abutments and pillars (structure shape breaks);
- contact points of abutments and pillars with the horizontal part of the bridge structure (bottom of the superstructure);
- top (roadway or railway traction) rows of the bridge (with a minimum of 3 points – in the centre of the structure and at abutment height) and the width of the bridge in top "B" (measured perpendicular to the main axis of the bridge);
- points of the watercourse between the elements of the structure of the object.

Notwithstanding the above, the lowest ordinate of the bottom of the watercourse under the bridge should be measured with a single measuring point (picket) below the object. The cross-section below the bridge required in the hydraulic model in the riverbed will be mapped by interpolation with reference to the measured ordinate, the valley part will be developed on the basis of DMT.

A site plan for geodetic measurement locations in the location of the bridge object is presented in Fig. 13a.

Fig. 13a. Sketch of the location of measurement points in the vicinity of the bridge object

For arched bridges, a minimum of 5 points at the bottom of the structure shall be measured, i.e. the starting point of the arc, the middle point of the arc (highest), the end point and at least 2 intermediate points of the arc.

Where the bridge has a suspended, unbuilt part of the falsework (truss type) through which water can flow, both its lower and upper edges must be removed.

If there is a sequence of consecutive bridge structures (footbridges, culverts) at distances of less than 100 m, the first and last of the structures shall be measured. Notwithstanding the above, for each of the objects, a picket at the lowest point of the riverbed/culvert shall be measured and the light size/culvert diameter determined. In this case it should be remembered that the riverbed cross-sections should be located according to the rules of chapter 5.1.1.1 at distances not greater than 500 m or 250 m in case of 2D modelling. The cross-sections required in the hydraulic model between structures in the riverbed area are mapped by interpolation with reference to the measured ordinates, the valley section is developed on the basis of DTM.

Moreover, when measuring the riverbed in the line of the upper bridge position, all characteristic points of the structure and points of contact between the bridge structure and the riverbed (pillars, abutments) must be taken into account. An example of location of measurement points for the riverbed cross-section in the line above the upper position of the object is shown in Fig. 13b. Example of location of measurement points in the line of the upper stand is shown in Fig. 13c.

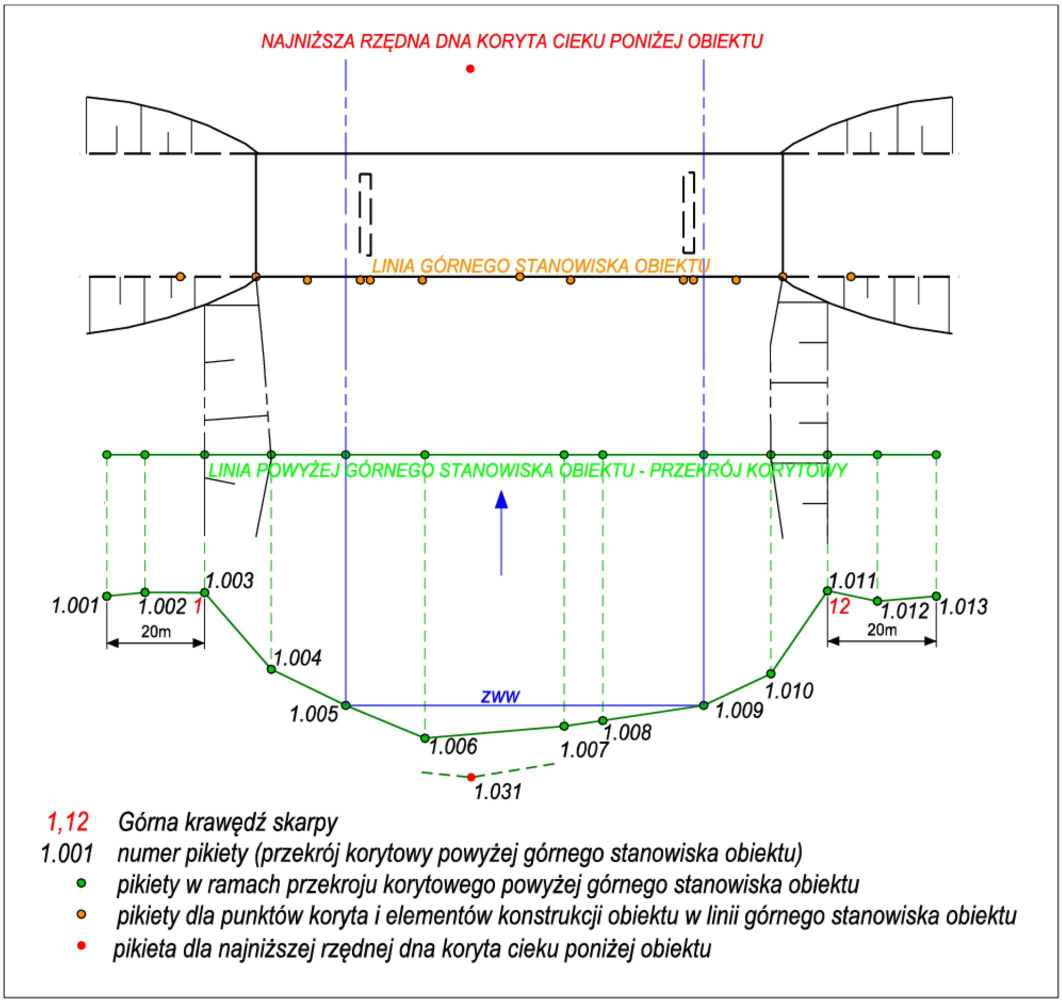


Fig. 13b. Horizontal and vertical projection of measurement points location for a riverbed section in the line above the top of the object's position

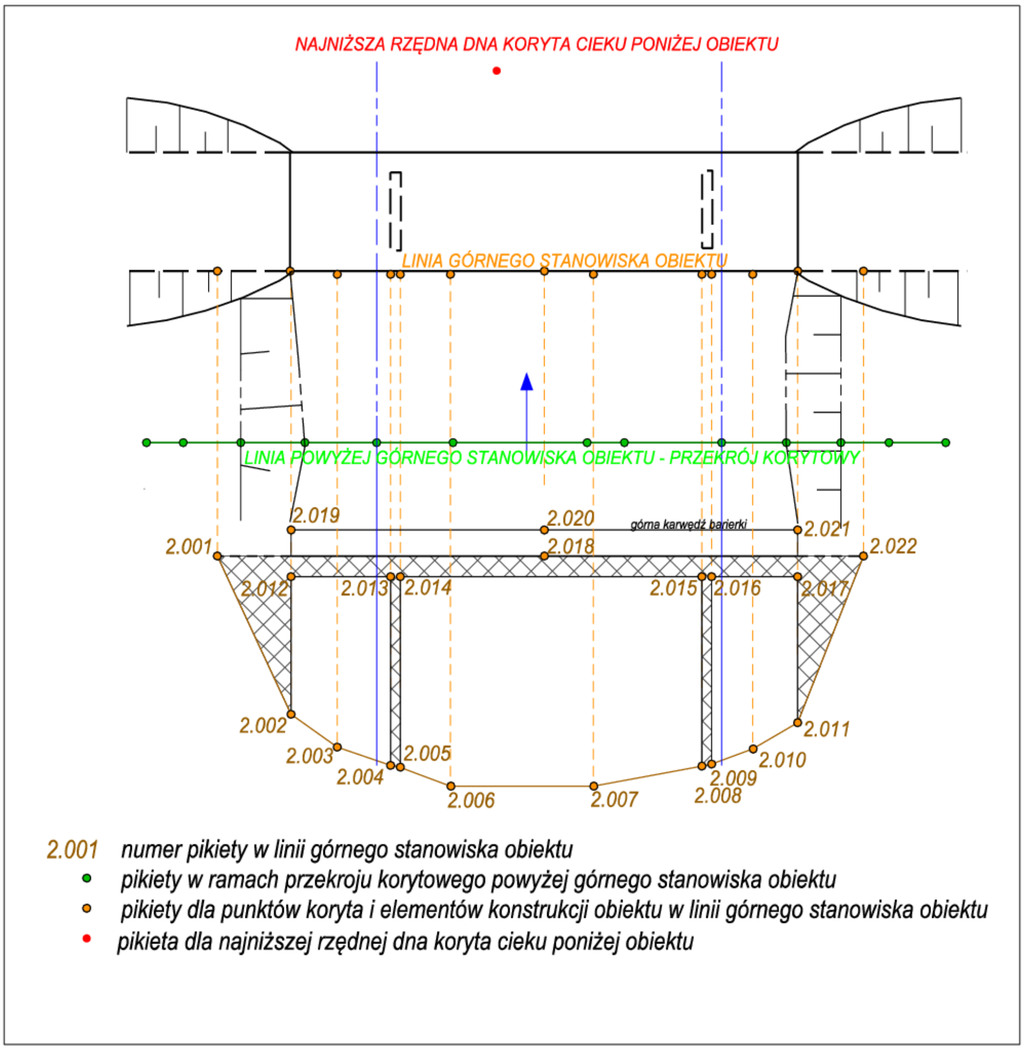


Fig. 13c. Horizontal and vertical projection of measurement points in the line of the upper position

For objects whose angle of intersection of the main axis of the structure (longitudinal axis) with the axis of the watercourse is different from 90°, the riverbed cross-sections and measurements of structural elements for the upper position of the object shall be made in the line of their actual location, in relation to the axis of the watercourse. In such case the riverbed cross-section together with the cross-section through the structure of the object is subject to transformation to the system perpendicular to the stream axis. The transformation consists in calculating the reduced distances between points in such way that the sum of these distances corresponds to the total length of the section situated in the line perpendicular to the axis of the watercourse. On the other hand, due to the condition of obtaining a proper connection of the extreme points (common contact point) of the riverbed cross-section with the extreme points of the left and right valley cross-section – the location of the cross-section line and its extreme points must remain in the actual location.

The riverbed cross-sections and valley cross-sections (resulting from the combination of riverbed sections with DTM-generated flood terraces cross-sections) carried out as a part of the geodetic survey of bridge structures shall meet all requirements as for “typical” cross-sections, i.e. in accordance with section *5.1.1*.

5.1.2.3. Development of a geodetic survey for measurements of riverbed cross-sections at the location of bridge facilities and measurements of structure of objects

The geodetic report of the measurements of riverbed cross-sections at the location of bridge structures and the measurements of objects' structure should contain analogous elements as in the case of the report for "typical" riverbed cross-sections, i.e.:

a) a tabular list of measurements for riverbed cross-sections containing the measurement of the object structure, according to the formula presented in Table 8;
b) site plans of cross-sections with plot numbers and the direction from which the photograph was taken (according to the drawing as for "typical" cross-sections of Fig. 12) – in a pdf file;
c) photographs of cross-sections (at least one photo for each cross-section) – in jpg format. The photo number should correspond to the cross-section number (in case of more photos for one cross-section – numbering: River_1A, River_1B, etc.);
d) cross-section diagram with the representation of the object geometry (in the view from the top water side). The numbers of all measurement points (pickets) should be written on the diagram. The pattern of the riverbed cross-section diagram in the place of the engineering object is shown in Fig. 13;
e) drawings of riverbed cross-sections together with a reproduction of the object geometry in the scale 1:100/500 (or other agreed with the customer), prepared in CAD environment, saved in dxf format and exported to PDF format (Fig. 14).

The geodetic report must be prepared in an electronic version.

Information on the location and height ordinates of measurement points for riverbed cross-sections at the location of bridge structures (including the measurement points of the objects' structure), as well as the course of lines of riverbed cross-sections and cross-sections through floodplain terraces should be included in the spatial layers for "typical" cross-sections.

If pipelines with a diameter of more than 300 mm are crossed with the media over the riverbed, the measurements should be taken in the same way as for bridges.

Table 8: Model of the geodetic measurement table for bridge structures and hydrotechnical structures

Name of the watercourse	Object number	Object type	Number of cross-section and measuring point	X-coordinate [m]	Y-coordinate [m]	Z-ordinate [m]	Distance [m]	Distance after transformation [m]	Point code	Code of land coverings form	Water ordinate [m.a.s.l.]	Date of measurement	Photograph number	Object width [m]	H – overflow threshold height [m]	α – angle of intersection of the main axis of the bridge with the ...	Object administrator	Comments
River name	1	road bridge	3.101	188010.3	643525.32	414.54	0.00					2017.11.07	River name_3.JPG	12.00		100	District Road Administration in ...	
			3.102	188004.94	643526.4	414.25	5.47			T01								
			3.103	188000.39	643527.33	414.19	10.11			T09								
			3.104	187996.62	643528.08	414.21	13.96		1	T01								
			3.105	187994.35	643528.55	411.81	16.27			T02								
			3.106	187990.52	643529.32	410.99	20.18			T02								
			3.107	187990.32	643529.37	410.39	20.39			T16								
			3.108	187987.27	643529.99	410.00	23.50		zww	T16	410.00							
			3.109	187986.59	643530.12	409.94	24.19			K04								
			3.110	187986.11	643530.22	409.88	24.68		7	K04								
			3.111	187985.6	643530.32	409.92	25.20			K04								
			3.112	187985.14	643530.41	410.00	25.67		zww	K04	410.00							
			3.113	187976.78	643532.11	410.71	34.20			T02								
			3.114	187975.9	643532.29	411.31	35.10		12	T01								
			3.115	187948.8	643537.78	413.23	62.75			T01								
			3.201	187990.29	643529.37	411.09	20.42		40									
			3.202	187988.87	643529.65	412.44	21.86		40									
			5.203	187987.5	643529.94	412.83	23.26		40									
			5.204	187985.07	643530.43	413.21	25.74		40									
			3.205	187983.37	643530.78	413.22	27.48		40									

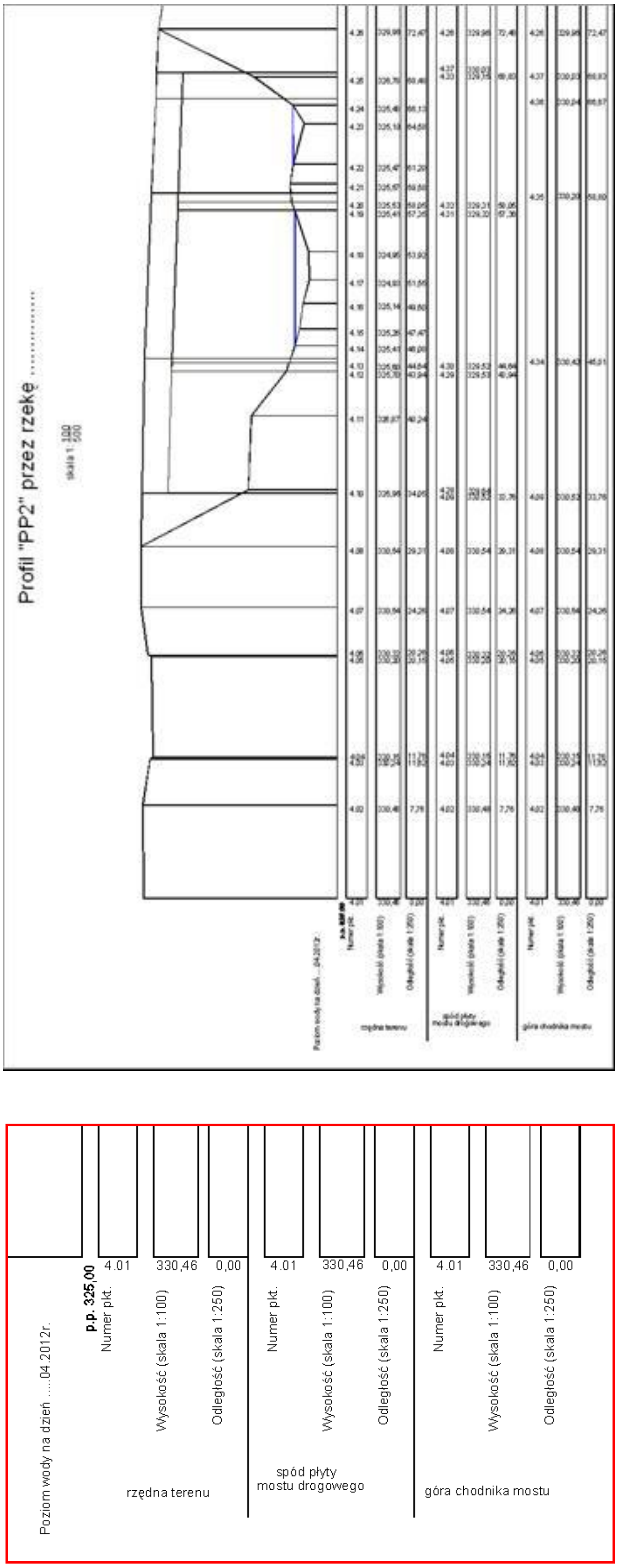


Figure 14: Example of a cross-section diagram with a bridge object entered

5.1.2.4. Geodetic measurements of riverbed cross-sections at the location of hydrotechnical objects and measurements of structure of objects

In the case of hydrotechnical objects, such as anti-debris dams, weirs and water barrages, geodetic measurements should be carried out according to a similar methodology as in the case of bridges.

For barrages and weirs with a constant accumulation and overflow threshold height of 0.8 m ≤ H < 1.5 m, a riverbed cross-section in the line of the upper object position should be carried out, taking into account the geometry of the object structure in the overflow line. In addition, the height of the threshold at the lowest point of the bottom of the bottom station must be measured with one picket. The hydrotechnical object integrated into the riverbed section, together with the marking and numbering of the measurement pickets, should be shown in the diagram. The location of the measurement pickets should also be shown on the site plan.

For the steps and weirs with a constant accumulation and overflow threshold height H ≥ 1.5 m and for all the anti-flood barriers, in addition to the above, it is also necessary to make a riverbed section for the lower site, just below the overflow. The arrangement of pickets in the cross-section of the lower site of the facility should also be illustrated on the site plan.

Fig. 15 shows an example of a site plan and a diagram of geodetic measurements for the above mentioned objects.

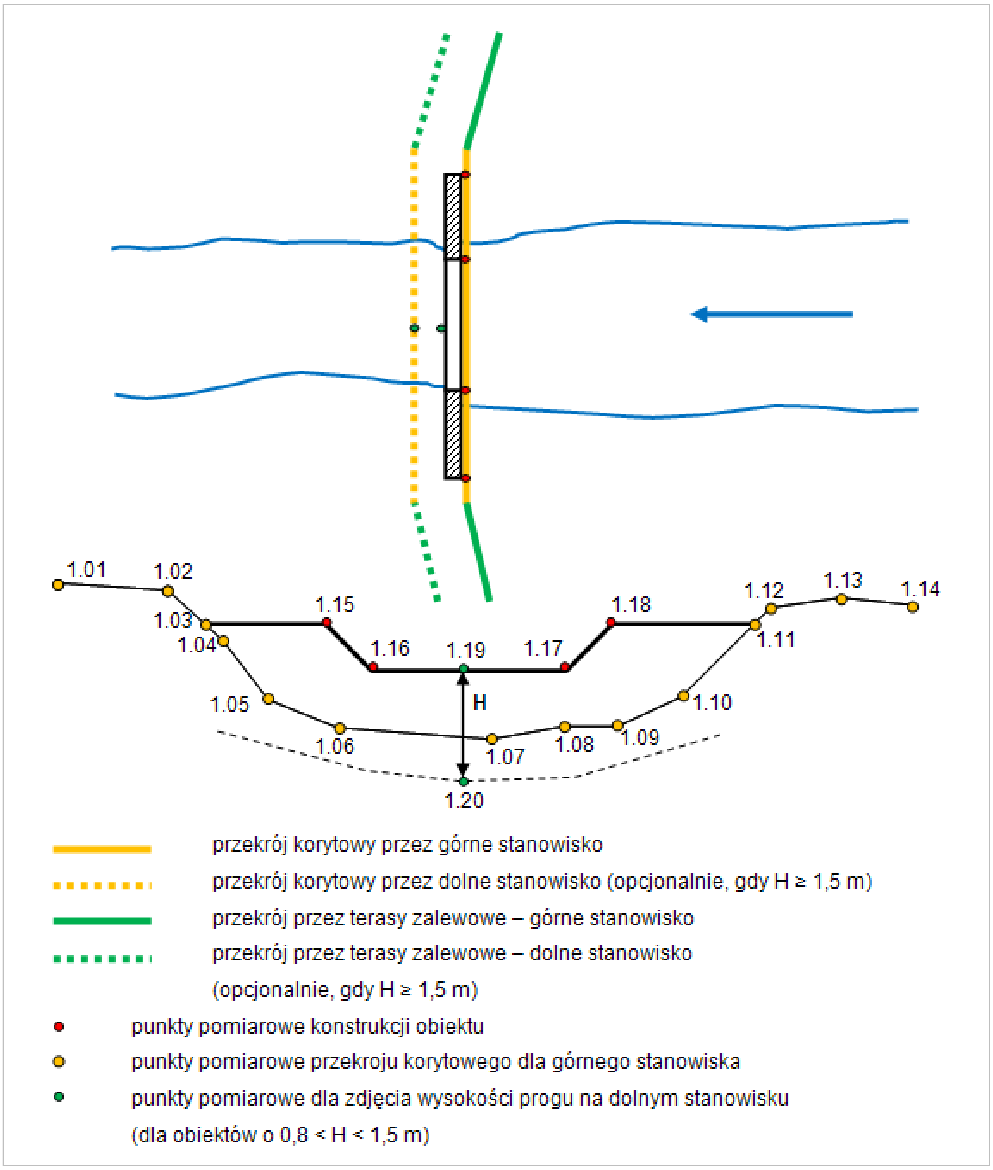


Fig. 15. Site plan and picket arrangement diagram for hydrotechnical objects such as dams, weirs and water levels

Steps or weirs with variable (controlled by raising the closures) accumulation should be measured without taking into account the design of the closures themselves, i.e. so as to reproduce the water flow conditions assuming they are completely absent (raising the closures, opening the sliders, position of the overflow flaps, etc.). Method and scope of geodetic measurements for structures and sections – as above (i.e. depending on the height of overflow threshold “H”).

Riverbed sections and valley sections (created after connecting the riverbed sections with the sections for flood terraces generated on the basis of DTM) carried out as part of the surveying study of hydrotechnical objects should meet all requirements as for “typical” cross-sections.

5.1.2.5. Development of a geodetic survey for measurements of riverbed cross-sections at the location of hydrotechnical objects and measurements of structure of objects

The surveying for the measurements of riverbed cross-sections at the location of hydrotechnical objects and measurements of object structures should contain analogous elements as in the case of the report for “typical” riverbed cross-sections and cross-sections for bridge objects, i.e.:

a) a summary table (in an Excel file) of measurements for riverbed cross-sections, containing the measurement of the object structure (formula in Table 8); for objects with H ≥ 1.5 m, the table should also contain the cross-sections through the lower position of the object;
b) site plans of cross-sections with plot numbers and the direction from which the photograph was taken (according to Fig. 12) – in pdf files;
c) cross-sectional photographs – in jpg format (minimum one photo for each cross-section – from the bottom water side), the photo number should correspond to the number of cross-section (in case of more than one photo for each cross-section – numbering: River_1A, River_1B name, etc.). For objects with overflow threshold height H ≥ 1,5 m and large hydrotechnical objects, at least 2 photographs should be taken – one from the bottom water side and the other from the top water side;
d) cross-section diagram with the representation of the object geometry (in the view from the top water side). The diagram should include the numbers of all measurement points (pickets). Cross-section diagrams with the mapping of the hydrotechnical object geometry in the scale 1:100/500 (or another one agreed with the customer), prepared in the CAD environment, saved in the dxf format and exported to the pdf format. A sample cross-section is shown in Fig. 16.

The report must be prepared in an electronic version.

Information on the location and height ordinates of measurement points for riverbed sections at the location of hydrotechnical objects (including the measurement points of object structures), as well as the course of the line of riverbed sections and sections through floodplain terraces should be included in the spatial layers for “typical” cross-sections.

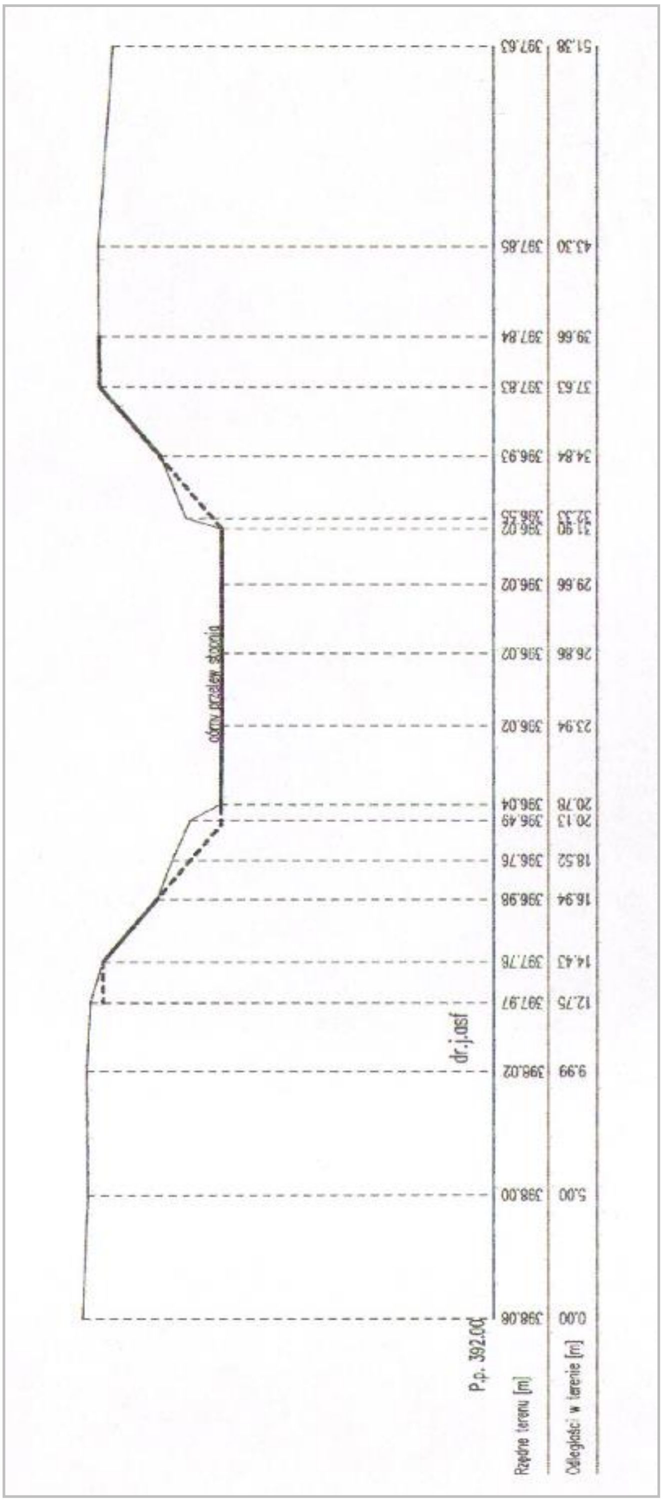


Fig. 16. Example of a cross-section with object geometry mapping

5.1.2.6. Development of spatial layers of engineering objects

Spatial layers shall be drawn up with the location of individual engineering survey points with assigned information, such as: river name, object number, elevation ordinates and land cover form codes, as well as pickets, object type and administrator. Layers should be created separately for:

– bridge objects (RIVER_NAME_”bridge objects”);
– hydrotechnical objects (RIVER_NAME_”hydrotechnical objects”).

The above mentioned layers should be prepared in the rectangular flat coordinate system PL-1992, in shp file format.

5.1.3. Geodetic inventory of flood embankments

5.1.3.1. Geodetic measurements of flood embankments

Flood embankments should be measured directly in the field using geodetic instruments:

– measurement by GNSS (RTK or RTN kinematics) with reference to reference stations of the ASG-EUPOS system or other reference station systems, if the location data of these stations have been included in the National Geodetic and Cartographic Database (PZGiK);
– measurement using electronic total stations with automatic recording of measurement results.

As a part of the geodetic works, in addition to the activities listed in the previous part of the methodology, the geodetic inventory of flood embankments located on the watercourses covered by the study should also be drawn up. The inventory is to identify the actual locations of embankments in the field and geodetic measurement of the ordinates in the place of the base of the drainage, as well as vent slope and the top of the embankments in the line of all the executed valley cross-sections. These measurements should be made for all valley cross-sections (i.e. for both “typical” cross-sections and cross-sections for engineering structures) in the areas where embankments are located.

In addition to the above, this inventory must also be carried out on the sections of embankments between the cross-sections, so that the distances between successive measuring points (base of the slope, vent and embankment top) do not exceed 50 m, counting along the embankment, with particular attention paid to places where the local depressions of the embankment top ordinate occur.

As a part of the inventory, the locations of all embankment locks (one picket for each lock) must additionally be removed by means of individual measuring points. These points are to be located in the axis of the embankment toptop at a height corresponding to the actual location of the sluice.

The results of the inventory should be compiled in a table of an Excel file and included in the geodetic report. The table should include, among other things: the numbers of measurement pickets for the top and the base of the embankments on the drainage and vent side, as well as their X, Y coordinates and height ordinates.

On the basis of the inventory results, a longitudinal profile of the embankment top and the base of the embankment’s drainage and vent slope should be drawn up for each analysed section. The profile must be in an Excel sheet with tabular data.

5.1.3.2. Development of spatial layers for flood embankment measurements

For inventory measurements of flood embankments, spatial layers should be prepared:

a) RIVER_NAME_"flood_embankments_ordinates" – a point layer containing information on the position and height ordinates (in the attribute table) of individual measurement points (pickets) for the base of the drainage slope, the embankment vent and the embankment top;
b) RIVER_NAME_"embankment_sluices" – a point layer containing information on the position of embankment sluices;
c) RIVER_NAME_"flood_embankments" – a linear layer containing the geometry of the axis of the measured flood embankments.

5.2. DEVELOPMENT AND PREPARATION OF HYDROLOGICAL AND METEOROLOGICAL DATA

Hydrological and meteorological data for the review and updating of flood hazard maps and flood risk maps shall be developed in hydrologically controlled catchments from the first planning cycle and in the catchments indicated for implementation in the second planning cycle.

The development of hydrological and meteorological data for the purpose of hydraulic modelling is carried out with an uniform approach for the whole area of Poland for the controlled and uncontrolled catchments.

The basis for the development of hydrological and meteorological data for the purpose of map review and update is: *Update of the methodology for calculating maximum flows and precipitation with a specific probability of exceedance for controlled and uncontrolled catchments, as well as identification of precipitation to outflow transformation models* [Association of Polish Hydrologists, 2017; developed for KZGW (agreement no. KZGW/DPiZW-ops/3/2017 of 6.03.2017)] – hereinafter referred to as "Updated methodology...". (Annex 1).

The hydrological data necessary to review and update the flood hazard maps and flood risk maps for the Polish area are developed according to an uniform methodology for three scenarios related to the probability of flooding:

- low – Q (0.2%),
- medium – Q (1%),
- high – Q(10%).

The hydrological calculations shall be carried out on the basis of the input data obtained from IMGW-PIB, which include:

- daily sums of precipitation from the last 30 years at stations located in the area of the analysed catchment;
- hyetographs of historical precipitation, which have caused the two largest floods in the last 30 years with the available time step (hour, day);
- maximum annual flows with a minimum of 30 years for the water gauge stations on watercourses for which FHM and FRM will be developed;
- hydrographs of flows and water levels, as well as flow rate curves for at least 2 of the largest floods that have occurred in the last 30 years – for model calibration and verification.

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

- hydrological characteristics of water gauges (river name, name of water gauge, chainage, catchment area, gauge zero ordinate);
- values of flows with a given probability of exceedance for the adopted flood scenarios (for flows with the probability of exceedance p = 10%, p = 1%, p = 0.2%) calculated for water gauge stations;
- update of the coincidence of maximum flows on the main river and its tributaries;
- Q/H flow curves for the two largest floods in the last 30 years;
- hydrographs of flows for selected two historical largest floods;

– hydrographs of hypothetical wave flows.

In the case of uncontrolled catchments, hydrological data include

– maximum flows for given probabilities of exceeding p = 10%, 1% and 0.2%;
– hypothetical waves for the given probabilities of exceeding p = 10%, 1% and 0.2%.

In specific cases derogations from the above methodology and the adoption of other calculation methods are allowed, provide that these have gained the approval of the PGW WP. In such cases a justification shall be provided, together with an indication of the alternative method and its description.

5.3. DIGITAL ELEVATION DATA

5.3.1. DIGITAL TERRAIN MODEL

One of the basic data necessary for the development of the FHM is the digital terrain model (DTM). It is a necessary element for the execution of valley cross-sections of one-dimensional models and raster (grid) calculative two-dimensional models, according to the proposed methodology. It is also a required input element for determining the flood depth during the process of processing hydraulic modelling results. A digital terrain model can be expressed as information in the form of a regular grid – a fixed spatial grid (e.g. GRID).

The digital terrain model is an element of the state geodetic and cartographic resource (PZGiK). Collection and maintenance of the state geodetic and cartographic resource and making the data available belongs to the Surveyor General of Poland. DTM is recorded in the form of text files containing coordinates (X, Y in the PL-1992 system; Z in the Kronstadt 86 system) of points in a regular grid with a spatial interval of 1 metre, as well as in the form of a raster with the same spatial resolution. The information about terrain ordinates were interpolated on the basis of the point cloud obtained from the airborne scan (LIDAR). The maximum average height error is 0.2 m. Individual DTM data files correspond to the sheets in the “1992” rectangular plane coordinate system in the scale of 1:5000. The accuracy of the product expressed by the mean height error, which is the result of the standard in which the LAS was made (number of measurement points per square metre), is presented in Fig. 17, while the actuality of DTM acquisition is presented in Fig. 18.

For urban areas the average measurement density is 12 points/m2 (standard II). The area range of single DTM files developed on the basis of the point cloud from LIDAR corresponds spatially to the sheets in the PUWG 1992 rectangular flat coordinate system on a scale of 1:1250 (area 0.5 × 0.5 km). For the remaining area, the average density is 4 or 6 points/m2 (standard I), in the same coordinate system, but on a scale of 1:2500 – area for a single sheet approximately 1 × 1 km. The spatial distribution of LIDAR together with information about its height standard is shown in Fig. 17. Whereas the timeliness of the available DTM is quite diverse and covers the period 2010-2018, and its graphic form is presented in Fig. 18.

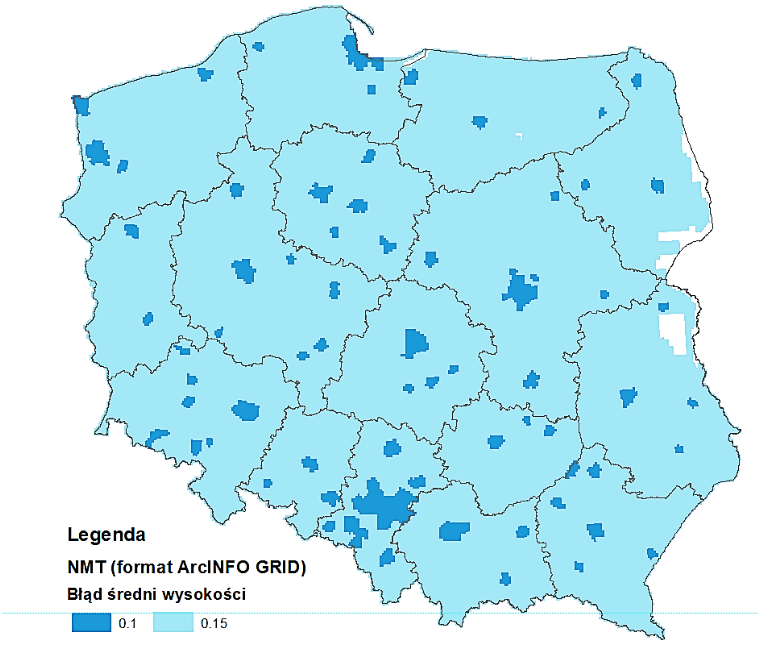


Figure 17: Average DTM altitude error (as of October 2017)

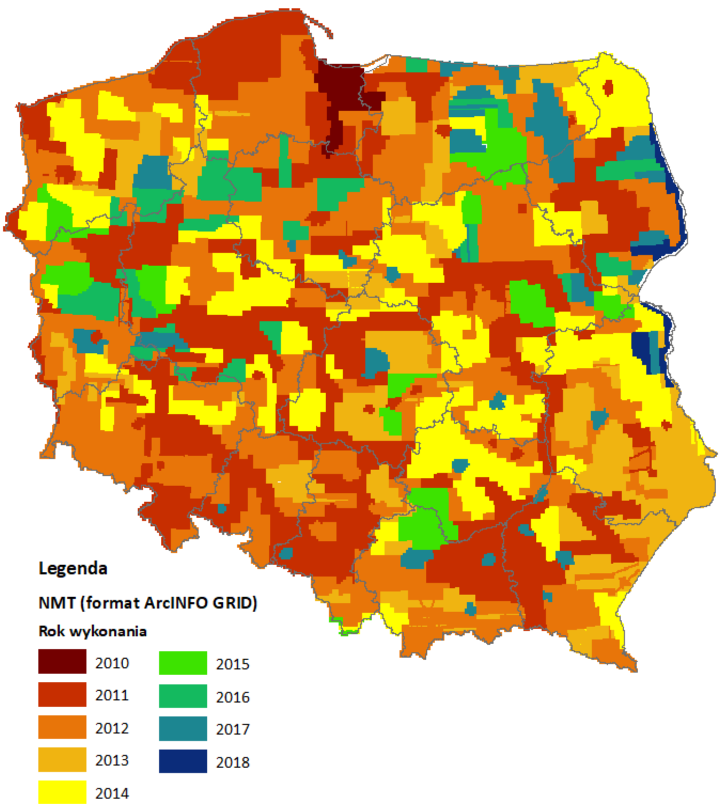


Fig. 18. DTM topicality in PZGiK (as of October 2017)

Due to the fact of constant changes in the area of the land, related to various types of investments, the material obtained from PZGiK may contain outdated information. From the point of view of flood protection, the most important are the changes in the terrain which change the hazard areas extend. These include, among other things, the construction of embankments, their modification, elevation of the land associated with the implementation of housing estates, road and rail embankments limiting the flood extend.

Two solutions are envisaged for such cases:

1) The first one focuses on geodetic embankment measurements for rivers for which an update of the riverbed cross-sections is planned, as well as for watercourses indicated for the development of maps in the second planning cycle.
2) The second solution concerns investments included in variant W0 of the FRMP for rivers for which no geodetic measurement will be carried out and planned investments to be implemented by end 2019. In such cases, land modification will be taken into account on the basis of executive designs or as-built geodetic inventory. In the absence of available documentation, depending on the individual case, data on investment parameters will be obtained by other methods.

5.3.2. DIGITAL SURFACE TERRAIN MODEL

The Digital Surface Terrain Model (DSTM), like DTM, is the result of processing a cloud of measurement points acquired from airborne laser scanning. The average height error for data is determined by the standard in which the input material was made, with a maximum error value of 0.2 m. Individual DSM files correspond to the range of sheets in the “1992” rectangular flat coordinate system in a scale of 1:5000. Selected DSM fragments are used in 2D modelling to update the DTM to actual building heights.

5.4. DATA FOR FHM AND FRM DEVELOPMENT

Table 9 Summary of input data needed to develop the FHM

N.	Data	Name of institution/resource	Format	Update of data
1	Orthophotomaps (pixel field size: 0.5 m, 0.25 m, 0.1 m)	Head Office of Geodesy and Cartography	*tif	2010-2018
2	National registry of borders and area of national territorial divisions (PRG)		*shp	2018
3	National registry of geographical names (PRNG)		*shp	2018
4	Topographical Object Database BDOT10k		*shp	2018
5	Digital Terrain Model (DTM) and Digital Surface Terrain Model (DSTM)		*xyz, *asc, *tif, *las, TIN *	2010-2018
6	Map index 1:10 000		*shp	2013
7	Hydrological and meteorological data	Institute of Meteorology and Water Management – National Research Institute	*doc, *xls, *pdf, *pdf, *tif, *jpg and others*	1956-2016 (most stations)
8	Flood hazard areas for rivers, water depths, water velocities, water flow directions, maximum water level ordinates, embankment top ordinates in cross-sections, embankment damage or destruction sites, embankment overflow sites	Consortium (IMGW-PIB/ARCADIS/MGGP)	*shp	2013-2019
9	Riverbed cross-sections: Brennica, Przemsza basin	State Water Holding Polish Waters – Regional Water Management Boards	*jpg, *pdf	2000-2016 2015-2016
10	As-built sections acquired as a part of the modernisation of the Wroclaw Water System		*txt	2015
11	Bathymetric data for coastal waters (RZGW in Gdansk)		*grd	2011-2012
12	Execution/pre-implementation projects, data on investments having a significant impact on the extent of floods		*xyz, *shp, *dwg, *dat, *pdf, *doc *	2010-2019
13	Current reservoir water management instructions/reservoir design or post-design documentation		*xyz, *shp, *dwg, *asc, *dat, *pdf, *doc	1998-2017
14	Riverbed cross-sections obtained from API development		*xns11	2013-2015
15	Riverbed cross-sections for the Żuławy area acquired under SMORP 2012		*shp	2012
16	Data on embankments and water facilities		*xls, *doc, *jpg and others *	2018-2019
17	Results of the QRG survey	State Water Holding Polish Waters	*xls	2010-2019
18	Results of the ZMiUW survey		*xls	2009 (10/11)-2019
19	Results of the survey of the General Directorate for National Roads and Motorways (GDDKiA)/PZD/WZD		*xls	2009-2019
20	Results of the railway authorities survey		*xls, *pdf, *jpg	2009-2019
21	Results of the survey of Maritime Offices		*xls	2009/10-2019
22	Wet riverbed cross-sections with photo documentation and inventory of hydrotechnical and communication structures – developed within the ISOK project		*shp, *xls, *txt, *jpg, *pdf	2012-2013
23	Valley cross-sections, including wet riverbed cross-sections together with photo documentation and inventory of hydrotechnical and communication		*shp, *xls, *jpg, *pdf, *dxf	2018-2019

N.	Data	Name of institution/resource	Format	Update of data
	structures – developed within the aFHMiMRP project			
24	Analysis of the current flood protection system for the development of flood risk management plans for river basin areas and water regions		*xls, *shp, *doc *	2013
25	Project data: Identification of pressures in water regions and river basin areas – Part I: Creating a national database on hydromorphological changes		geobase	2017
26	Map of Hydrographic Division of Poland MPHP10k		*shp	2017
27	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
28	Execution/pre-implementation projects, data on investments having a significant impact on the extent of floods	Railway authorities	*xyz, *shp, *dwg, *dat, *pdf, *doc *	2009-2019
29	Riverbed and bridge cross-sections for the Lower Vistula river section – project for the Lower Vistula Cascade	State Water Holding Polish Waters – Regional Water Management Board in Gdansk	*jpg, *pdf	2016-2017
30	Riverbed and water structure cross-sections, digital terrain model, orthophotomaps, Nysa Łużycka river	Land of Saxony, Land of Brandenburg, Germany, via the MKOOpZ	*shp, *xls, *txt, *jpg, *pdf	2009-2010
31	Bridge cross-sections and water structures of Nysa Kłodzka basin and its tributaries	State Water Holding Polish Waters – Regional Water Management Board in Wroclaw	*xls	2018
32	Ranges of operation of MaxPP reservoirs		*shp	2020
33	A model of the Gdansk System distribution for flood protection of the Dead Vistula river basin (Żuławy Gdańskie and the city of Gdansk); Hydrological analysis for the catchment areas of the Radunia river, the Radunia canal, the Motława river, the Motława draining, Czarna Łacha, Bielawa and Kłodawa, taking into account the influence of water levels in the Gulf of Gdansk, discharge of water from polders and drainage channels and streams, retention reservoirs, existing and planned water metastases and taking into account the degree of urbanisation of the catchment area, now and in the future.	IMGW-PIB Maritime Department in Gdynia	-	2003
34	Analysis of the adaptation of the Vistula river from Wloclawek to the mouth of the Gulf of Gdansk large and small cascades – modelling	IMGW-PIB, DHV Hydroprojekt Sp. z o.o.	*pdf	2017-2018
35	Routing of the technical and protective belt, ports and harbours boundaries, chainage of the coastline	Maritime Offices	*shp, *dwg, *txt, *pdf	2019
36	Storm embankments		*shp	2019
37	Bathymetric data for coastal waters		*xyz, *shp, *dwg, *asc, *dat, *pdf	
38	Execution/post-construction projects, data on investments having a significant impact on the extent of floods		*xyz, *shp, *dwg, *dat, *pdf, *doc *	2018-2019

Table 10: Summary of data needed to develop FRM

N.	Data	Name of institution/resource	Format	Update of data
1	Land use	GUGiK/BDOT10k resource	.shp	2018
2	Population	GUS/System of Address Identification of Streets, Real Estates, Buildings and Dwellings (NOBC) GUS/Local Database	.xlsx, .txt, .docx, .shp, .pdf .xlsx	2018 2018
3	Address points	GUGiK/Geoportal/Dictionary services	.xml	2018
4	Housing buildings and buildings of social importance (hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, social welfare homes, nursing homes, hospices, penitentiaries, correctional facilities, detention wards, police units, fire protection units, border guard units)	GUGiK/BDOT10k resource	.shp	2018
5	Social welfare homes, 24-hour care facilities	UW	.shp, .xlsx, .docx	2018
6	Hospices	NFZ	.xlsx	2018
7	Penitentiaries, custodial facilities	CZSW	.xlsx	2018
8	Correctional facilities	MS	.xlsx	2018
9	Groundwater abstractions	PIG PIB PGW WP (Pressure identification*)	.xlsx, .shp	2019 2018
10	Surface water abstractions	GUGiK/BDOT10k resource PGW WP (Identification of pressure)	.shp .shp	2018 2018
11	Protection zones of water abstractions	PGW WP	.shp	2018
12	Swimming pools	PIS-GIS	.shp,	2018
13	Boundaries of Natura 2000 areas, including areas of special bird protection and areas of special habitat protection	GDOŚ	.shp	2018
14	National parks borders	GDOŚ	.shp	2018
15	Nature reserves borders	GDOŚ	.shp	2018
16	Fixed monuments	NID	.shp	2018
17	Objects inscribed on the UNESCO World Heritage List	NID	.shp	2018
18	Extermination monuments	Act, regulations of the Ministry of Culture and National Heritage	.pdf	2019
19	Open-air museums and museums listed in the National Register of Museums	MKiDN	.xlsx	2018
20	Libraries forming the national library stock	MKiDN Regulation	.pdf	2019
21	Archives forming the national archive stock	MKiDN	.pdf	2018
22	Zoos	GUGiK/BDOT10k resource	.shp	2018
23	Industrial plants	GUGiK /BDOT10k PGW WP (Identification of pressure)	.shp .shp	2018 2018
24	Industrial plants with high and increased risk of a major industrial accident	GIOŚ WIOŚ KG PSP	.xlsx .xlsx, .docx, .pdf, .rtf .pdf	2018 2018 2018
25	IPPC installations (register of installations with integrated permits)	register of installations holding integrated permits	.xlsx	2018
26	Cemeteries	GUGiK/BDOT10k resource	.shp	2018
27	Landfills	GUGiK/BDOT10k resource PGW WP (Identification of pressure) WIOŚ	.shp .shp .shp, .xlsx, .mdb, .docx, .pdf	2018 2018 2018
28	Wastewater treatment plants	WIOŚ PGW WP (Identification of pressure) GUGiK/BDOT10k resource	.shp, .xlsx, .pdf .shp .shp	2018 2018 2018
29	Wastewater pumping stations	GUGiK/bDOT10k resource	.shp	2018
30	Values of flood damages calculated on the basis of potential loss factors for individual land use classes in 2016.	IMGW-PIB/ARCADIS/MGGP consortium	.shp	2019
31	Cities	GUGiK/BDOT10k resource	.shp	2018

* *Identification of pressure in water regions and river basin areas, 2018* (work carried out for PGW WP)

5.5. INVENTORY OF INVESTMENTS AFFECTING THE RANGE OF FLOOD HAZARD AREAS

Inventory of investments affecting the extent of flood hazard areas is one of the bases for reviewing and updating FHM and FRM developed in the first planning cycle, as well as for making new maps for the rivers or river cross-sections indicated for the development of maps in the second planning cycle. Taking into account significant investments that have been made in the period between cycle I and II or will be completed by the end of 2019 determines the preparation of hydraulic models reflecting the current state of affairs and thus determining the correct flood hazard areas.

5.5.1. Input data

Input data for the investment stocktaking are the results of surveys of local government units and institutions and spatial data for hydraulic modelling. The analysis should also include comments, which were submitted to the maps developed in the first planning cycle.

Spatial data for hydraulic modelling

As a result of various investments, the spatial data used for hydraulic modelling may change. In the case of investments related to earthworks, the land ordinates are subject to change, and thus DTM and valley cross-sections are outdated. Changes in the dimensions of bridge structures and hydrotechnical structures are also an important element of geometry in the hydraulic model – both in case of change of parameters and introduction of new structures may affect the change of water level ordinates, both in the vicinity of the structure and in the section located below. For these reasons it is important to check the timeliness of the spatial data for hydraulic modelling for both first and second cycle areas in relation to completed investments.

The following spatial data types shall be used for hydraulic models:

- DTM and DSM LIDAR available in PZGiK for the area covering the first and second planning cycle;
- riverbed cross-sections together with parameters of bridge and hydrotechnical structures, obtained for the rivers for which FHM were developed in the first planning cycle;
- geodetic surveying of river basin cross-sections together with parameters of bridge and hydrotechnical structures and embankments, obtained as a part of flood protection studies and analyses of investment programmes for the water region of the Upper Vistula, including rivers indicated for FHM and FRM in the second planning cycle.

Survey results

The data on investments which may have a significant impact on the change in flood risk are the result of a survey of local government institutions and units (communes, poviat starosties).

The questionnaires sent to the institutions allow to collect data on investments made by them:

- Regional Water Management Boards (RZGW),
- Regional Boards of Land Facilities and Water Management (ZMiUW),
- Maritime Offices (UM),
- Provincial Road Authorities (PRA),
- District Road Authorities (DRA),
- General Directorate for National Roads and Motorways (GDDKiA),

– Railway Authorities.

In the questionnaires, the criterion for selecting an investment is the time of the project implementation. The institutions indicate the completed, ongoing and planned investments to be completed by the end of 2019. However, these should not be older than the spatial data for hydraulic modelling, i.e. digital terrain model, riverbed cross-section measurements and parameters of bridge and hydrotechnical structures. The list of dates of the period of data collection on investments that may affect the change in the level of flood hazard is presented in Table 11.

The survey contains questions about basic information about the investment: name, short description, realization status, start and end date and location.

The surveys contain data as of November 2017. The inventory of investments should also take into account the investments reported during the implementation of the *WORP review and update*. Within the framework of this project, the questionnaires were addressed to:

– municipalities: including municipal offices, town halls, town and commune offices;
– poviat starosties;
– drainage and water equipment management boards;
– provincial fire brigades and the National Fire Service Headquarters;
– water supply and wastewater plants;
– crisis management centres.

Table 11: Summary of dates of the investment data collection period

Institutions surveyed	Data collection period about investments
RZGW	2010-2019
City Hall in Gdynia	2009-2019
City Hall in Słupsk, City Hall in Szczecin	2010-2019
ZMiUW/WZD/PZD Lower Silesia voivodeship	2011-2019
ZMiUW/WZD/PZD Kuyavia-Pomerania voivodeship	2011-2019
ZMUW/WZD/PZD Lublin Province	2009-2019
ZMUW/WZD/PZD Lubusz voivodeship	2011-2019
ZMiUW/WZD/PZD Łódź voivodeship	2011-2019
ZMiUW/WZD/PZD Lesser Poland voivodeship	2009-2019
ZMiUW/WZD/PZD Masovia voivodeship	2011-2019
ZMiUW/WZD/PZD, Opole voivodeship	2011-2019
ZMiUW/WZD/PZD Subcarpathia voivodeship	2009-2019
ZMiUW/WZD/PZD Podlaskie voivodeship	2011-2019
ZMiUW/WZD/PZD Pomerania voivodeship	2010-2019
ZMiUW/WZD/PZD Silesia voivodeship	2011-2019
ZMiUW/WZD/PZD Holy Cross voivodeship	2009-2019
ZMiUW/WZD/PZD Warmia-Masuria voivodeship	2010-2019
ZMiUW/WZD/PZD Greater Poland voivodeship	2011-2019
ZMiUW/WZD/PZD West Pomerania voivodeship	2011-2019
GDDKiA	2009-2019

Institutions surveyed	Data collection period about investments
Railway authorities	2009-2019

The units are asked questions about flood protection investments (weirs, relief canals, embankments, mobile flood protection systems, flood reservoirs, dry reservoirs, polders and other flood protection) and other investments that may affect the level of flood risk (communication investments on embankments, detached and multi-family houses, public buildings, etc.), housing estates, cubature facilities built on an elevated area, other facilities that may affect the extent of flooding) implemented or planned to be implemented in the period from 2010 to 2019.

For the investments indicated in the questions, general information about the investment is also obtained, such as location, status of the investment and dates of start and completion. Units also have the possibility of spatial location of individual investments.

Comments from municipalities, institutions and society

In the process of stocktaking of investments affecting the extent of flood hazard areas, comments to FHM and FRM made in the first planning cycle by municipalities, institutions and society are also taken into account. The comments may concern both substantive errors and lack of acceptance for the designated flood hazard areas, as well as investments made or planned. As part of the stocktaking, those concerning investments should be selected from the comments submitted. Other comments should be analysed as a part of the review of the FHM and FRM.

5.5.2. Criteria of investment inventory

Not all investments have an impact on changing the extent of flood hazard areas, so it is crucial to adopt criteria that allow a pre-selection of those that have a potential impact on flood hazard areas. For this purpose, a two-stage analysis of the investments should be carried out in terms of preliminary compatibility and substantive criteria (Figure 19). The surveys are a huge data set. For this reason, in the first stage investments should be selected in relation to the criteria concerning e.g. the date of investment completion, the status of investment implementation or the location of the investment. Then investments selected in the first stage are assessed in terms of substantive criteria. The result of this analysis is the selection of investments which may potentially have a significant impact on the extent of flood hazard areas and will be analysed in detail as part of the review of the FHM and FRM, according to the adopted methodology and as a part of the development of the FHM and FRM second planning cycle.

Fig. 19. Diagram of carrying out an inventory of investments having a potential impact on the extent of flood hazard areas (own study)

Preliminary compliance criteria

These criteria relate to the investments meeting requirements, such as: completion of the investment, its location or implementation status. These include:

Ia. Completion date of commenced/planned investments – the investment should be completed by the end of 2019.

Ib. Completion date of completed investments – the end date of the investment is later than the date of validity of the spatial data for hydraulic modelling (e.g. in the case of DTM – raid date).

Ic. Location of the investment – the investment is carried out in an area/water course which was developed in the first planning cycle or is developed in the second planning cycle.

Id. Implementation status – the investment has been completed or is planned, and its financing is ensured.

Ie. Full information on the investment – the investment has completed information on its status and completion date. In case of lack of such information, it is necessary to ask the relevant authority to complete the missing data.

If criteria Ia, Ib and Ic are not met, the investment should be excluded from further analysis. If an investment is assigned to criterion Id. "Implementation status", a list of flood protection investments should be drawn up and their status monitored by the end of 2018. If monitoring results in information that the investment will be completed by the end of 2019, the investment should be included in the FHM update.

In addition, for criterion Ie. "Full information concerning the investment", a list of investments for which there is no detailed information should be prepared and their acquisition should be carried out in the following order: repeated questionnaire, urging correspondence, request for the support of RZGW. The investment is excluded from the analysis only if it is impossible to obtain data as a result of additional steps taken.

Criteria on substance

The substantive criteria allow the selection of investments which may have a significant impact on the extent of the flood hazard area. As mentioned earlier, the surveys are a huge collection of data and often have useless data. In the case of a survey, the scope of the reported investments (works) often does not influence the change of the range of the flood hazard area, such as e.g. modernization of wastewater pumping stations, renovation of bank fortifications or dredging and desilting works several years ago. Therefore, investments which will be analysed in detail, in accordance with the methodology of FHM and FRM review (Chapter 4. Method and scope of the review
and update of FHM and FRM), should be selected according to the following criteria:

IIa. Significant change of parameters of bridge structures, hydrotechnical structures and embankments – investment parameters may have a significant impact on the change of data for hydraulic modelling.

IIb. Construction of new bridge structures, hydrotechnical structures, embankments or other structures used for flood protection purposes – investment parameters may have a significant impact on the change of data for hydraulic modelling.

IIc. Significant change of riverbed cross-sections.

IId. Significant change of terrain.

IIe. Ability to obtain investment parameters – possibility of obtaining documentation containing description of basic investment parameters.

If one of the IIa-IId criteria is met, the investment may have a potential impact on the flood hazard area. The assessment should be based on an expert analysis. However, for further analysis it is necessary to fulfil criterion IIe "Ability to obtain investment parameters". If detailed information is not provided when the surveys are resubmitted, these investments should be listed together with the investments with criterion Ie and further data acquisition should be carried out. The result of the inventory is a list of all inventoried investments which may have a potential impact on the extent of flood hazard areas, with the attribution of the result of the verification of the validity of the inclusion of investments in the designation of current flood hazard areas. These investments should then be analysed in detail when reviewing the FHM and FRM and developing new FHM and FRM for river sections of the 2nd planning cycle.

5.5.3. Description of the resulting data

Data acquired during the inventory shall be presented in the form of Excel tables and .shp spatial layers (Figure 20). Table lists and .shp layers should be prepared for both investments, as well as river sections.

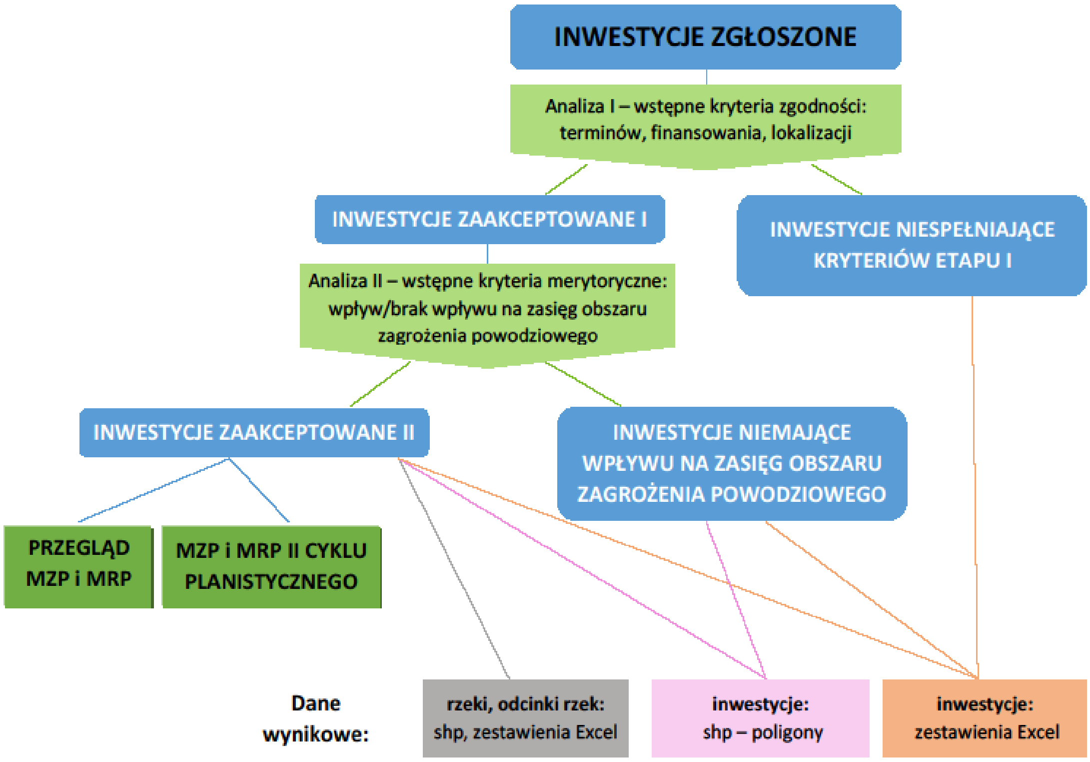


Fig. 20. Diagram of carrying out an inventory of investments with potential impact on the extent of flood hazard areas, taking into account the resulting data (own study)

List of investments

All the investments submitted in the survey and comments should be summarised in an Excel table, regardless of whether or not any of them were rejected during the analysis. Each investment should be given an individual identifier. For investments that have passed the first and second stage of the inventory, this identifier will allow to assign the investments to river sections. In order to maintain consistency, these identifiers should also be used during the review of the FHM and FRM. Then the investments should be assigned information on the indication for further analysis, indicate the criterion for rejecting the investment (when the investment does not affect the extent of the flood hazard area) and give the final result of the verification (whether the investment has a potential impact on the extent of flood hazard areas). The positive result of the verification indicates the investments to be analysed in detail during the review of the FHM and FRM. Investments for which it is not possible to assign the final result of the verification (criteria Id, Ie and IIe) should be assigned "in progress", while the indication for further analysis should be described as: "monitored investment" or "in the process of obtaining documentation".

For investments which have passed the first stage of investment stocktaking, it is necessary to specify detailed information concerning the river, the RZGW, the current status of spatial data for hydraulic modelling and recommendations for obtaining current data. The topicality status of spatial data for modelling is assigned on the basis of dates of investment completion and execution (topicality) of particular spatial data. Thus it was assessed whether DTM, riverbed cross-section measurements and parameters of bridge structures, hydrotechnical structures and embankments are up-to-date. The table should also list the investments which were indicated in the FRMP (action identifier from the FRMP) and were analysed in the W0 FRMP variant.

List of river sections

The river sections should be prepared to reflect the lengths of the model sections. For rivers in the second cycle, it should be assumed that a section is the whole length of the river. Then, for each section, investments which may have a potential impact on the extent of flood hazard areas, i.e. those which have passed both stages of the investment inventory, should be assigned. This should be done by assigning the appropriate investment identifiers. General information on the current status of the DTM, available measurements of the riverbed cross-sections, parameters of bridge and hydrotechnical structures, reasons for possible lack of topicality and recommendations for obtaining current data should also be assigned to rivers.

The river sections should be presented in the form of a linear spatial layer in which the course of the rivers will comply with MPHP10k.

5.5.4. Documentation of investments affecting the change in flood hazard level

Investments with a potential impact on the extent of flood hazard areas concern both first and second cycle rivers. In order to assess the potential impact of investments to change the extent of flood hazard areas, it is necessary to obtain documentation with information on the parameters of the investment for rivers in the first planning cycle. This information will be used to assess the validity of spatial data for hydraulic modelling. In the case of rivers from the second cycle, where field measurements have not yet been carried out, it is necessary to obtain documentation of investments not yet completed and those which may have an impact on the digital terrain model (if the investment has been carried out after the date of LIDAR raids conditioning the validity of the DTM and concerned changes in the terrain). This information determines the performance of a full inventory of the investment and, at a later stage, the review of FHM and FRM and the development of new FHM and FRM.

6. METHODOLOGY OF DEVELOPING FHM IN THE 2nd PLANNING CYCLE

6.1. METHODOLOGY OF HYDRAULIC MODELLING

To determine the extent of flood hazard areas, a one-dimensional (1D) model should be developed, based on the full one-dimensional equations of Saint-Venant – the mass conservation equation and the energy conservation equation – a two-dimensional (2D) or hybrid model combining 1D and 2D models. Model calculations are performed for unsteady flow conditions.

Modelling is carried out in MIKE software from DHI (version 2011 or earlier), owned by the State Water Holding Polish Waters, which is the recipient and downstream user of the models. Hydraulic models in the first planning cycle were also developed in the above software. Therefore, a consistency should be ensured, so that it is possible to develop models for entire river basins for both first and second planning cycle rivers. The following description of the modelling was done using examples of functions found in the MIKE software.

The hydraulic model must be built according to the following steps:

1) Model building:
    a) 1D: schematisation of the river network, introduction of cross-sections, determination of roughness coefficient values, introduction of engineering structures, introduction of water reservoirs,
    b) 2D: preparation of a digital terrain model, determination of the roughness coefficient value,
    c) 1D/2D: schematisation of the river network, introduction of cross sections, determination of the roughness coefficient value, introduction of engineering structures, introduction of water reservoirs, preparation of the digital terrain model, combination of 1D and 2D models;
2) Determination of boundary conditions;
3) Calibration and verification;
4) Performing model calculations of flood scenarios.

6.1.1. Methodology of 1D hydraulic modelling

6.1.1.1. Schematisation of a river network

This stage includes the identification of the existing river network, the analysis of the impact of individual tributaries on the size of the flood flows in the watercourses covered by the model, the vectorisation of the watercourses selected for inclusion in the model. Verification of the course of watercourses from the Map of Hydrographic Division of Poland in the scale 1:10,000 selected for inclusion in the model should be carried out. In the process of verification, geodetic measurements of the riverbed cross-sections, digital terrain model and orthophotomap should be used. The watercourses should be given a chainage, taking as a kilometre 0+000 a topological node with a receiver.

A chainage of the beginning and end of modelled sections of watercourses, nodal points, locations of water gauge stations is rounded to one metre (1 m).

In the case of flood terraces, vectorisation should be carried out, according to the shape of the valley, so that the flow of floodwater is properly reflected throughout the width of the valley. Flood terraces should be vectorised on the basis of DTM and an orthophotomap. In river valleys where the terrain causes the flow of floodwater to be separated, parallel floodwater flow routes should be separated and links (connection channels) between them defined. Special care should be taken when determining the width of floodplains and the total number of connecting channels belonging to a floodplain. The principle of one cross-section/connection channel should apply, unless the modeller finds that in a given cross-section the exchange of volumes between the main channel and the floodplain is not possible.

Examples of river networks are shown in Figures 21 and 22.

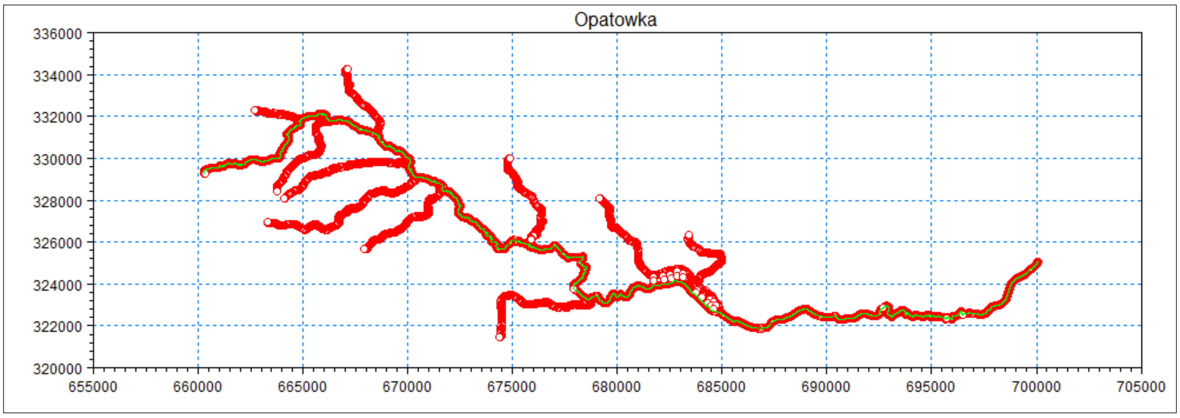


Fig. 21: River network in graphical form

Definitions

Branch Name	Topo ID	Upstr. Ch.	Downstr.Ch.	Flow Direction	Maximum dx	Branch Type
OPATOWK	2314	0	57600	Negative	500	Regular

Connections

	Branch Name	Chainage
Upstream		
Downstream		

Edit Link Channel Parameters...

Overview

	Name	Topo ID	Upstr. Ch.	Downstr. Ch.	Flow Direction	Maximum dx	Branch Type	Upstr.Conn. Name	Upstr.Conn. Ch.	Downstr. Conn. Name	Downstr. Conn. Ch.
1	OPATOWKA	2314	0	57600	Negative	500	Regular				
2	ZYCHAWA	23146	0	7400	Negative	500	Regular	Opatowka	27688		
3	KANIA	23144	0	5600	Negative	500	Regular	Opatowka	41958		
4	RZEKA_MARCINKOWSKA	231434	0	9290	Negative	500	Regular	Opatowka	43667		
5	GRABOWKA	231432	0	6800	Negative	500	Regular	Opatowka	44477		
6	DOPLYW_SPOD_WRZOSU	231414	0	5200	Negative	500	Regular	Opatowka	49600		
7	DOPLYW_SPOD_NIEMIENIC	231412	0	2400	Negative	500	Regular	Opatowka	51360		
8	DOPLYW_SPOD_SADOWIA	23142	0	3600	Negative	500	Regular	Opatowka	47097		
9	DOPLYW_SPOD_BRZEZIA	231454	0	5650	Negative	500	Regular	Opatowka	34092		
10	POTOK_DAROMINSKI	231482	0	4000	Negative	500	Regular	Potok_Lisowski	1566		
11	POTOK_LISOWSKI	23148	0	9600	Negative	500	Regular	Opatowka	19250		
12	L4357	L4357	0	10	Positive	500	Link Channel	Opatowka	23260	Potok_Lisowski	4358
13	L3941	L3941	0	10	Positive	500	Link Channel	Opatowka	22780	Potok_Lisowski	3941
14	L3535	L3535	0	10	Positive	500	Link Channel	Opatowka	22340	Potok_Lisowski	3535
15	L3155	L3155	0	10	Positive	500	Link Channel	Opatowka	22220	Potok_Lisowski	3155
16	L2826	L2826	0	10	Positive	500	Link Channel	Opatowka	21990	Potok_Lisowski	2827
17	L1651	L1651	0	10	Positive	500	Link Channel	Opatowka	21040	Potok_Lisowski	1760
18	BRANCHDSBRZEZIA	2314541	250	800	Negative	500	Regular	DOPLYW_SPOD	245		
19	L793	L793	0	10	Positive	500	Link Channel	DOPLYW_SPOD	796	BRANCHDSBRZEZIA	794
20	L509	L509	0	10	Positive	500	Link Channel	DOPLYW_SPOD	509	BRANCHDSBRZEZIA	509

Figure 22: River network in tabular form

Side tributaries which in the outlet sections have a significant retention compared to the volume of modelled waves, should be added to the modelled river network. In case of lack of geodetic measurements it is allowed to use cross-sections prepared on the basis of DTM and BDOT10k.

The river network developed in such way should be introduced into the hydraulic model, keeping the chainage and names of the watercourses. Nodal points should be entered at the points of connection of the watercourses.

The river network should be reviewed and possibly modified after analysis of modelling results and floodplains.

6.1.1.2. Introduction of cross-sections and determination of roughness coefficient

This stage includes the preparation of the cross-sections to a format that enables them to be imported into the model, the import of data and the analysis of the roughness coefficients between individual measuring points in each of the cross-sections included in the model. The chainage of each cross-section must be unambiguously determined by intersecting the cross-sectional line with the watercourse line developed under the "river network diagram" point. The assigned cross-sectional length must be rounded to the nearest 1 m.

For each of the cross-sections, based on the codes assigned to all sections of the cross-section, which determine the nature of the riverbed (according to the code table in 3, paragraph 5.1.1.2), roughness coefficients shall be chosen. Orthophotomaps, BDOT10k and topographic maps shall be used to determine roughness coefficients on flood terraces.

The determination of roughness coefficients in one-dimensional modelling is to reflect the flow resistance due to a specific land cover with a specific geometric representation of the modelled reality. Two methods are allowed to define the lateral variability of the roughness coefficient in cross-sections:

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

The choice of the method of representation of roughness coefficients should depend on the specificity of floodplains and variability of land use types. When using the *High/Low flow zones* method, the main riverbed, the left flood terrace and the right flood terrace should be determined in each cross-section. Roughness coefficients should be determined separately for each of the terraces (left, right). In each cross-section, the roughness coefficient averaged over the section of the terraces covering half the distance to the adjacent cross-sections should be taken. Its value should be determined as a weighted average of the different land uses and the corresponding roughness coefficient values. For each of the cross-sections, on the basis of the codes assigned to all sections of the cross-section, which define the land-use character (according to the code table in Chapter 6.1.1), the roughness coefficients for the main riverbed shall be selected.

Where the *Distributed* method is used, the roughness coefficients corresponding to the coverage codes of the individual points of cross-section shall be taken. To determine the coverage codes in the main riverbed, geodetic measurements should be used, whereas BDOT10k for flood terraces. Where the coverage codes are not representative of the land between the sections, additional cross-sections should be introduced, the shape and roughness coefficients of which for floodplains result from DTM and BDOT10k. The location of additional cross-sections will be determined by an expert method by a modelling specialist on the basis of the BDOT10k analysis, the digital terrain model and orthophotomaps. The decisive criterion in this case should be the percentage difference of average roughness coefficient for maximum filling in the modelled scenarios between the additional cross-section and adjacent cross-sections included in the model. Due to the lack of geodetic measurements, the additional cross-sections in the riverbed part will be interpolated using MIKE 11 or equivalent procedures, and outside the riverbed part will be determined on the basis of DTM and BDOT10k.

Examples of cross-section are shown in Figures 23 and 24.

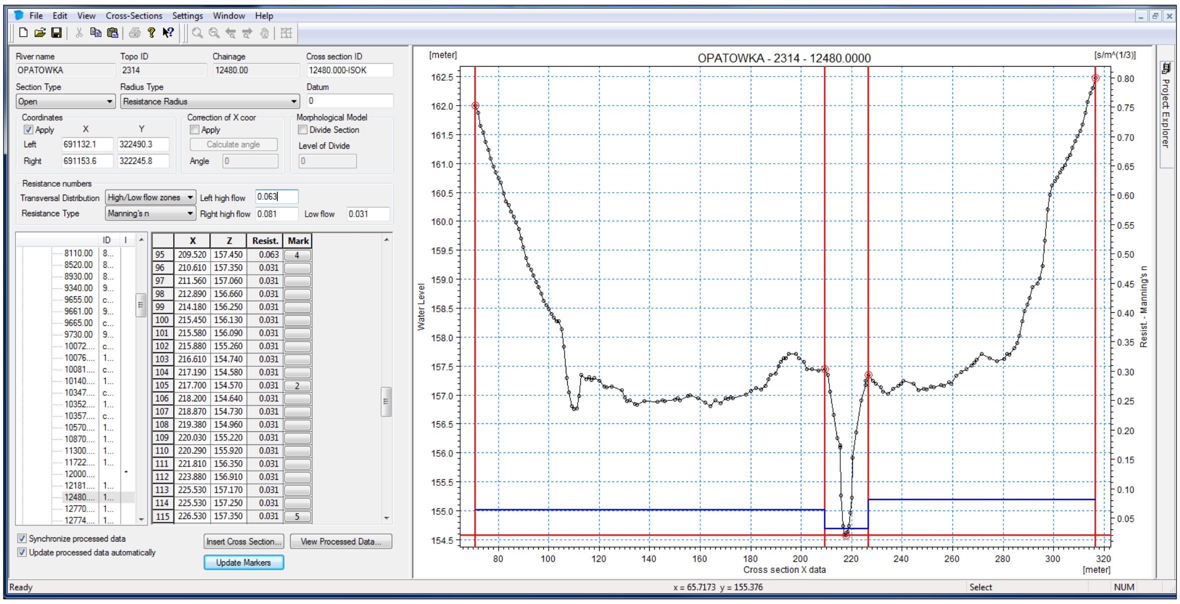


Fig. 23 Example of a cross-section

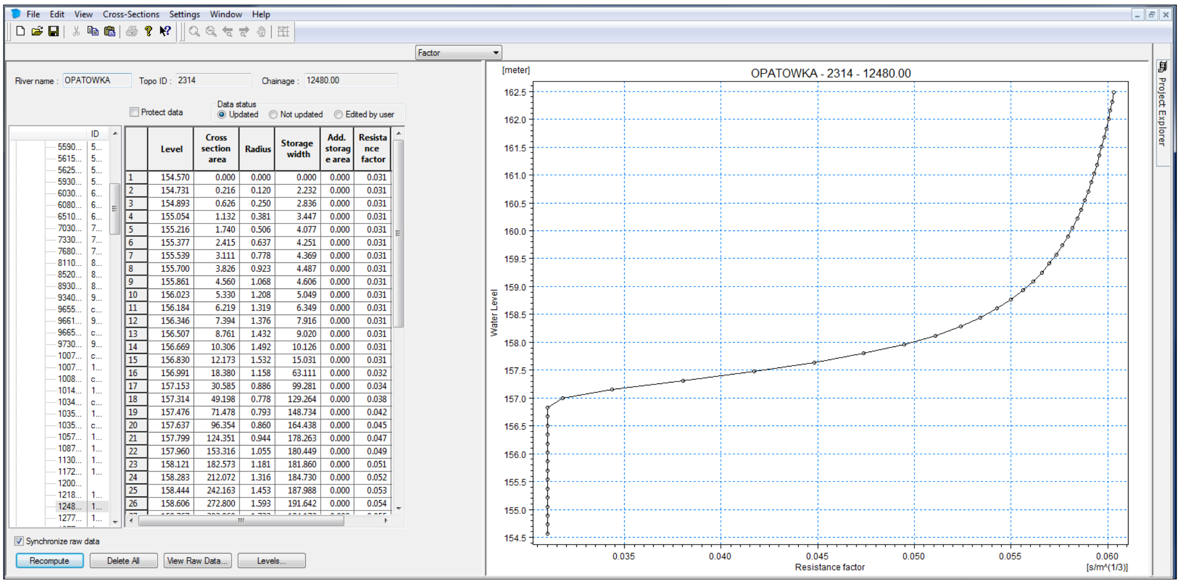


Fig. 24 Example cross-section – processed data

For cross-sections describing flood terraces, the same procedure should be followed as for riverbed/valley cross-sections, with chainage to be determined locally for each of the terraces. A table should be prepared in which each flood terrace cross-section corresponds to the name and chainage of the watercourse (or watercourses) adjacent to the terrace in question.

6.1.1.3. Introduction of engineering structures (bridges, culverts, hydrotechnical facilities)

In hydraulic models developed for the purpose of updating hazard maps and flood risk maps, all engineering structures relevant for flood water flow, such as bridges, culverts and hydrotechnical structures, should be inventoried and measured in the field and then incorporated into the models. Taking into account the impact of engineering structures on floodwater flow conditions is of key importance in the context of the correctness of the final product, i.e. the extent of flood hazard areas, which is among others the basis for defining flood hazard areas.

The detailed scope of inventories and measurements in this area is described in Chapter 2.3 *Inventory of investments affecting the extent of flood hazard areas*. This chapter also contains indications on the selection of objects significantly affecting the flood water flow conditions. The indications in this respect should be treated as general and the decision whether a particular object should be implemented into a hydraulic model should be made on a case-by-case basis by a person responsible for hydraulic modelling who has experience and knowledge in this field.

In the case of bridge structures of compact construction, significantly narrowing the flood water flow field, as well as culverts, it is recommended to use the method consisting in mapping the structure with two interlinked hydraulic elements, describing the water flow over and inside the bridge (through its light). This method can be used in the MIKE11 software, where it is possible to simulate the flow through and over the bridge, using a combination of culverts/weirs (module "structures – culverts/weirs" in the NWK11 river network file). This method is particularly applicable in cases of typically mountainous river valleys, where the carriageway of the bridge is in many cases strongly sloped along the longitudinal axis, as well as in situations where the cross-section through the light of an object is irregular in shape or consists of several culverts, for example, and also in the case of arched bridges. This solution is particularly recommended in situations where the bridge cross-section significantly narrows the natural width of the water level, causing the water to accumulate and overflow over a significant width of the valley cross-section. This method, in comparison with typical bridge procedures, is more sensitive to the method of introducing geometrical data, which often makes corrections necessary. The application and effectiveness of this method requires a control by the modeller, in particular the height of the obtained floors in structures.

An example of a bridge implementation in the form of a combination of culvert and overflow is shown in Figures 25 and 26.

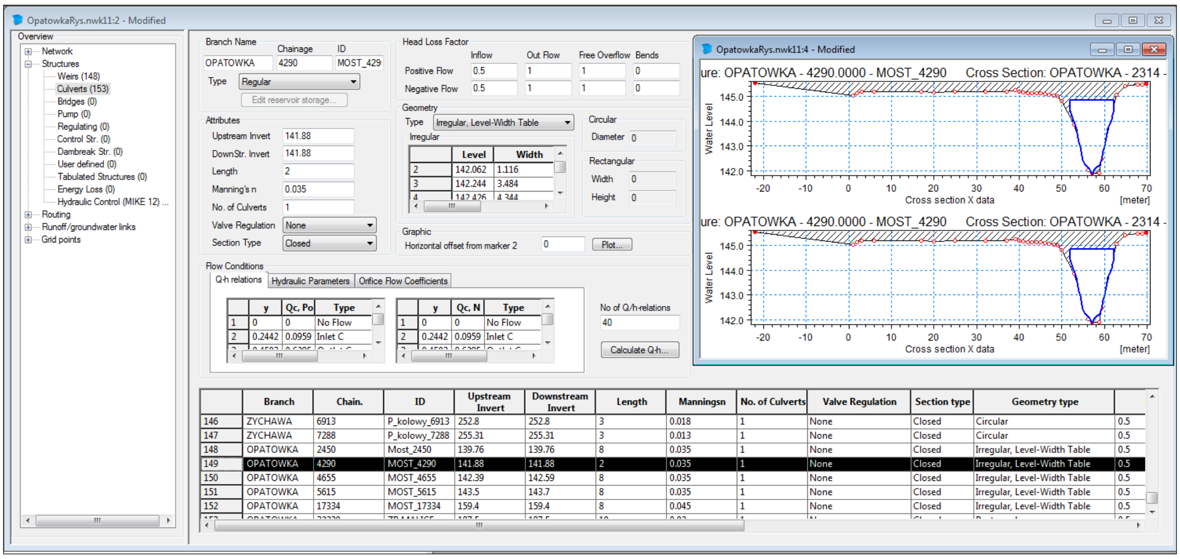


Fig. 25 Example hydrotechnical structure – part describing the flow under the bridge (culvert)

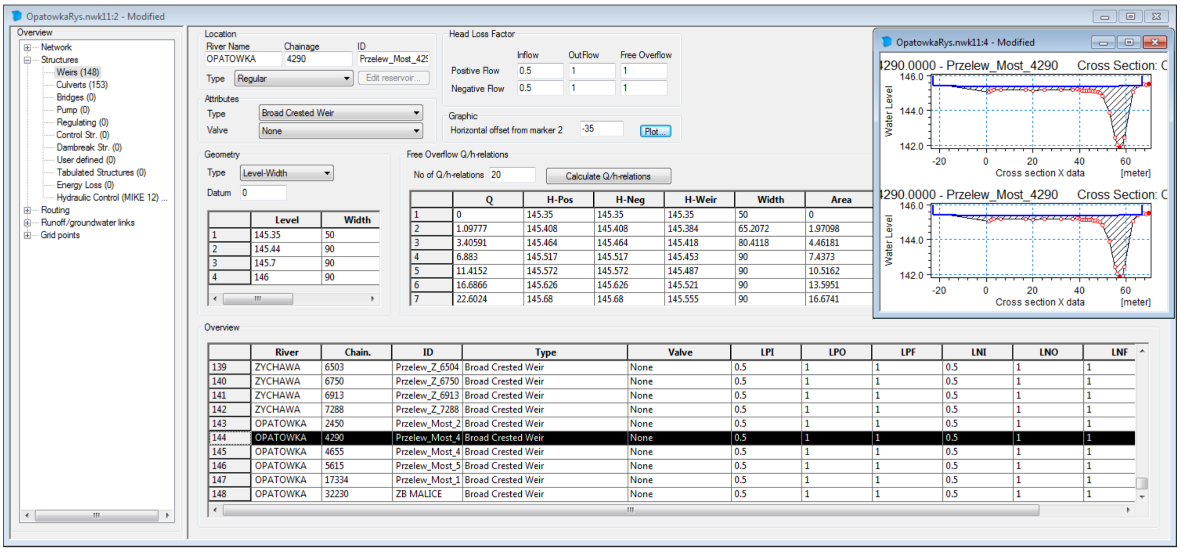


Fig. 26. Example hydrotechnical structure – part describing the flow over the bridge (overflow)

In other cases, it is recommended to use a dedicated module for bridges in the MIKE software, by selecting a method appropriate to the conditions. The preferred solution in this respect is to use one of the methods enabling simulation of free flow at the same time (i.e. for situations where the water level is below the bottom of the bridge structure), as well as under pressure (the water level between the bottom of the bridge structure and the roadway level), as well as under flow conditions above the object (the water level above the roadway level). It is recommended to use one of the standard methods used in hydraulic modelling tools (including MIKE11 software by DHI): *Energy Equation*, *Federal Highway Administration Water Surface Profile* (FHWA WSPRO) and *United States Bureau of Public Roads* (USBPR), with *Energy Equation* being the preferred method.

In the case of a situation where several bridge objects are located on a watercourse, for which the condition of maintaining the distance between two adjacent objects greater than half of the width of individual objects is not met, the following objects should be considered for extension in the model, in relation to each other or replace them with a single object with a similar impact.

In this case, an object with the most unfavourable hydraulic parameters (the shortest light or the ordinate of the bottom of the structure) should be introduced into the model and the impact of the other objects should be taken into account by applying the total width of all objects. These changes serve to ensure numerical stability of the calculations.

Non-controlled hydro-technical objects, such as: steps, water thresholds and weirs should be reproduced in the model by means of an overflow. In MIKE11 software by DHI a dedicated tool for this purpose is the "structures – weirs" module included in the NWK11 river network file.

In case of objects with controlled accumulation, an appropriate algorithm of flow control can be used, depending on the variable, which most often is the size of the inflow, the level of water level at the upper or lower position, and sometimes also time (date). In the MIKE11 software the module "structures > control structures" or "structures > regulating" contained in the NWK11 river network file is used for this purpose.

Retaining walls and mobile flood protection systems should be included in the model as devices which may affect the extent of flood hazard areas. The parameters of the listed objects should be obtained on the basis of administrators' documentation (e.g. RZGW, ZMiUW, JST).

6.1.1.4. Introduction of water reservoirs

The proper mapping of the impact of a water reservoir on the flood water flow conditions is one of the key elements that ensure the correct delineation of the flood hazard areas and a reliable assessment of the flood hazard level in the valley below. It is essential that the water reservoir model is an integral part of the hydraulic model developed for the whole catchment area or river, which is the basis for generating the extent of flood hazard areas. Only such an approach allows for a comprehensive assessment of the level of flood hazard throughout the whole analysed river section and ensures methodological consistency of hydraulic analyses.

The correct mapping of the transformation of flood flows through a water reservoir requires the construction of a hydraulic model based on transient movement, i.e. based on flood waves with a certain probability of maximum flow. Only such an approach allows for correct balancing of the volume of water intercepted by the reservoir during the passage of the flood wave and generating a hydrograph of an outflow, taking into account the reduction of flows through the reservoir.

The implementation of the water reservoir into the hydraulic model for the river network requires the following elements:

a) description of reservoir and dam geometry;
b) calibration of the reservoir capacity curve;
c) implementation of the principles of reservoir outlet control.

Re. a)

The geometry of the reservoir bowl in the hydraulic model should be mapped using actual cross-sections based on current bathymetric data. In case of lack of bathymetric data, which would allow to describe the bowl shape by means of real cross-sections, it is acceptable to use artificial cross-sections (so-called virtual ones). Distances and distribution of the cross-sections in the area of the bowl depends on its shape and size and should be assessed individually each time.

The geometry of the front dam of the water reservoir should be mapped in the model as an overflow with a wide top. The ordinate of the dam's top, its width and height above the valley bottom should correspond to the actual values contained in the documentation for the object.

Re. b)

The basis for the mapping of the water reservoir volume is the current reservoir capacity curve, developed on the basis of bathymetric measurement results and included in the facility's water management manual. The capacity curve shall cover the full range of water accumulation in the reservoir, including the highest theoretically achievable level, corresponding to the order of the dam top. Where the capacity curve ends at an ordinate lower than the dam top, the curve shall be extrapolated to the ordinate corresponding to the dam top.

In order for the model to reproduce as precisely as possible the actual reservoir capacity (described in the model structure by means of cross-sections) it is necessary to carry out the so-called "capacity curve calibration". The calibration is performed for predetermined, characteristic levels of water accumulation in the reservoir, resulting from the division of the reservoir capacity and the way the object works during flooding.

The calibration process shall take into account mandatory accumulation levels, such as minimum, normal and maximum accumulation level, dam top level and all intermediate levels, where the drain control procedures are changed. In the case of "dry" (uncontrolled) reservoirs, calibration is sufficient for the maximum accumulation level and for the level of the dam top.

Calibration should be carried out on a hydraulic model with the introduced geometry of the front dam closing the outflow from the reservoir and setting a constant series of inflows of a fixed size and duration, allowing the reservoir to be filled to the determined ordinate at the determined time. In this way, the points on the capacity curve calculated by the model which correspond to the assumed calculated accumulation levels must be determined consecutively and the results obtained must be compared with the "output" curve from the reservoir manual. Acceptable differences between the water level level mapped by the model and the level resulting from the curve in the water management manual should not exceed a few centimetres for each of the calculation points. In practice, the acceptable accuracy of results depends on the depth and volume of the reservoir and should be determined individually for each object. In doubtful cases, KZGW and RZGW should be consulted.

The calibration calculations shall be carried out until the assumed consistency of the results for each calculation level is achieved. In this case, the calibration parameter is the retention area built up by the reservoir cross-sections between the individual calculation levels (in MIKE11 software by DHI this parameter is called "additional retention area"). There are two ways to include in the model additional retention built by the cross-sections:

– If the actual reservoir cross-sections are available, it is recommended to carry out calibration by iterative selection of the parameter "additional retention area" in each reservoir section – for each layer of water in the reservoir for which the calibration is carried out. In this respect it may be necessary to take into account the positive or negative retention volume. The calculations should be carried out starting from the lowest calculation level, and the assumed additional retention area in the layer for which the calibration is currently carried out should be distributed in cross-sections proportionally to the share of cross-sections in building the reservoir capacity in the analysed layer. After obtaining the compatibility referred to above, the next layer shall be passed and the calculation process shall be repeated. The calculations should be completed at a level corresponding to the water reservoir dam top.

– If no bathymetric data or current cross-sections are available for a given reservoir, it is acceptable to use virtual cross-sections in the reservoir bowl. Then, before starting the calibration process, the retention built by each reservoir cross-section should be limited as much as possible ("storage width" parameter in MIKE11 software by DHI), and then distributed proportionally to the share of each cross-section in building the reservoir capacity, calculated on the basis of the capacity curve, the so-called "retention area growth curve". As in the previous case, the adjustment of the calculated capacity curve to the actual curve should be made by means of subsequent iterations – taking into account the assumed accuracy of the results.

Example results of reservoir capacity curve calibration are shown in Fig. 27 and in Table 12.

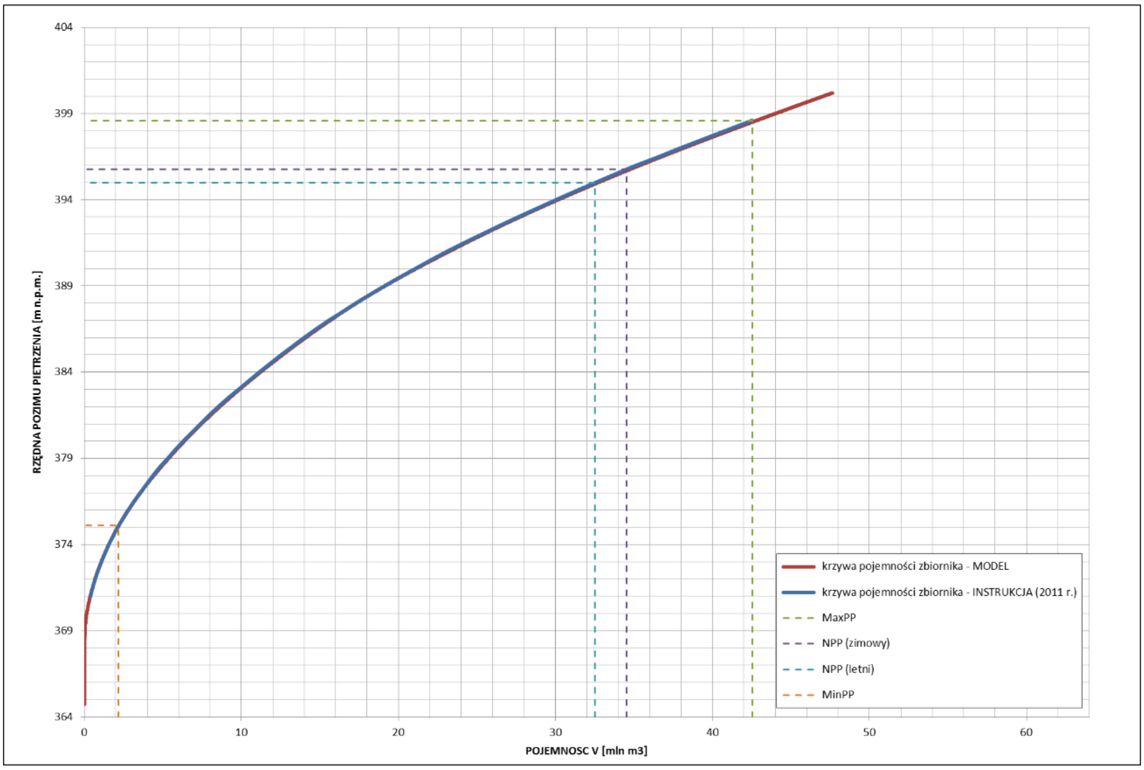


Fig. 27. Calibration results of the reservoir capacity curve (graphical form)

Table 12 Results of reservoir capacity curve calibration (tabular form)

Reservoir capacity [million m³]	Accumulation level [m.a.s.l.] curve	Accumulation level [m.a.s.l.] model
0.18	370	370.12
0.39	371	371.07
0.69	372	372.04
1.08	373	373.01
1.55	374	374.00

Reservoir capacity [million m³]	Accumulation level [m.a.s.l.] curve	Accumulation level [m.a.s.l.] model
2.12	375	375.01
2.18	***MinPP – 375.10***	***375.10***
2.78	376	375.98
3.54	377	376.97
4.37	378	377.95
5.29	379	378.93
6.29	380	379.93
7.38	381	380.94
8.54	382	381.93
9.78	383	382.93
11.1	384	383.92
12.5	385	384.92
13.99	386	385.94
15.58	387	386.96
17.28	388	387.98
19.11	389	388.98
21.05	390	389.97
23.1	391	390.95
25.28	392	391.94
27.59	393	392.94
30.02	394	393.94
32.52	***NPP (summer) – 394.99***	***394.92***
32.55	395	394.93
34.54	***NPP (winter) – 395.76***	***395.68***
35.18	396	395.92
37.92	397	396.91
40.77	398	397.90
42.53	***MaxPP – 398.60***	***398.50***

Re. c)

After completing the procedure to calibrate the capacity of the reservoir, proceed with the introduction of drain control rules – according to the current facility's water management manual. In order to be able to carry out the above work, it is necessary to have a thorough knowledge of the reservoir control procedures, both during the passage of the flood wave and outside the period of flood hazard, as well as of the maximum expenses of the discharge devices (bottom venting, surface overflow). Water management procedures in the "normal" and "flood" periods are an integral part of the documentation for flood-relevant reservoirs. They are included in the water management manual in the form of a text description or tables linking the size of the reservoir drain to the accumulation level, inflow or other additional variables.

The recommended way to implement the rules for controlling the outflow from the water reservoir in a hydraulic model is to map them by means of a system of logical conditions and tables linking individual variables. The module enabling this approach in the MIKE11 software by DHI is the "control structures" module included in the NWK11 river network file.

Prior to the implementation of the control rules, the drain and overflow curves should be developed for all characteristic levels of the water level in the reservoir. Calculated maximum (total) expenses should be compared with the maximum outflow values for particular levels of water accumulation in the reservoir – in order to eliminate possible situations when the outflow disposition could exceed the actual flow capacity of the outflow and overflow.

If there is a variation in the outflow control procedures during the filling and restoration phase of the flood reserve, this should be taken into account in the model under development by applying appropriate logical conditions. Also in the situation when a certain control method depends on a time variable (date), this fact should be adequately reflected.

After the introduction of the drain control principles in the model, it is necessary to check the correctness of the individual procedures. After confirming the correct mapping of control procedures by the model, the developed model can be used to calculate the transformation of flood waves by the reservoir and to generate the range of flood hazard areas in the valley below the object.

Any detailed problems, specific to the modelled reservoirs, should be solved in consultation with the National Water Management Authority (KZGW) and the relevant regional water management board.

An example of implementation of reservoir control rules as "control structures" is presented in Figure 28.

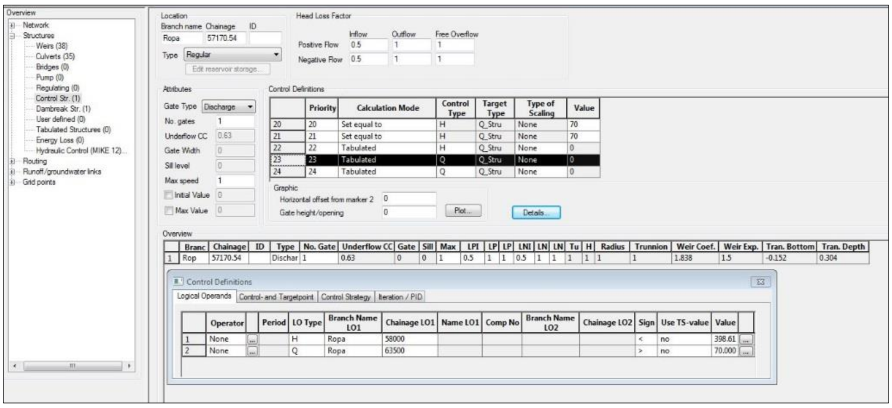


Fig. 28. Example of implementation of reservoir control rules as "control structures"

6.1.1.5. Determination of boundary conditions

In the hydrodynamic model based on the Saint-Venant equations there are maximum (upper) and minimum (lower) boundary conditions, as well as optional internal boundary conditions. Upper boundary conditions are defined in the form of hydrograph flows or water levels (water level ordinates). These conditions must be established for all riverbeds. The lower boundary conditions closing the network system of river channels, depending on the modelling assumptions, can be a water level hydrograph (in estuary sections) or a flow intensity curve when defined in the closing profile. For a river on which a reservoir with a flood protection function is located, the values of the inflow to the reservoir contained in the current reservoir water management manual (IGW) are taken into account when determining boundary conditions. For rivers entering the sea, the average sea state shall be taken as the lower boundary condition.

Boundary conditions should be prepared for the calibration and verification of the model and the calculation of possible water scenarios with probabilities of exceeding p = 10%, p = 1%, p = 0.2%.

The basis for the construction of flood scenarios should be hypothetical waves, the peak of which corresponds to the value of flows with a certain probability of occurrence.

The boundary conditions for calibration and model verification for controlled watercourses should be prepared on the basis of hydrographs of selected historical nodes.

Where a precipitation-drainage model has been developed for the modelled catchment area, the results of the model for the relevant scenarios should be used to develop boundary conditions.

Scenarios are to cover all modelled watercourses. For these watercourses it is necessary to develop values of flows constituting upper boundary conditions (Q), distributed flows (Qr), taking into account the increase of the catchment area size, introduce as concentrated inflows (Qs) the watercourses not included in the modelling but which may influence the wave transformation and introduce values of control flows in water level gauge cross-sections (Qw), according to Figure 29, which shows a diagram of an exemplary river network.

First, a summary of boundary conditions should be prepared in accordance with Table 13.

Some boundary conditions can only be determined iteratively at the calibration, verification and model calculation stages. The boundary conditions that can be determined on the basis of the developed hydrological data should be prepared as *.dfs0 files.

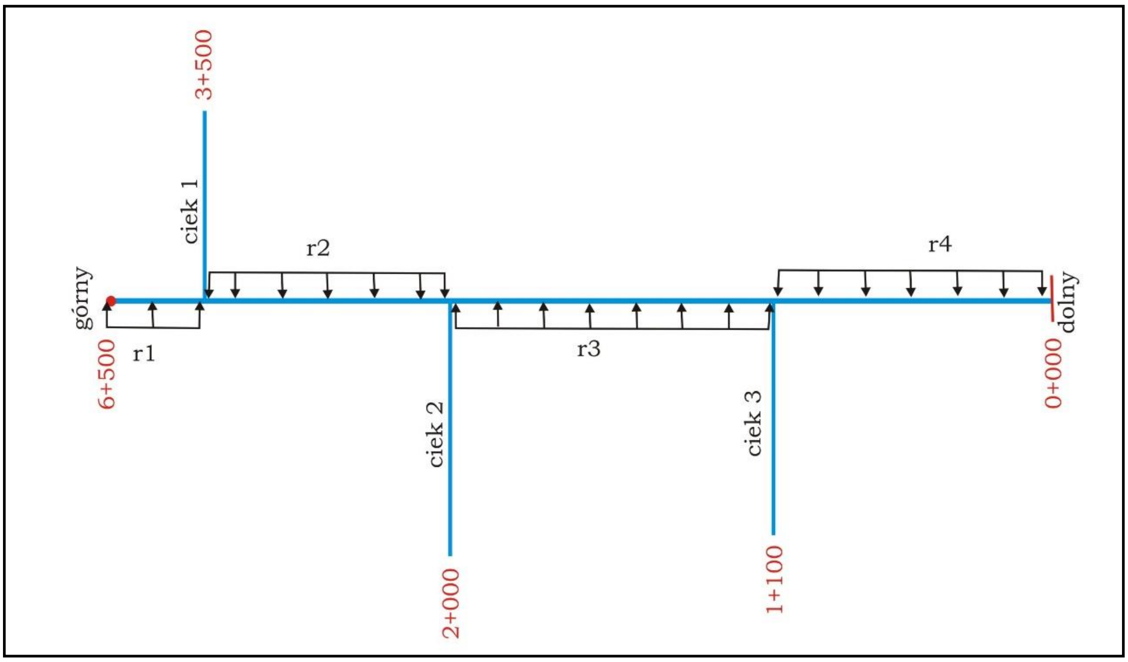


Figure 29: Diagram of a sample river network

Table 13: Example of boundary conditions

Section	Type of coastline conditions	Riverside	Chainage		Description of the condition
			top	bottom	
top	top	-	6+500		top

Section	Type of coastline conditions	Riverside	Chainage		Description of the condition
			top	bottom	
upper – watercourse 1 (r1)	distributed	L/P	6+500	3+500	upper – watercourse 1 (r1)
watercourse 1	concentrated	L	3+500		watercourse 1
watercourse 1 – watercourse 2 (r2)	distributed	L/P	3+500	2+000	watercourse 1 – watercourse 2 (r2)
watercourse 2	concentrated	P	2+000		watercourse 2
watercourse 2 – watercourse 3 (r3)	distributed	L/P	2+000	1+100	watercourse 2 – watercourse 3 (r3)
3 watercourse	concentrated	P	1+100		3 watercourse
watercourse 3 – lower (r4)	distributed	L/P	1+100	0+000	watercourse 3 – lower (r4)
lower (ordinate)	bottom	-	0+000		bottom

6.1.1.6. Calibration and verification

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

Calibration and verification shall be carried out using surge waves from at least two of the largest floods that have occurred in the last 30 years and have complete and reliable hydrological data. In the case of similar size of the floods, newer ones should be preferred, especially if flow conditions in a riverbed or valley have changed significantly. The data for the niches older than 10 years should be treated with caution or as an aid in the assessment of model performance.

Calibration and verification shall be carried out for controlled watercourses, i.e. those on which at least one signpost is located. Additionally the condition that the water gauges must be located on the section covered by the hydraulic model must be fulfilled.

At the calibration and verification stage, boundary conditions corresponding to uncontrolled (concentrated and distributed) tributaries should be iteratively prepared, taking into account the hydrological realities of the shape, size and time distribution of the individual waves.

Parameters to be analysed during the calibration and verification of the hydraulic model:

- Correlation coefficient (R);
- Special correlation coefficient (R_s);
- Total square error (CBK);
- Culmination error (ΔH_{max});
- Peak flow error (ΔQ_{max});
- Culmination shift (Δt_{max});
- Flood wave volume error (ΔV_{max}).

The correlation coefficient should be determined for states from the following formula, where: h_o – observed state, h_c – calculated state:

$$R = \frac{N\sum_{i=1}^{N} h_{o(i)} \cdot h_{c(i)} - \sum_{i=1}^{N} h_{o(i)} \cdot \sum_{i=1}^{N} h_{c(i)}}{\left\{\left[N\sum_{i=1}^{N} h_{o(i)}^2 - \left(\sum_{i=1}^{N} h_{o(i)}\right)^2\right]\left[N\sum_{i=1}^{N} h_{c(i)}^2 - \left(\sum_{i=1}^{N} h_{c(i)}\right)^2\right]\right\}^{1/2}}$$

The correlation coefficient should be determined for flows from the following formula, where: Q_o – observed flow, Q_c – calculated flow:

$$R = \frac{N\sum_{i=1}^{N} Q_{o(i)} \cdot Q_{c(i)} - \sum_{i=1}^{N} Q_{o(i)} \cdot \sum_{i=1}^{N} Q_{c(i)}}{\left\{\left[N\sum_{i=1}^{N} Q_{o(i)}^2 - \left(\sum_{i=1}^{N} Q_{o(i)}\right)^2\right]\left[N\sum_{i=1}^{N} Q_{c(i)}^2 - \left(\sum_{i=1}^{N} Q_{c(i)}\right)^2\right]\right\}^{1/2}}$$

Criterion for determining the compliance measures for the correlation coefficient:

- 0.95 < R ≤ 1.00 excellent
- 0.80 < R ≤ 0.95 very good
- 0.70 < R ≤ 0.80 good
- 0.60 < R ≤ 0.70 reasonable
- 0.00 < R ≤ 0.60 unsatisfactory

A special correlation coefficient shall be determined for states from the following formula, where: h_o – observed state, h_c – calculated state:

$$R_s = \left[\frac{2\sum_{i=1}^{N} h_{o(i)} \cdot h_{c(i)} - \sum_{i=1}^{N} h_{c(i)}^2}{\sum_{i=1}^{N} h_{o(i)}^2}\right]^{1/2}$$

A special correlation coefficient should be determined for flows from the following formula: Q_o – observed flow, Q_c – calculated flow:

$$R_s = \left[\frac{2\sum_{i=1}^{N} Q_{o(i)} \cdot Q_{c(i)} - \sum_{i=1}^{N} Q_{c(i)}^2}{\sum_{i=1}^{N} Q_{o(i)}^2}\right]^{1/2}$$

Criterion for determining compliance measures for a special correlation coefficient:

- 0.95 < Rs ≤ 1.00 excellent
- 0.85 < Rs ≤ 0.95 very good
- 0.70 < Rs ≤ 0.85 good

- 0.60 < Rs ≤ 0.70 reasonable
- 0.00 < Rs ≤ 0.60 unsatisfactory

The total square error should be determined for states from the following formula, where: h_o – observed state, h_c – calculated state:

$$CBK = \frac{\left[\sum_{i=1}^{N}\left(h_{o(i)} - h_{c(i)}\right)^2\right]^{1/2}}{\sum_{i=1}^{N} h_{o(i)}} \cdot 100\%$$

The total square error should be determined for flows from the following formula: Q_o – observed flow, Q_c – calculated flow:

$$CBK = \frac{\left[\sum_{i=1}^{N}\left(Q_{o(i)} - Q_{c(i)}\right)^2\right]^{1/2}}{\sum_{i=1}^{N} Q_{o(i)}} \cdot 100\%$$

Criterion for determining the compliance measures for total square error:

- 0.0 ≤ CBK [%] < 3.0 excellent
- 3.0 ≤ CBK [%] < 6.0 very good
- 6.0 ≤ CBK [%] < 10.0 good
- 10.0 ≤ CBK [%] < 25.0 reasonable
- 25.0 ≤ CBK [%] unsatisfactory

The culmination error should be determined for states as the difference of the ordinates between the maximum value of the calculated and observed hydrographs.

Criterion for determining the compliance measures for culmination error:

- 0 cm ≤ (ΔH_{max}) < 5 cm excellent
- 5 cm ≤ (ΔH_{max}) < 10 cm very good
- 10 cm ≤ (ΔH_{max}) < 15 cm good
- 15 cm ≤ (ΔH_{max}) < 20 cm reasonable
- 20 cm ≤ (ΔH_{max}) unsatisfactory

The peak flow error should be determined for flows as the difference between the maximum value of the hydrograph calculation and that observed.

Criterion for determining the compliance measures for peak flow error:

- 0% ≤ (ΔQ_{max}) < 3% excellent
- 3% ≤ (ΔQ_{max}) < 6% very good
- 6% ≤ (ΔQ_{max}) < 10% good
- 10% ≤ (ΔQ_{max}) < 25% reasonable
- 25% ≤ (ΔQ_{max}) unsatisfactory

The culmination shift should be determined for states as the time shift of the maximum value of the calculated and observed hydrographs:

Criterion for determining the compliance measures for the shift of culmination:

– $0\ h \leq (\Delta t_{max}) < 0.5\ h$ excellent
– $0.5\ h \leq (\Delta t_{max}) < 1.0\ h$ very good
– $1.0\ h \leq (\Delta t_{max}) < 1.5\ h$ good
– $1.5\ h \leq (\Delta t_{max}) < 2.0\ h$ reasonable
– $2.0\ h \leq (\Delta t_{max})$ unsatisfactory

The flood wave volume error should be determined for flows as the difference in the volume of the calculated and observed wave.

Criterion for determining the compliance measures for the flood wave volume error:

– $0\% \leq (\Delta V_{max}) < 3\%$ excellent
– $3\% \leq (\Delta V_{max}) < 6\%$ very good
– $6\% \leq (\Delta V_{max}) < 10\%$ good
– $10\% \leq (\Delta V_{max}) < 25\%$ reasonable
– $25\% \leq (\Delta V_{max})$ unsatisfactory

During the calibration for each criterion, the model must be rated "excellent", "very good" or "good".

For verification of each criterion, the model must be rated "excellent", "very good", "good" or "reasonable".

In justified cases (e.g. occurrence of ice phenomena, necessity to adapt the river network geometry depending on the flood, embankments failure, non-stationary dependence of traffic resistance on filling, poor quality of hydrological data) it is possible to accept a model which does not meet certain criteria after obtaining the consent of the Contractor. Justification for not meeting the calibration criteria should be included in the modelling report.

Examples of calibration and verification results are shown in Figures 30-33.

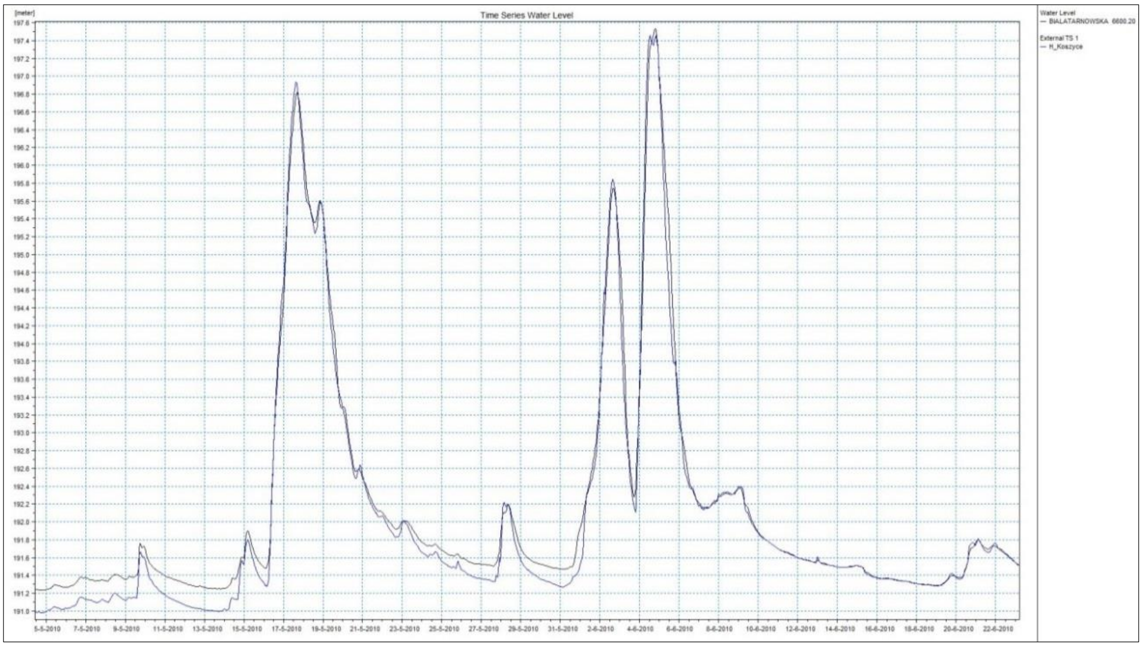


Fig. 30. Example of water level calibration results

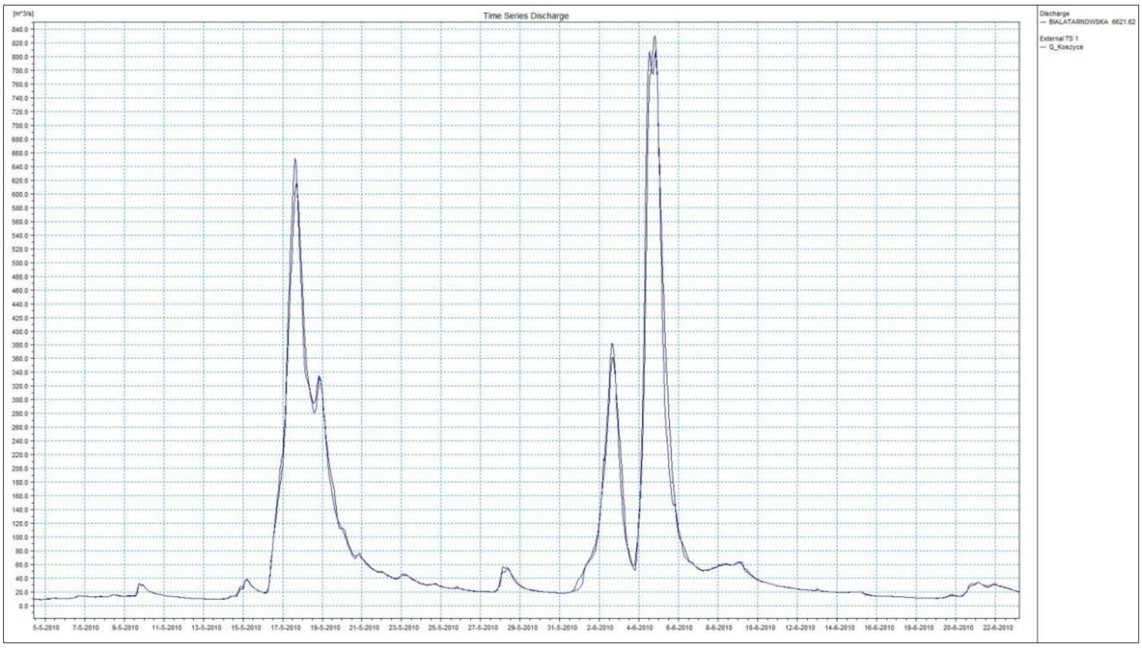


Fig. 31. Example of flow rate calibration results

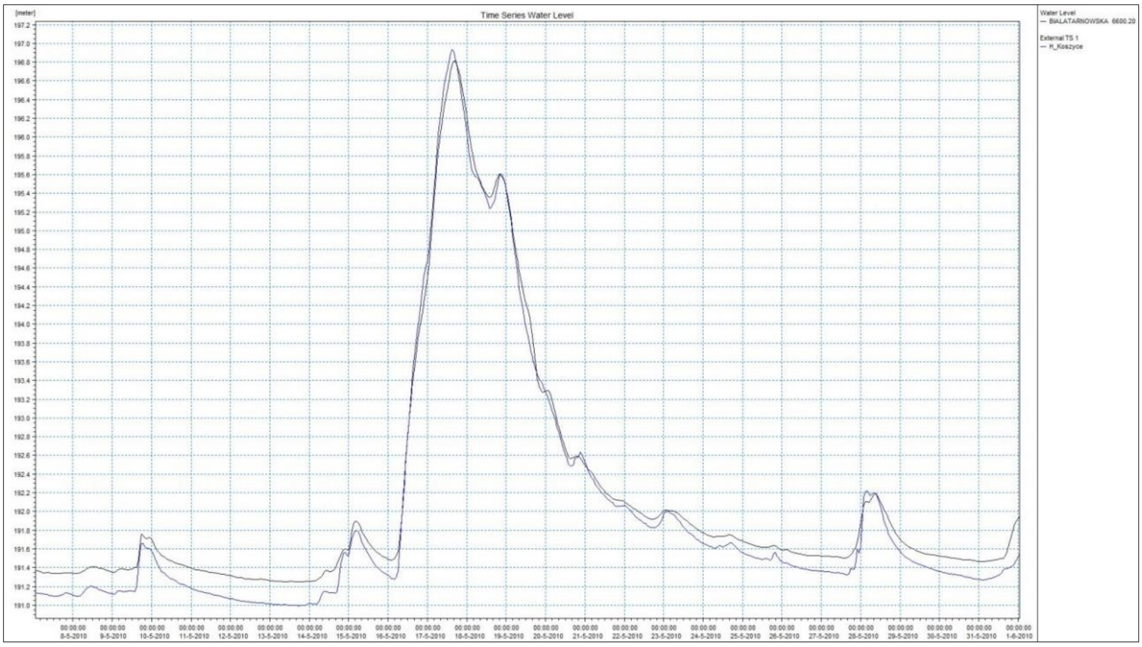


Fig. 32. Example of results of water level verification

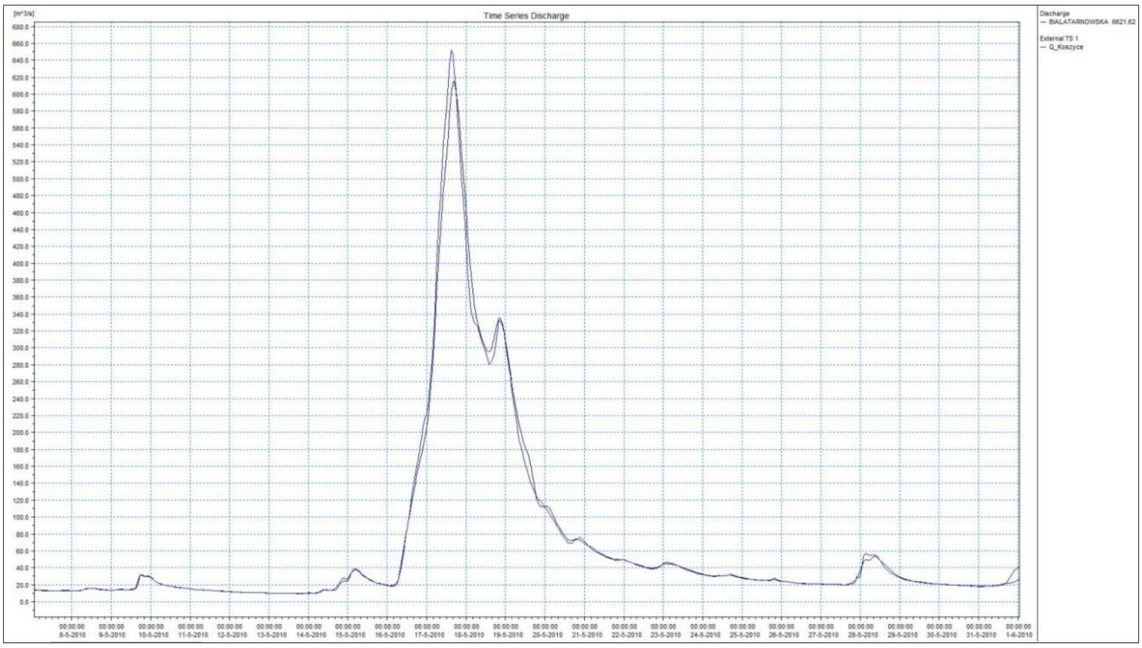


Fig. 33. Example of results of flow rate verification

At the model calibration stage, the cross-sections (valley sections) should be corrected, if necessary, by elongating them so that the start and end ordinates are higher than the maximum water level level obtained in the model.

6.1.1.7. Performing model calculations

With a calibrated hydraulic model, model calculations should be made for hypothetical waves with peaks corresponding to flows with a defined probability of exceedance.

At the model calculation stage, the necessary boundary conditions corresponding to uncontrolled (concentrated and distributed) inflows should be prepared, taking into account specific hydrological characteristics (shape, size and time distribution of individual waves). If a precipitation-drainage model has been developed for a given river, its results will be used as boundary conditions in relevant model scenarios.

The (valley) cross-sections shall be reviewed and, if necessary, lengthened so that the start and end ordinates are higher than the maximum water level level obtained in the model.

Once the calculations have been carried out, the resulting water level layout and flow distribution in the longitudinal profile of the river should be analysed to ensure that the results are correct and consistent for all analysed scenarios.

6.1.2. Methodology of two-dimensional 2D modelling

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) is performed for voivodeship cities and cities with poviat rights, as well as other cities with population over 100,000. However, the Regulation does not exclude the development of two-dimensional models in other areas.

An analysis and selection of the appropriate type of modelling (one-dimensional, two-dimensional, hybrid) should be carried out in areas other than those indicated above, with particular regard to the applicability of two-dimensional or hybrid modelling for:

- the estuaries of rivers to the sea;
- depressive areas, such as: Żuławy Wiślane, the area of seaside lakes and the vicinity of the Szczecin Lagoon and the Vistula Lagoon;
- river sections, where the schematization of river network in 1D model would be too complicated and labour-intensive, and the results of the one-dimensional modelling would be subject to a large error (based on a detailed analysis of the river and valley geometry, the layout of the main river network and its tributaries, as well as the location and layout of hydrotechnical and communication structures in relation to the riverbed) or river sections where, due to the width of the flood valley, the assumptions of one-dimensional traffic are not met;
- areas within the range of impact of mining subsidence (mining damage).

The concept of using the models on individual watercourses/sections of watercourses should be presented to State Water Holding Polish Waters for agreement together with the justification.

The classical two-dimensional model can be made for watercourses or sections of watercourses, where riverbed morphology and topography of flood terrains allow appropriate mapping in the calculative grid. The size of the calculative cell should be selected accordingly. Due to limited possibilities of implementation of hydrotechnical structures (e.g. weirs, culverts), it is suggested that classical two-dimensional models should be carried out in areas where such hydrotechnical structures are not present in significant numbers or do not significantly affect the level of flood hazard. Therefore classical two-dimensional models can be made in particular for estuarial sections of rivers that flow into the sea (floodplains, bays), for larger rivers or specific cases of smaller rivers, but with a higher grid resolution to ensure correct solutions.

The chosen model developed within the framework of this task is to enable the analysis of unsteady flow and to be based on the Saint-Venant equations: the mass conservation equation and the energy conservation equation. The hydraulic models will be developed and submitted in the MIKE 21 format by DHI (2011 or earlier), which is held by the Contractor and by the regional water management authorities of the recipient and downstream users of the models.

6.1.2.1. Development of a two-dimensional model

In order to develop the two-dimensional model accordingly, the necessary data for the calculation must be implemented. This concerns mainly: digital terrain model, roughness coefficients, initial conditions, boundary conditions and calculation parameters.

6.1.2.1.1. Preparation of a digital terrain model

The basic task during the development of a two-dimensional model is to prepare a digital terrain model, so that it correctly reflects the topographical variability of the entire area. When defining the model's range, it is necessary to determine the optimal size of the model and its resolution, which usually represents some compromise between accuracy and efficiency (time consuming) of calculations. It is necessary to ensure that the model range comprehensively takes into account factors that may affect the level of flood hazard (shape of the valley, tributaries, buildings, coastal conditions). The size of the model should always be determined in such way that its range allows for the correct modelling of all adopted flood scenarios.

In two-dimensional models, it is possible to use a digital terrain model of calculation rasters in the form of regular or irregular calculation grids. For two-dimensional modelling of fluvial floods it is suggested to use regular (raster) grids with appropriately selected size of the calculation cell and properly implemented structures, affecting the flood water flow conditions in river valleys. In the digital terrain model the structures influencing the flood water flow conditions should be taken into account. Care should be taken to select the appropriate resolution (in order to take into account important topographic elements and structures: embankments, banks, dikes, etc., which may affect the range of floodplains). During the implementation of individual structures, their impact on floodwater flow should be taken into account.

Two-dimensional hydraulic models, based on regular grids are sensitive to changes in grid resolution, which may result in different results [Horritta in. 2006]. On the other hand, grid size optimization is a necessary process to eliminate model instability or long calculation time. Height data reduction is also a useful process, when reducing the volume of data sets without losing their quality.

K. Bakuła [2014] in his doctoral dissertation analysed selected methods of quantitative reduction of altitude data from airborne laser scanning contained in digital terrain models in the GRID structure. The analysis was carried out in relation to the efficiency of processing and use in the process of hydraulic modelling.

Three groups of quantitative data reduction were applied:

1) changing the spatial resolution of the model;
2) integration of ALS data with the addition of discontinuity lines on the embankment top;
3) selection of important points (VIP algorithm, TPI algorithm, Z-tolerance algorithm).

The research was conducted under the conditions of MIKE FLOOD hybrid modelling in test areas located mainly in the southern part of Poland, but representing significant topographical diversity (Jasło city, Czarna Staszowska river basin, Nysa city, lowland area – a part of the Mazovian Lowland, low mountains). The analyses used diverse spatial resolution: 3 m, 5 m, 10 m and 20 m.

The results of the study indicate that it is not possible to apply quantitative data reduction through the selection of relevant points (point 3) for two-dimensional or hybrid modelling, based on regular calculation rasters. For this purpose, the best results were obtained by sampling the altimetric data (point 1) and by adding discontinuity lines on the embankment top (point 2). A similar procedure to create 2D/Flood models was also used in the first planning cycle. It can be carried out semi-automatically, but needs to be controlled by a GIS specialist and a hydraulic modelling specialist.

Therefore at the stage of preparing a 2D model it is extremely important to convert the digital terrain model (generalization) to the resolution adopted in the given 2D model. In this DTM implementation it is important to remember about the possibility of loss or distortion of some important data, such as embankment top ordinates, which obviously affect the range of floodplains.

Therefore, the digital terrain model should be properly prepared and verified by (Fig. 34, 35) updating line structures (sometimes point structures – water structures, bridges).
It is also necessary to include buildings in the 2D model. Two solutions are possible:

1) extracting buildings from the digital surface terrain model (DSTM) 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 $m^{1/3} s^{-1}$).

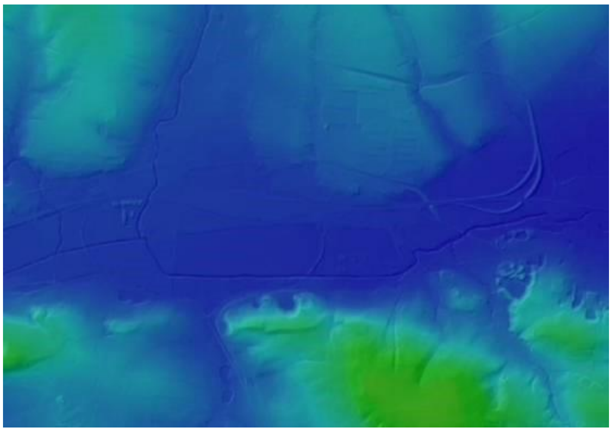


Fig. 34. Raw DTM image as a raster file

The next figure shows a digital model of the terrain with entered information about the objects (buildings, embankments).

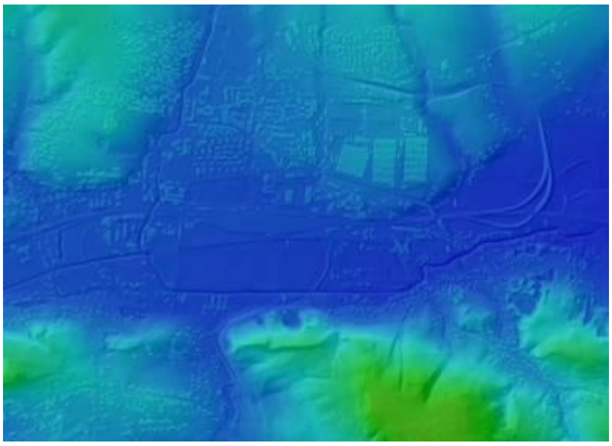
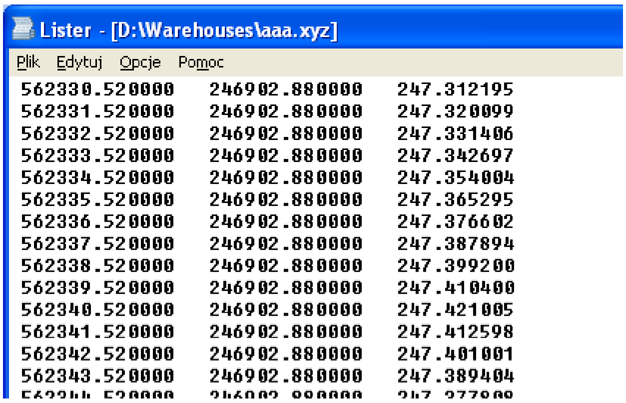


Fig. 35. Digital terrain model with entered information about objects (buildings) and structures (embankments, etc.)

The digital terrain model prepared in this way should be prepared in the form of *.xyz or *.asc files, where x-coordinate x in the PUWG 1992 system, y-coordinate y in the PUWG 1992 system, z-ordinate above sea level (Kronstadt 86) (Fig. 36).


Lister - [D:\Warehouses\aaa.xyz]
Plik Edytuj Opcje Pomoc

```
562330.520000   246902.880000   247.312195
562331.520000   246902.880000   247.320099
562332.520000   246902.880000   247.331406
562333.520000   246902.880000   247.342697
562334.520000   246902.880000   247.354004
562335.520000   246902.880000   247.365295
562336.520000   246902.880000   247.376602
562337.520000   246902.880000   247.387894
562338.520000   246902.880000   247.399200
562339.520000   246902.880000   247.410400
562340.520000   246902.880000   247.421005
562341.520000   246902.880000   247.412598
562342.520000   246902.880000   247.401001
562343.520000   246902.880000   247.389404
```

Fig. 36. Format of a sample .xyz file for a calculation raster

6.1.2.1.2. Determination of the roughness coefficient

The basic parameter describing the flow resistance is the roughness coefficient. This coefficient is determined spatially (two-dimensionally) for the modelled area. It is determined separately for the specific riverbed and for floodplains, taking into account the variation in land cover.

The determination of roughness coefficients in two-dimensional models shall be carried out in the same way as for one-dimensional modelling. Based on the Topographical Object Database (BDOT10k) and DTM for the area to be modelled, zones/classes of land cover should be determined and assigned coefficient values. In the first stage the polygons with different roughness coefficient values should be separated (Fig. 37), and then a raster file of roughness coefficients created (Fig. 38).

Fig. 37. Image of polygons with different values of roughness coefficient

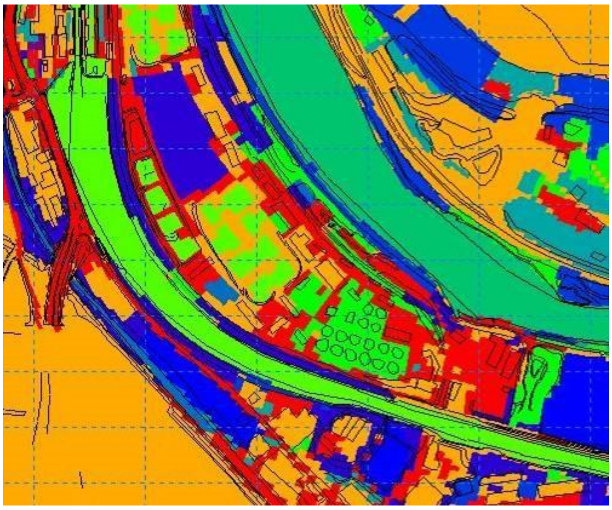


Fig. 38. Roughness factor raster file

The raster file should be saved in the format *.xyz or *.asc, where x-coordinate x in PUWG 1992, y-coordinate y in PUWG 1992, z-value of the roughness coefficient.

6.1.2.2. Determination of boundary conditions

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

Boundary conditions should be prepared for model calibration and verification, as well as calculations of possible water scenarios with probabilities of exceeding p = 10%, p = 1%, p = 0.2%. The basis for the construction of flood scenarios should be hypothetical waves, whose culmination corresponds to the value of flows with a certain probability of occurrence. The boundary conditions for the calibration and verification of the model for controlled watercourses should be prepared on the basis of hydrographs of selected historical calls.

For modelled watercourses it is necessary to develop values of flows constituting upper boundary conditions (Q), distributed flows (Qr), taking into account the increase of the catchment area size; introduce as concentrated inflows (Qs) the watercourses which are not included in the modelling but may influence the wave transformation; and introduce values of control flows in water gauge cross-sections (Qw), according to Figure 21 (Chapter 6.1.1.1) on which a diagram of an exemplary river network is presented.

Before implementing boundary conditions, the boundaries of the model should be defined accordingly. For closed model boundaries, i.e. boundaries where no transfer will occur, a pixel value equal to the “land value” should be established. For open model limits, i.e. limits where water transfer will occur (for upper and lower boundary conditions), the pixel value should be determined in accordance with the watercourse/reservoir bathymetry and/or terrain shape (Fig. 39).

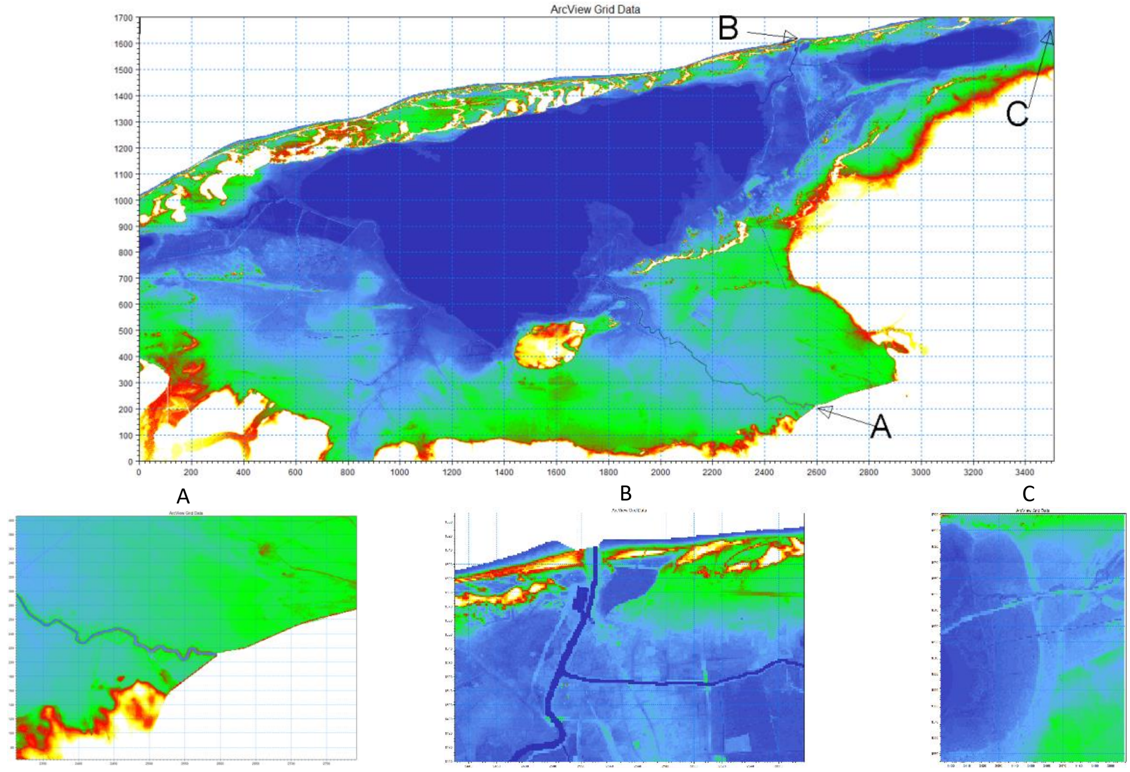


Fig. 39. Definition example: A) open border for upper boundary condition, (B) open border for the lower boundary condition, (C) closed border

Upper boundary conditions (Q), distributed flows (Qr) and concentrated flows (Qs) should be entered into the model using the options available in the 2D model. For this purpose, the flow implementation option for predefined open limits of the model (Fig. 40A) or the option to implement the flow in the form of point inflows “source” (Figure 40B) should be used. The lower boundary condition closing the network of the riverbeds, depending on the modelling assumptions, may be a hydrograph of water ordinates (in estuary sections) or a constant value of the water ordinate, e.g. for rivers that enter the sea an average sea level should be taken as the lower boundary condition. For this purpose a hydrograph or a fixed water ordinate value for a predefined open model limit should be adopted.

Boundary

Boundary 1 : (2529,1612) - (2531,1612)			
Formulation:	Flux	...	
Type 0 data file:	.dfs0	...	View
FAB type:	12	...	
No tilting	0	...	
No user defined flow direction		...	View

A)

Source Sink	Type	Magnitude	Velocity	Outlet Dir.	File name	Item Name Magnitude	Item Name Velocity		
1: (2595,210)->	From file	0.000000	0.000000	90.000000				...	View
2: (2595,211)->	From file	0.000000	0.000000	90.000000				...	View
3: (2595,212)->	From file	0.000000	0.000000	90.000000				...	View

B)

Fig. 40. Example of flow implementation: A) for previously defined open limits of the model, B) in the form of point tributaries

A summary of boundary conditions shall be prepared in accordance with Table 13 (Chapter 6.1.1.5). Some boundary conditions can only be determined iteratively only at the stage of calibration, verification and model calculations. The boundary conditions that can be determined on the basis of the developed hydrological data should be prepared as *.dfs0 files.

6.1.2.3. Calibration and verification

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

6.1.2.4. Performing model calculations of flood scenarios

Calculations with the two-dimensional model should be made for hypothetical waves with peaks corresponding to flows with a defined probability of exceedance.

For the area of two-dimensional calculations, the result will be 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 more than 100,000 inhabitants). The results should be attached in raster files in *.dfs2 format.

6.1.3. Methodology of 1D/2D hybrid modelling

For areas indicated for two-dimensional modelling, according to the Regulation, hybrid models (1D/2D) consisting of a one-dimensional model for watercourse beds and a two-dimensional model for floodplains from natural watercourses and canals can be made.

The selected model developed within the framework of the task in question is to enable the analysis of unsteady flow and to be based on the Saint-Venant equations – the mass preservation equation and the energy preservation equation. The hydraulic models will be developed and delivered in the format of the MIKE FLOOD software (including the one-dimensional model in MIKE 11 and the two-dimensional model in MIKE 21) by DHI (2011 or earlier), which is owned by the Contractor and the regional water management authorities who are the recipients and downstream users of the models.

6.1.3.1. Preparation of one-dimensional 1D models for 1D/2D hybrid modelling

In order to develop a hybrid model, previously developed one-dimensional hydraulic models can be used, in particular for voivodeship cities and cities with poviat rights, as well as other cities with population over 100,000.

The main assumption of preparing one-dimensional models for the needs of hybrid modelling is to limit the scope of its calculations. In the one-dimensional part of the hybrid model, the range of the calculation cross-section should be limited to the watercourse (to the upper edge of edge slopes) or – in the case described in chapter 6.1.3.3 – to the top of flood embankments (Fig. 41).

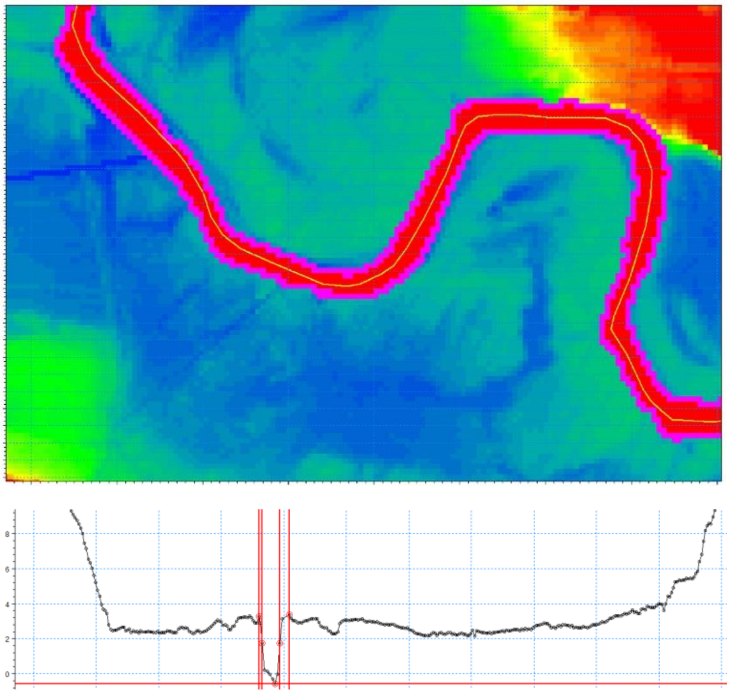
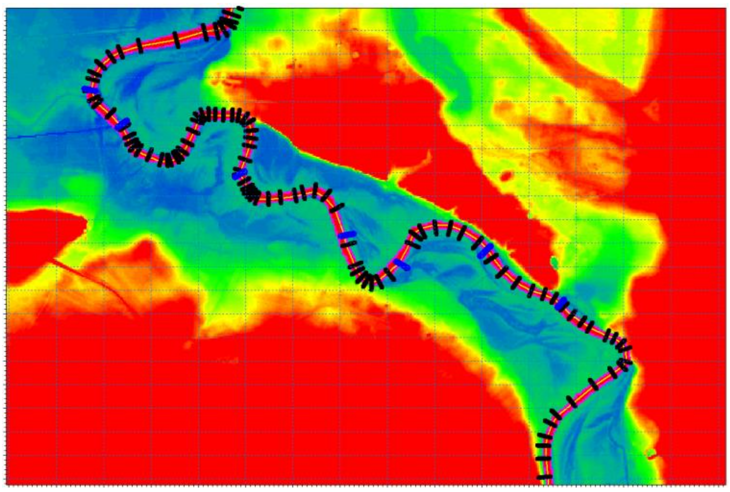


Fig. 41. Example of limiting the range of one-dimensional calculations to the upper edge of edge slopes

In one-dimensional models the distances between cross-sections should not exceed 50 m (this can be achieved by densities based on the interpolation algorithms included in the modelling software) (Fig. 42). At the same time, on the basis of an analysis of the correctness of model calculations, it is possible to locate cross-sections at a distance of more than 50 m at the stage of “condensing” the cross-sections in the one-dimensional model.



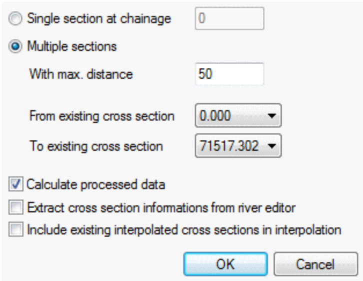


Fig. 42. Example of condensing the cross-sections

6.1.3.2. Development of two-dimensional models

The development of a two-dimensional model being a component of a hybrid model should be done in a similar way to the classical version of the two-dimensional model.

For a two-dimensional model as a part of a hybrid model, it is necessary to take care of the proper definition of the model boundaries and exclusion from the calculation of the area to be mapped in the one-dimensional model (Fig. 43).

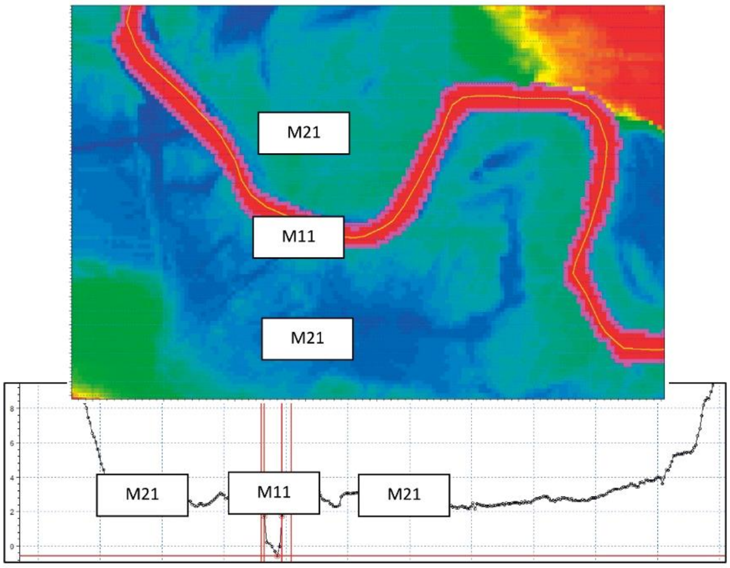


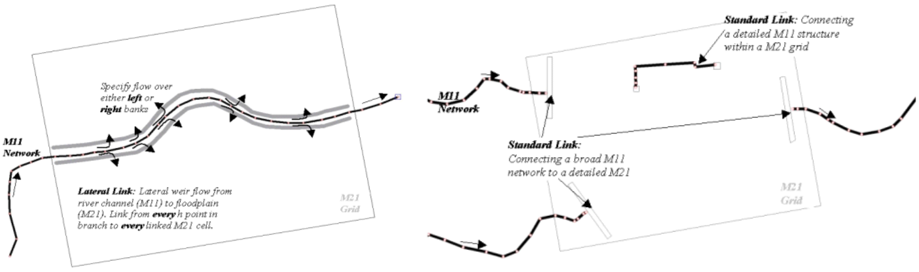
Fig. 43. Example of excluding the range of one-dimensional calculations from calculations in a two-dimensional model

6.1.3.3. Combination of one-dimensional and two-dimensional models

The two-dimensional model as a part of the hybrid model shall be combined with the one-dimensional model. For this purpose, a parallel (lateral) connection should be used, which is based on the use of connections parallel to the riverbed, operating on the principle of wide-top side overflows with an ordinate fixed at the height of the edges (possibly a top of embankments or similar structures) (Fig. 44). The area between the riverbed edge and the embankment is taken into account in the two-dimensional model, when it is possible to depict on a map at least few symbols representing the directions of water flow in the width of this area (see 6.2.8.).

On the calculative raster of a two-dimensional model, cells that will reflect the calculation area of a one-dimensional model should be eliminated from the calculation in order to avoid duplicate calculations (both in the one-dimensional model and the and two-dimensional).

In justified cases, including in particular estuarial sections of rivers flowing into the sea (bays, floodplains), standard connections based on the use of wide overflows located perpendicularly to the river valley are also allowed with ordinates consistent with the valley cross-section (Fig. 44).



AB

Figure 44: Connection diagram of one-dimensional and two-dimensional models in hybrid software: A – parallel connection (lateral), B – standard connection (MIKE 2011 technical support)

6.1.3.4. Determination of boundary conditions

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

6.1.3.5. Calibration and verification

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

6.1.3.6. Performing model calculations of flood scenarios

Calculations with the hybrid model should be made for hypothetical waves with culminations corresponding to 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) shall be presented in shp files containing states and flows. For the area of two-dimensional calculations, the result will be 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). The results should be attached in raster files in *.dfs2 format.

6.1.3.7. List of model files

The hydraulic model should be submitted in a format that allows the modelling process to be started and repeated, thus containing all elements of the model in the form of appropriate files:

Model element/Data	File type	Model type
1D model design	*.sim11	1D
2D model design	*.m21	1D; 1D/2D
Hybrid model design 1D/2D	*.couple	1D/2D
River network	*.nwk11	1D; 1D/2D
Cross-sections	*.xns11	1D; 1D/2D
Boundary conditions	*.bdn11	1D; 1D/2D
Time series of boundary conditions (flows, states)	*.dfs0	1D; 2D; 1D/2D
Hydrodynamic parameters	*.hd11	1D; 1D/2D
Bathymetry	*.dfs2	2D; 1D/2D

Roughness	*.dfs2	2D; 1D/2D
DWSM (initial condition)	*.dfs2	2D
“Hotstart” file (if applicable)	*.res11	1D; 1D/2D
Results of 1D model	*.res11	1D; 1D/2D
Results of 2D model	*.dfs2	2D; 1D/2D

All files shall be compiled in an appropriate unified file structure and nomenclature of files and directories (separate for each file type), allowing for an easy access and comprehensible overview of models. The data making up the hydraulic models for each river section should cover all modelled scenarios.

6.2. PROCESSING OF MODELLING RESULTS AND DETERMINATION OF FLOOD HAZARD AREAS

The results of 1D and 2D hydraulic modelling in the form of water level ordinates form the basis for designating flood hazard areas and depth zones in the actual river valley formation. Flood hazard areas and depth zones are determined using GIS software. A detailed description of the procedure for their creation includes the following steps:

- Generating a Digital Water Surface Model (DWSM) and water depth raster.
- Verification of water depth raster.
- Designation of flood hazard areas and depth zones.
- Arrangement of flood hazard areas at the interfaces of modelling areas.
- Final verification of water depth zones and flood hazard areas.

According to the Regulation, in the case of cities which are the seat of the voivodeship self-government authorities or a voivode, cities with poviat rights and other cities with a population of more than 100,000 the additional measures are taken for scenarios I-III:

- Generating flow rate raster.
- Determining flow velocity zones.
- Developing water flow direction vectors.

6.2.1. Generating a digital water surface model and water depth raster

Flood hazard areas and water depth zones are determined on the basis of the results of 1D and 2D hydraulic modelling, i.e. water level ordinates.

In the case of 2D modelling, the results are in the form of DWSM raster, depth raster and flow rate raster; in this form they can be further processed in GIS systems.

In case of 1D modelling, the result is tabular data presenting the ordinates of the water level in the calculation cross-sections. This data is reduced to a format supported by GIS systems, i.e. linear layers with an assigned water level ordinate value. Then, in order to obtain a two-dimensional plane with continuous information about the ordinate of the water level (i.e. DWSM raster), an interpolation is performed. TIN interpolation is recommended. It is controlled by appropriate cross-section densities and selection of cross-section lengths to determine its spatial range. This allows to take into account, in the process of DWSM generation, linear objects separating the main riverbed from floodplains, which most often have different water level ordinates.

In the next step, by subtracting the digital terrain model (DTM) from the DWSM and rejecting values smaller than zero, a water depth grid is generated (Fig. 45).

DWSM raster from a two-dimensional model has different resolutions, depending on the adopted resolution of the hydraulic model (from 2 to 10 m, or in special cases – lower resolution, i.e. up to 15 m). The standard resolution of the DTM used is 1 m. If there is a big difference in the resolution of DWSM and DTM, the following procedure is used to obtain a depth raster with a resolution of 1 m and with preserved edge details: (i) before cutting, the DWSM raster shall be enlarged by two pixels where the calculated values meet empty cells and new pixels shall be extrapolated from the values of adjacent pixels; (ii) a rounded vector mask shall be created from the original raster to limit the area where the cutting operation will be performed; (iii) the enlarged DWSM raster shall be cut by DTM (Fig. 46).

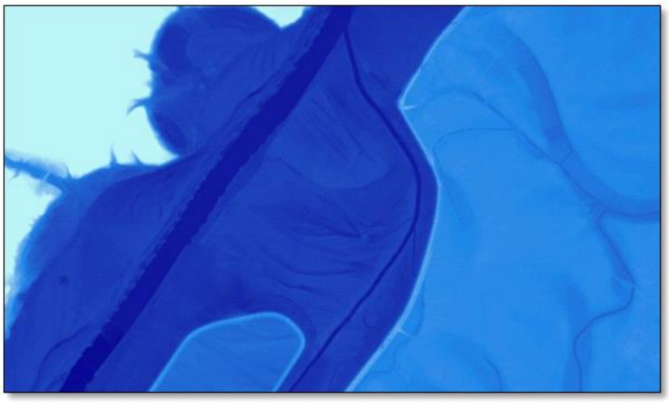


Fig. 45. Water depth raster

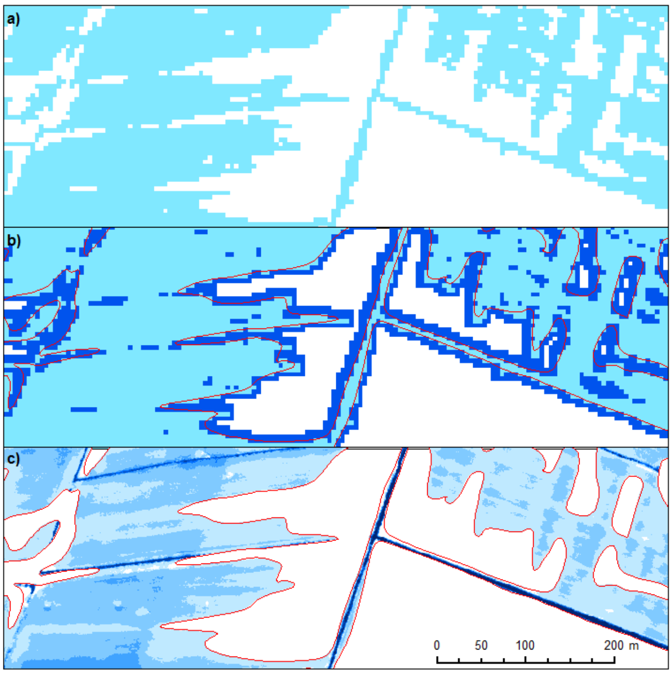


Fig. 46. Process of generating the water depth raster from the result of a two-dimensional model; a) raw ZW raster, b) raw ZW raster, ZW raster increased by 2 px, mask limiting the area of subtraction operation (red line), c) water depth raster against the background of the mask

6.2.2. Verification of water depth raster

In case of depth raster obtained from the results of 1D modelling it is necessary to analyse it on the basis of orthophotomap, DTM (shaded relief) or topographic map. The irregularities found require correction.

Initially, the verification of water depth raster is carried out by analysing and eliminating the identified errors in the form of: anomalies in DTM (e.g. unremoved layer of vegetation), areas not directly connected to the stream in the riverbed – e.g. in the case of backwater (e.g. in an old riverbed), a constant ordinate of water level equal to the ordinate in the place where the old riverbed connects with the main river is introduced (Fig. 47). It is also possible to correct the model network schematization and to repeat hydraulic calculations.

In the next step, the water depth grid is reclassified to four depth classes (Fig. 48), as indicated in the Regulation (0-0.5 m; 0.5-2 m, 2-4 m; over 4 m). The result of the reclassification is automatically generated in order to remove noise from the raster image using appropriate filters. This allows the elimination of smaller, irrelevant (1:10,000) objects in each depth class. Thus, the capacity of the data set is also reduced.

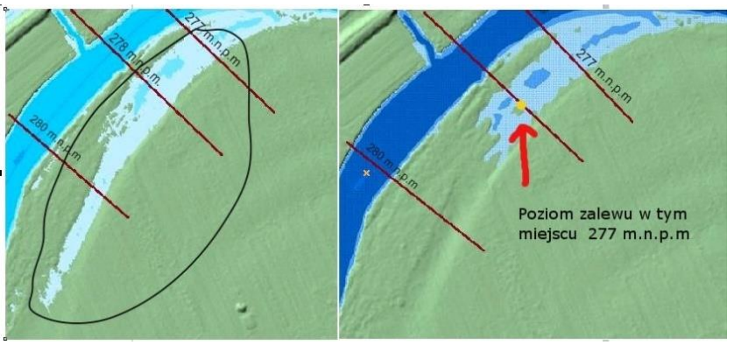


Fig. 47. Example of verification of floodplain areas for the case of backwater in an old riverbed

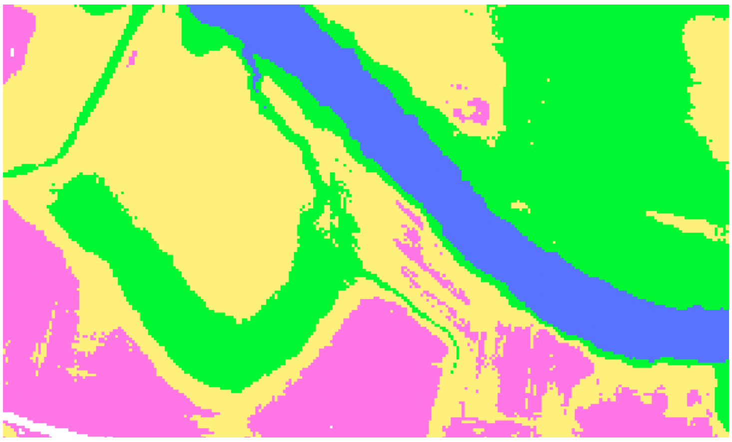


Fig. 48. Water depth raster after reclassification to 4 classes

Finally, a smoothing (two times) of the water depth raster is performed (generalisation in the range of raster data), consisting in removing so-called noise from the raster images after classification by means of a majority filter (Fig. 49). A method is used to find single pixels with an outlier value and then assign them the values of most of the adjacent pixels. This helps to get rid of the so-called "salt and pepper" effect characteristic for classified raster images, i.e. the occurrence of single, dispersed pixels in the image.

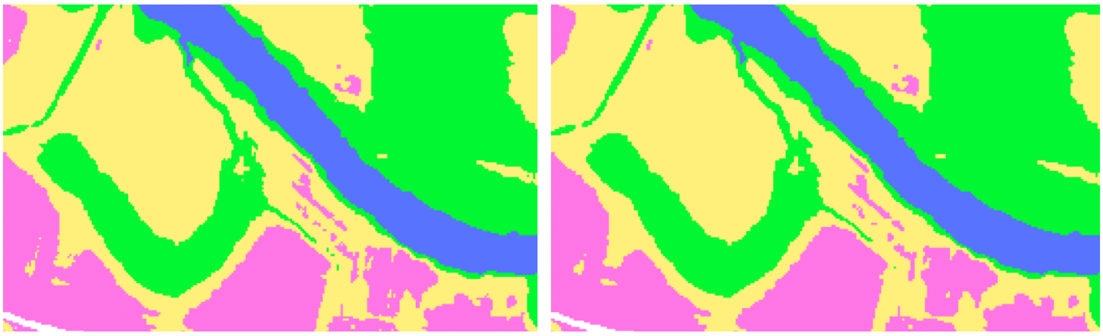


Fig. 49: Depth of water raster with one (left) and two (right) smooths with the ArcGIS Majority Filter

In the procedure of developing flood hazard areas, 4 neighbouring pixels are taken into account. In this case (quadruple neighbourhood) only those pixels that are surrounded by three or four pixels of equal value change the value (Fig. 50).

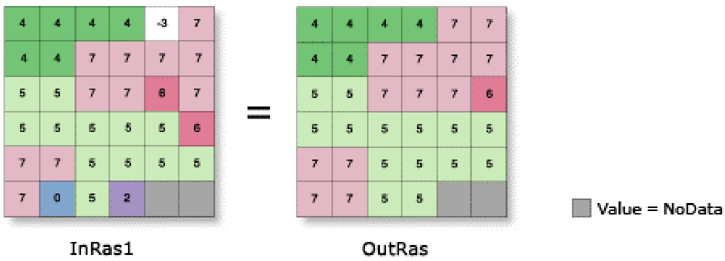


Fig. 50. Example of smoothing using a majority filter for the quadruple neighbourhood option [source: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009z00000037000000.htm]

6.2.3. Determination of flood hazard areas and depth zones

By converting the water depth raster (at the external borders of the individual depth classes) into a vector form, using the preliminary algorithm of edge smoothing, working depth fields are obtained. Their outer envelope is the preliminary boundary of the flood hazard area. At this stage, changing the coordinates of points on the line it deviates from the original external borders of the raster by half the diagonal of the pixel of the input file, i.e. about 0.7 m (based on the analysis of the results obtained). The obtained water depth zones are characterized by sharp edges and a large number of artifacts (e.g. triangles in single pixel locations) (Fig. 51).

These polygons are subject to further topographical verification, consisting of visual inspection of the created flood zone and the process of rejection of areas that do not have a hydraulic connection with the main riverbed (Fig. 52). In case of ambiguous/problematic sites (e.g. large floodplains resulting from a narrow/shallow area of overflow of water through some hollow in the field), a decision is made to leave or reject them by means of verification of the result by specialists. They will determine the most probable scenario using DTM, orthophotomap, topographic map, hydrodynamic model analysis, as well as knowledge and experience. These analyses may also result in a decision to change the model and recalculate the scenario.

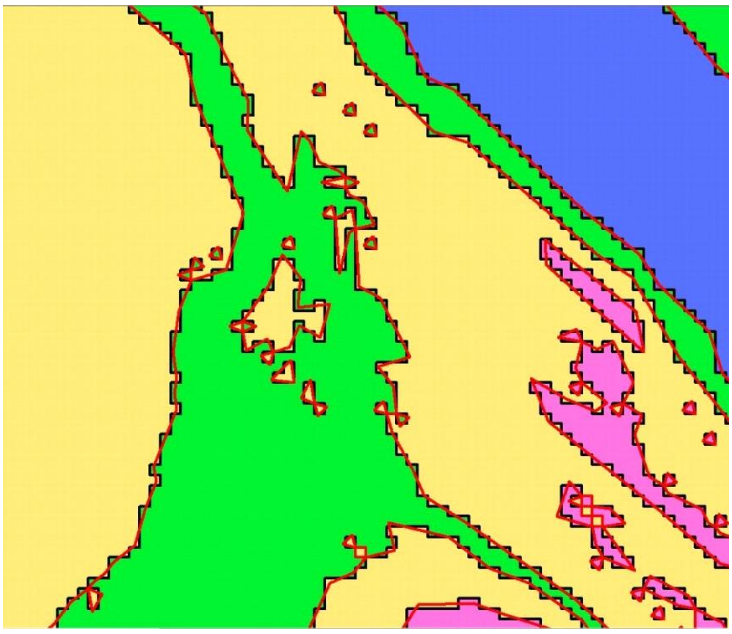


Fig. 51. Field layer after conversion from raster (black line) and after initial smoothing (red line)

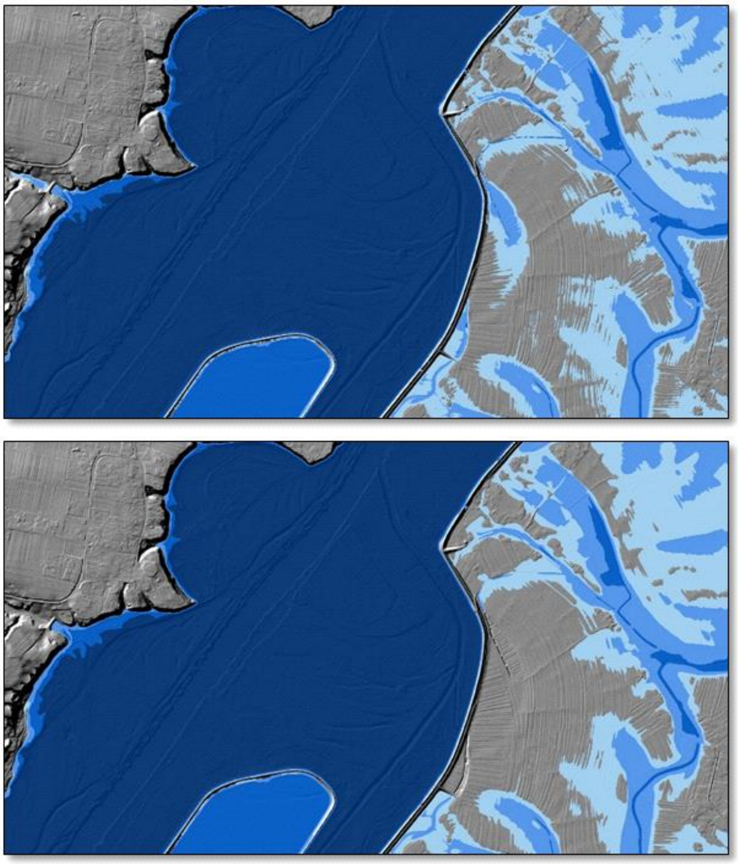


Fig. 52 Working (at the top) and verified smoothed depth polygons

Similarly, the hazard areas resulting from water overflowing through embankments are analysed (in the basic scenarios). An additional help in this case is the analysis in the river network GIS environment used in the 1D model, in particular the layer of hydraulic connections and additional run-off routes. The analysis of the maximum flow values at individual hydraulic connections allows to make a decision on whether or not a given fragment of the zone should be classified as an actual flood hazard area. For example, areas which, as a result of GIS analyses, theoretically indicate the overflow may be rejected when both the width and depth of the potential overflow and the flow value at this point are very small.

Further verification is aimed at the elimination of small polygons (vector data generalization) from water depth classes. Fields with an area of less than 400m² are aggregated to adjacent, larger fields. In case of lack of a neighbour, the field which does not meet the surface criterion is removed. A similar approach is used for small (less than 400 m²) "holes" and "islands" within the depth classes.

In addition, the possibility of complementing flood hazard areas in planned polders is accepted. These locations are reported by the respective RZGW.

The next step is to simplify the geometry of the depth and flood hazard areas. This way "teeth" and "loops" structures are eliminated. The edge of the polygon is smoothed in order to eliminate the effect of sharp line bends. Subsequently, the depth zones are generalised. The generalization parameters are selected in such way as to limit the size of vector data while maintaining the data quality, bearing in mind the purposes for which maps are used (e.g. planning and land use).

Generalization of depth polygons in order to reduce the size of files and the number of vertexes is done using the ET Geowizard – Generalize Polygons tool with a parameter of 0.5 or using the Simplify Polygons tool. Thus, the following parameters are reduced for the depth polygons compared to cycle I:

- Shapefile file size: reduction of 78%;
- Database file size: 74% reduction;
- Vertex number: 80% reduction.

The depths of the polygons shall be maintained at a scale of 1:1000, and the maximum deviation from the corresponding first cycle fields shall not exceed 0.5 metre. Next, the area of the riverbed is cut out of the smoothed depth polygons with a mask representing the range of still and flowing waters during normal hydrological conditions (surface water layer from BDOT10k).

Finally, as the outer envelope of the depth zones in a given scenario, a flood hazard area is generated.

6.2.4. Connecting flood hazard areas at the interfaces of modelling areas

Compatibility at the interfaces of the modelling areas is to be ensured primarily by hydrodynamic modelling, through the correct and consistent adoption of water level ordinates at model boundaries as boundary conditions and the transfer of these ordinates between models. In addition, the structure of the river network and the links of its elements should best reflect the real continuity of the water level.

At the stage of analysis of the results of 1D modelling in the GIS environment, when a part of the zone separated from the main riverbed is connected by a field obstacle, such as embankment or dike, "masks" determining the range of a separate area should be used, when generating the DWSM raster (Fig. 53). When combining 1D and 2D modelling, the interpolation in the 1D model should be performed after adding points at the contact with the 2D model with an assigned value of the water level ordinate from the 2D model, in order to ensure a smooth connection.

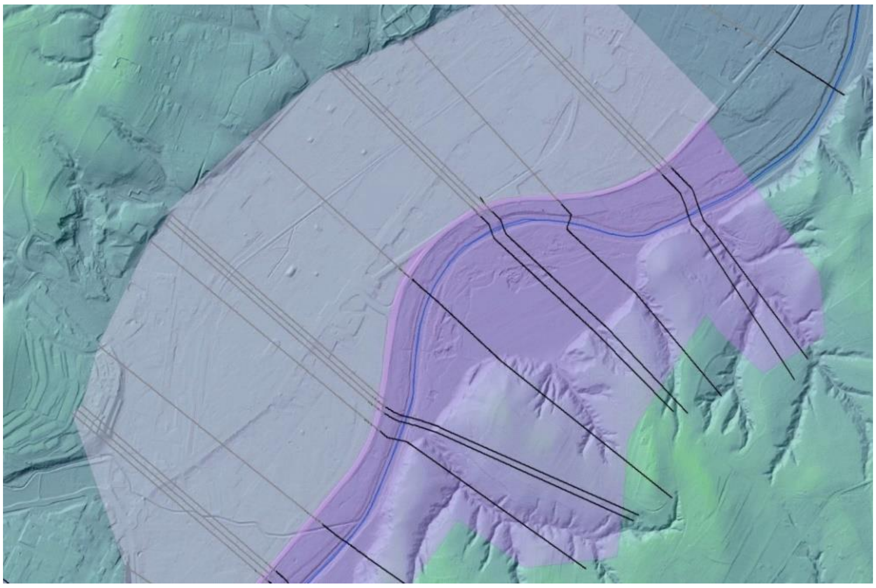


Fig. 53. Example of defining masks determining the maximum range and zone of connecting two DTSMs; the masks are connected in the area of road embankment, it separates zones with separate ordinates of water levels

In the case of reconciliation of flood hazard areas at the junction of 1D modelling areas for inflow and receiver, it is recommended to develop first of all DWSM rasters and depth for the receiver. Next, the interpolation of water level ordinates for the inflow should be made, including ordinates of DWSM raster of the receiver from an accepted border (edge) of its zone (Fig. 54). When interpolating the ordinates of the water level for the inflow, its cross-sections within the range of the receiver's zone (below the assumed limit) should be omitted. In each case, the determination of this limit should be considered individually. In the absence of a clear backwater or when the ordinates of the inflow water level up to the outlet are higher than the ordinates of the receiver (which may occur in mountain areas), this limit should run parallel to the receiver, while its course should be determined by a specialist as the most probable limit of the range of influence of the receiver on the inflow (Fig. 55).

The method described above allows for a continuous combination of the DWSM raster and inlet depth and receiver and allows for the same ordinate values of the water level and depth at their contact. The agreed inflow and recipient rasters will be finally divided according to the flood hazard areas assigned to each river (for inflow the area should also include the estuary section of the river).

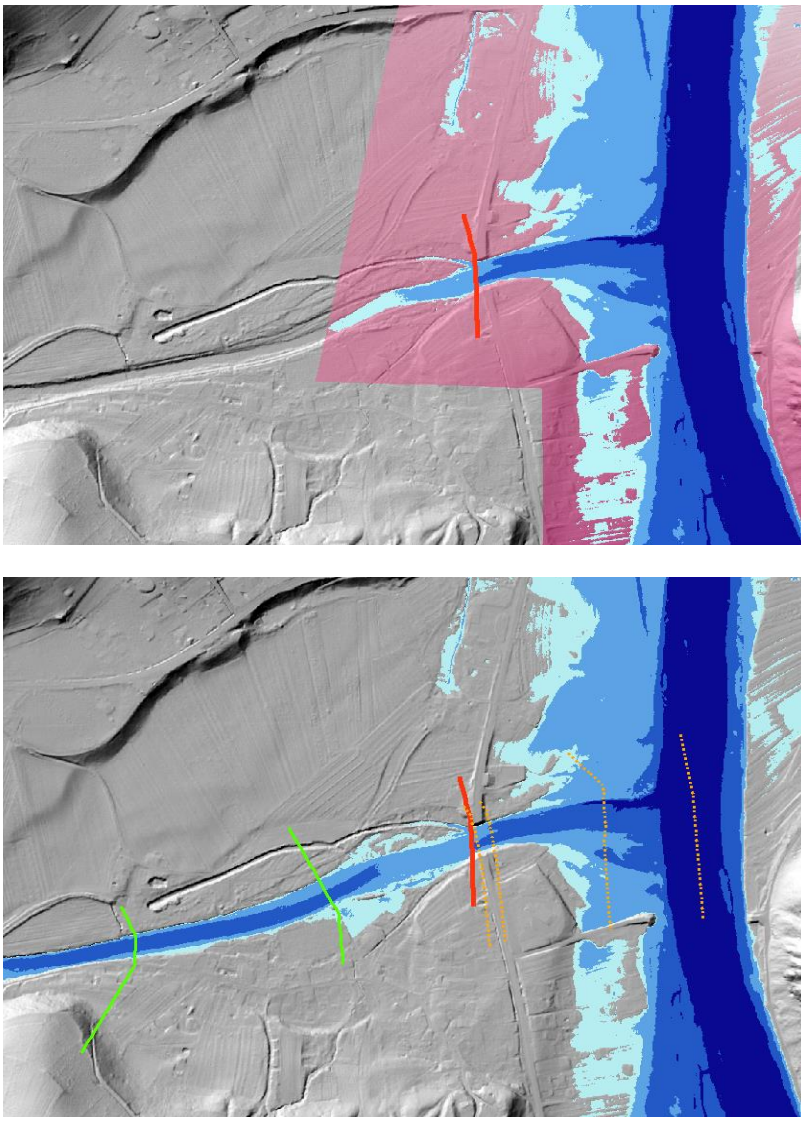
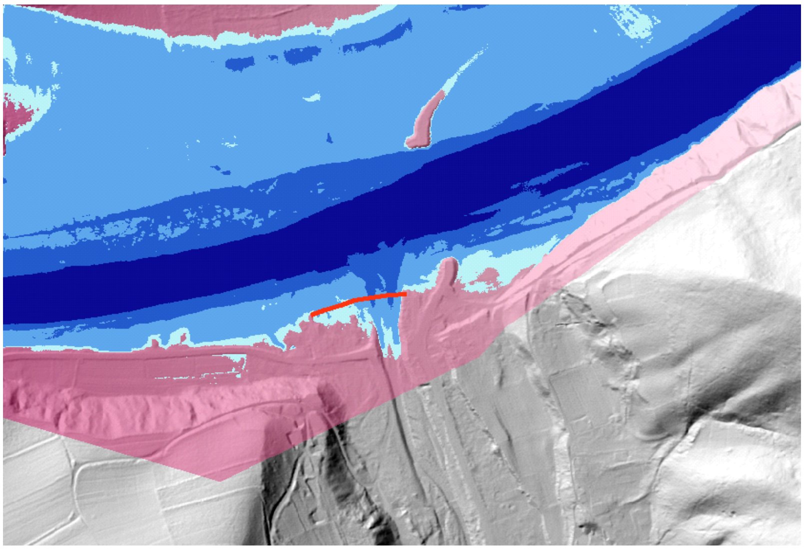


Fig. 54. Top: depth and DWSM rasters of the receiver and the backward range forming the boundary of the receiver zone (red line), to which the ordinates of the inflow water level are interpolated; bottom: inflow cross-sections: included in the interpolation (green lines) and not included in the interpolation (orange dashed lines); generated for the inflow rasters by interpolation to the adopted boundary have the same values at the contact as the recipient rasters



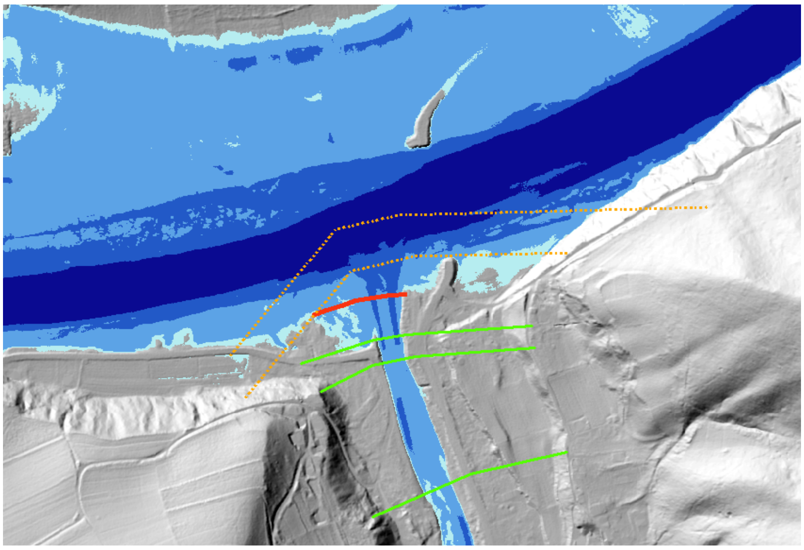


Fig. 55. Top: depth and DWSM rasters of the receiver and the accepted border of the receiver zone (red line), to which the inflow water level ordinates are interpolated; bottom: inflow cross-sections: included in the interpolation (green lines) and not included in the interpolation (orange dashed lines); generated for the inflow of the raster by interpolation to the adopted border have the same values at the contact as the recipient rasters

In case the receiver developed in the first planning cycle will not be updated within the framework of the aMZPiMRP project, the following method will be used. The solution adopted corresponds to a situation in which at the moment of hypothetical wave culmination at the mouth of the tributary, in the main river (recipient) there are water states caused by the flow with the same probability as the modelled probability. The process associated with model calculations at the tributary should be carried out taking into account the following aspects:

1) The river is modelled up to the mouth, i.e. up to kilometre 0 (not to the point where the modelled river flows into the floodplain of the recipient). The modelled river network does not include the main river (recipient);
2) The lower boundary condition is the ordinate of the water level calculated by modelling the main river (on the basis of calculations carried out in the first planning cycle for the same probability, in the cross-section corresponding to the location of the modelled inflow outlet). If necessary, the value of the ordinate of the water level is obtained from the interpolation of the results from the adjacent sections;
3) On the section under the direct influence of the receiver (e.g.: in the interval of the receiver; within the range of the receiver's backwater), the model is built in a simplified way, full schematization is not performed. The cross-sections may not take into account the full width of the valley, but the assumed cross-section width should limit the possibility of throttling the flow;
4) In the case when the ordinates obtained as a result of inflow modelling were larger than the ordinates of the recycling water catchment area, the respective cross-sections should be extended;
5) The compatibility of the developed floodplains with the existing recipient floodplains should be achieved with GIS tools, extending the recipient floodplains upstream with a constant ordinate.

Due to the complexity of the problem and the possible complications resulting from, among other things, different approaches to modelling of embankments or the occurrence of hydrotechnical objects, it is possible to apply other solutions, taking into account the results of modelling on the river tributaries developed in the first planning cycle.

6.2.5. Final verification of water depth zones and flood hazard areas

The water depth zones and flood hazard areas will ultimately be checked for topology and consistency between the different scenarios (whether the more likely areas are not larger than the less likely areas). Such a situation may result from the application of the process of smoothening the water depth zones. The smoothing algorithm adjusts the smoothing curves individually for each set of polygon, without being able to take into account the relationship between flood hazard areas. Figure 56 shows conflict situations in red. The error is usually small, ranging from a few centimetres to several metres. The error is corrected by eliminating the erroneous parts of the polygon.

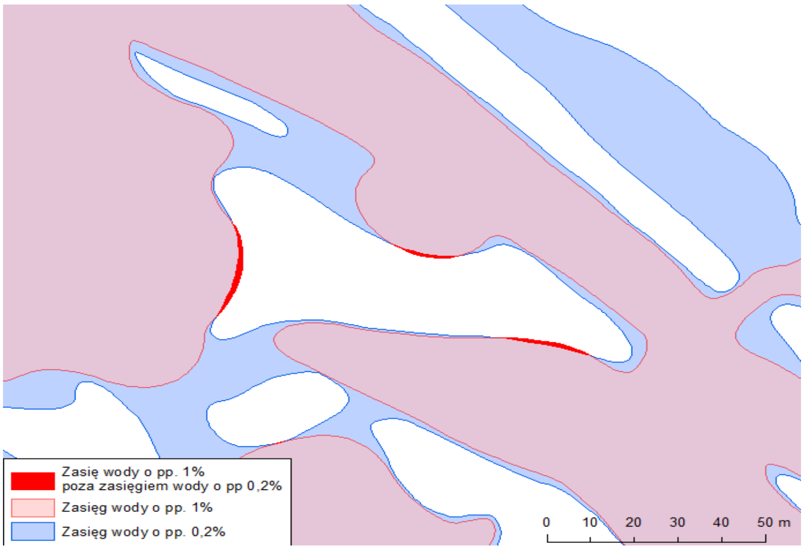


Fig. 56. Example of an error in the range of a hypothetical flood caused by the process of smoothing out the polygon

6.2.6. Generating a flow velocity raster

In accordance with the Regulation, in the case of cities which are the seat of the voivodeship self-government authorities or a voivode, cities with poviat rights, as well as other cities with a population of more than 100,000 people, a flood hazard map showing the velocity and directions of water flow. Taking into account the above requirements, it is necessary to develop a raster of flow velocity, flow velocity zones and directions of water flow (Chapter 6.2.6. – 6.2.8.).

As a result of 2D modelling in .dfs2 files, in addition to the DWSM raster, the maximum values of flow current velocity are also obtained, allowing to generate the maximum flow velocity raster (Fig. 57). This raster has the same resolution as the DWSM raster and undergoes a similar procedure as the DWSM raster (Chapter 6.2.1.). Ultimately, the maximum flow velocity raster is used in the next stage of the work of delimiting flow velocity zones.

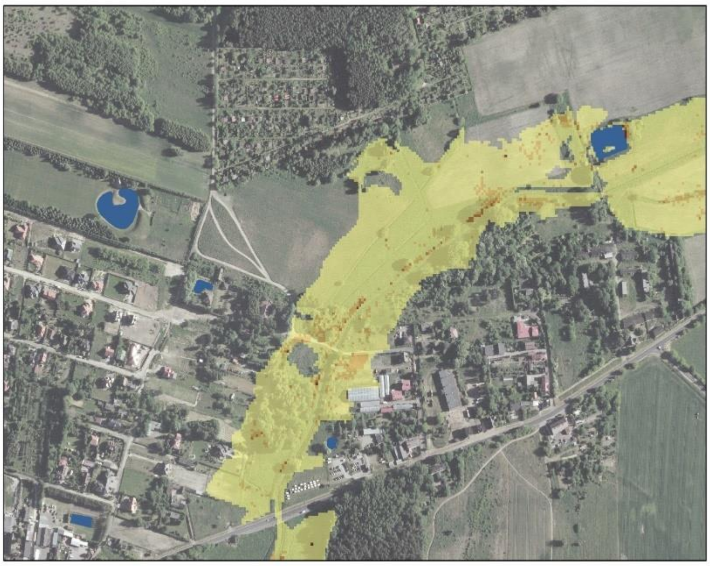


Fig. 57 Example of a flow velocity raster

6.2.7. Determination of velocity zones

In the process of developing flow velocity polygons a similar procedure is used as for depth raster (Chapter 6.2.3.). A properly prepared flow velocity raster is subjected to the procedure of creating flow velocity polygon. By converting the flow velocity raster (at the external borders of the individual flow velocity classes) into a vector form, working flow velocity polygons are obtained. Finally, the obtained flow velocity polygons are cut by corresponding depth zones (Fig. 58).

Fig. 58. Example of a maximum flow velocity polygon

6.2.8. Development of water flow direction vectors

On the basis of the maximum velocity raster data and the corresponding velocity components, information on flow directions is developed. In order to ensure an uniform distribution of symbols representing the water flow directions (Fig. 59) and to ensure proper legibility of the maps, a point layer prepared separately for each scenario is developed. This layer is then trimmed with the range of the flow velocity polygon, reduced by a 5-meter buffer, in order to filter out the points located near the polygon boundary. In addition, it is necessary to remove those flow direction symbols that are located in the main riverbed and those that go beyond the flow velocity zone.

Fig. 59. Example of a maximum flow velocity polygon with the directions of water flow

7. METHODOLOGY OF FRM DEVELOPMENT

According to the Water Law Act (article 170, paragraph 1) flood risk maps are drawn up for flood hazard areas.

According to the Regulation, the potential negative effects associated with a flood are presented on the flood risk maps by identifying:

- negative effects on human life and health,
- economic activities,
- protected areas,
- objects that pose a threat to the environment in the event of flooding, including those that may adversely affect human health,
- cultural heritage areas and sites,
- the value of potential flood damages.

7.1. POTENTIAL NEGATIVE EFFECTS ON HUMAN LIFE AND HEALTH

Negative effects on the population are identified by presenting on maps:

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

Estimated number of inhabitants

Flood risk maps show the estimated number of people living in buildings located in a flood hazard area in a given location.

The number of people inhabiting a given building is estimated on the basis of statistical data made available by GUS, i.e. the average number of people per apartment in the municipality and the NOBC register, from which a tabular information on the number of apartments located at a given address is obtained.

In order to give the table data a spatial dimension, these are linked to address points by the identifier with a following form:

[TERRITE of the town]_[TERRITE of the street]_[number of the building]

Address points are obtained from the dictionary service provided by GUGiK within the Geoportal: http://mapy.geoportal.gov.pl/wss/service/SLNOFF/guest/slowniki-offline?wsdl.

After the number of people living at a given address has been assigned to the address points, the same information is passed on to the BDOT10k residential building sites by means of a spatial connection.

In the case of residential buildings which, by the above method, do not receive the number of inhabitants, the estimate shall be made on the basis of an alternative method in which the number of apartments in a building is calculated on the basis of its area and number of floors.

A summary of data, source, timeliness and level of detail is presented in Table 14.

Table 14. Data for calculating the estimated number of inhabitants in buildings exposed to flooding [source of CSO data: https://bdl.stat.gov.pl/BDL/dane/podgrup/wymiary].

Data	Source	Unit	News
Area of buildings (A)	BDOT10k, PZGiK	single building	2018
Number of floors (B)	BDOT10k, PZGiK	single building	2018
Average usable floor area of one apartment (C)	BDL GUS	municipality	2016
Average number of people per apartment (D)	BDL GUS	municipality	2016

In order to estimate as reliably as possible the number of people living in buildings in the flood hazard area, the calculation groups shall be specified: single-family residential buildings, double-dwelling buildings and multi-family buildings. Both information on the nature of the object and its geometry shall be determined on the basis of the BDOT10k from the "Buildings, structures and equipment" layer (according to BDOT10k coding – BUBD layer), in accordance with the following grouping (Table 15):

Table 15 Calculation groups for residential buildings

Calculation group	Classification according to BDOT10k	
	Code	function
single-family houses	BUBD01	1110.Dj
double-dwelling buildings	BUBD02	1121.Db
multi-family buildings	BUBD03	1122.Dw

The first step is to calculate the number of households in individual municipalities (GD_gm). Based on the buildings obtained from BDOT10k, each single-family building is assigned one household, while buildings with two dwellings are assigned two households respectively. To estimate the number of households in multi-family buildings, the following formula is used, from which, on the basis of the area of the BDOT building outline, the number of storeys (BDOT) and the average usable area of one dwelling in $m^{2,}$ the number of apartments per one storey is calculated first, and then, multiplying the result obtained by the number of floors in the building, the estimated number of dwellings (GUS data for municipalities;

https://bdl.stat.gov.pl/BDL/metadane/cechy/2430?back=True#)

The formula for calculating the estimated number of households in multi-family buildings (GD_BUBD03) is presented below:

$$GD\_ BUBD03 = ROUND\ (A/C)*B$$

where: ROUND – rounding to the nearest integer value; A – area of buildings in m^2; B – number of storeys; C – average usable area of one apartment in m^2.

According to the description of BDOT10k, multi-family buildings are buildings with three or more apartments (BUBD03), so the expected result should not be less than 3. The result obtained is subject to verification and where the value is less than 3, a value equal to 3 shall be assigned.

Then, based on the above data for municipalities, the buildings in the flood hazard area are assigned the number of inhabitants (LM), according to the formula below:

$$LM = ROUND\ (\text{number of households per building} * L.os)$$

where: ROUND – rounding to the nearest integer value; LM – estimated number of occupants of the building; L_os – average number of occupants per 1 dwelling in the municipality.

The average number of people per 1 flat in a municipality is published at the GUS website in the Local Data Bank, at the address: https://bdl.stat.gov.pl/BDL/dane/podgrup/wymiary.

The result obtained, when rounded to the nearest integer gives an estimated number of inhabitants in a given building.

Flood risk maps shall show the estimated number of people living in buildings located in a flood hazard area in a given village and the part of it. For this purpose, the number of people living in buildings located in a flood hazard area with a given probability of occurrence (10%, 1% and 0.2%) is added together.

In case of localities, it is necessary to match the territorial division units from BDOT to the attribute structure of FRM, according to the following division:

<table>
<tr><td>Ms – city</td><td>ADMS01 – city</td></tr>
<tr><td>Ws – village</td><td>ADMS03 – village</td></tr>
<tr><td rowspan="11">In – part of a town, part of a village or other separated part of a locality</td><td>ADMS02 – part of the city</td></tr>
<tr><td>ADMS04 – part of the village</td></tr>
<tr><td>ADMS05 – colony</td></tr>
<tr><td>ADMS06 – part of the colony</td></tr>
<tr><td>ADMS07 – settlement</td></tr>
<tr><td>ADMS08 – part of a settlement</td></tr>
<tr><td>ADMS09 – housing estate</td></tr>
<tr><td>ADMS10 – hamlet</td></tr>
<tr><td>ADMS11 – forester’s lodge</td></tr>
<tr><td>ADMS12 – wilderness hut</td></tr>
<tr><td>ADMS13 – other object</td></tr>
</table>

Facilities of particular social interest

Flood risk maps show objects of particular social importance which may be difficult or impossible to operate, due to the occurrence of floods, i.e.: hospitals, sanatoriums, schools, kindergartens, nurseries, police units, fire protection units, Border Guard units, social welfare homes, nursing homes, hospices, shopping and service centres, market halls, hypermarkets, penitentiaries, correctional facilities, detention centres, hotels, motels, inns, guest houses, holiday homes and orphanages, educational care centres, halls of residence, dorms, student houses, worker’s hostels, homes for the homeless, monasteries, parish houses.

Also in this case, information about the nature of the object and its geometry is obtained from the BDOT10k from the Buildings, structures and equipment layer (BUBD object class – building). Information about the character of the building is derived from the detailed function of the building, assigned in BDOT. If several detailed functions are assigned to one building, the so-called superior function is determined, i.e. the detailed function that is most relevant for flood risk. The following hierarchy of functions is adopted:

N.	Function	Description of function	Classification	Shortcut on the map
1	1122.Dw	multi-family building	m	-
2	1121.Db	two-apartment building	m	-
3	1110.Dj	detached house	m	-
4	1130.Dd	orphanage	m	-
5	1130.In	hall of residence	m	-
6	1130.Bs	dorms	m	-
7	1130.Ds	student house	m	-
8	1130.Hr	workers' hostel	m	-
9	1130.Db	homeless house	m	-
10	1130.Kl	monastery	m	-
11	1130.Dp	parish house	m	-
12	1130.Po	educational care centre	s	*d. wych.*
13	1264.Sz	hospital	s	*szpit.*
14	1264.Hs	hospice	s	*d. op.*
15	1130.Os	nursing home	s	*d. op.*
16	1264.St	sanatorium	s	*san.*
17	1263.Sp	primary school	s	*szk.*
18	1263.Sd	high school	s	*szk.*
19	1263.Sw	college	s	*szk.*
20	1263.Ps	kindergarten	s	*przedszk.*
21	1264.Zb	nursery	s	*żłb.*
22	1274.Ace	penitentiary	s	*z. kar.*
23	1130.Zk	penitentiary	s	*z. kar.*
24	1130.Zp	correctional facility	s	*z. kar.*
25	1274.Zp	penitentiary or correctional facility	s	*z. kar.*
26	1211.Ht	hotel	s	*H*
27	1211.Mt	motel	s	*H*
28	1211.Zj	inn	s	*H*
29	1211.Pj	guest house	s	*H*
30	1212.Dw	leisure house	s	*d. wyp.*
31	1230.Ch	mall	s	*c. han.*
32	1230.Ht	market hall	s	*c. han.*
33	1230.Hm	hypermarket or supermarket	s	*c. han.*
34	1220.Pc	police	s	*P*
35	1220.Sp	fire service	s	*rem.*
36	1220.Sg	border guard	s	*SG*

m – residential building

s – objects of particular social importance

For buildings of particular social importance, no population estimate is provided.

For each residential building and facility of particular social importance, the average flood depth is determined separately for each flood scenario, then classified in two compartments:

- 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 is determined in relation to the adopted water depth ranges and their influence on the degree of threat to the population and the buildings.

7.2. TYPE OF ECONOMIC ACTIVITY

Determining the types of business activities referred to in article 170, paragraph 2, point 2 of the Water Law Act is carried out by determining the land use classes listed in the in the Regulation, i.e.:

1) residential areas;
2) industrial areas;
3) communication areas;
4) woods;
5) recreation and leisure areas;
6) arable land and permanent crops;
7) grasslands;
8) other areas;
9) surface waters.

The class of surface waters, due to its specificity, has been classified as a separate layer from land use layers.

Land use classes are developed on the basis of the BDOT10k database as described below. The exact mapping of land use classes with object classes and attributes from BDOT10k is shown in Table 16.

Table 16 Mapping of land use classes with object classes from BDOT10k

Land-use class	Object class BDOT10k	Attribute
Residential areas	PTZB_A – housing	01 – multi-family housing
		02 – single-family housing
		04 – commercial and service buildings
		05 – other buildings
Industrial areas	PTZB_A – housing	03 – industrial and storage buildings
	PTNZ_A – remaining undeveloped area	02 – industrial and storage site
Communication areas	PTKM_A – area under roads, railways and airports	01 – area under the road
		02 – area under the trackside
		03 – area under the road and the trackside
		04 – area under the airport road
	PTPL_A – square	01 – square
Woods	PTLZ_A – forest and wooded area	01 – forest
		02 – grove
	PTUT_A – permanent crop	04 – forest nursery
Leisure and recreation areas	PTUT_A – permanent crop	01 – allotment garden
	PTTR_A – grassy vegetation and arable	01 – grassy vegetation (selection of those located in

	farming	built-up areas or on the basis of KUSK_A usage complexes)
	PTLZ_A – forest and wooded area	03 – wooding (selection of those which perform a recreational function on the basis of KUSK_A complexes)
	PTRK_A – shrubby vegetation	02 – shrubs (selection of those that serve a recreational function)
Arable land and permanent crops	PTTR_A – grassy vegetation and arable farming	02 – cultivation on arable land
	PTUT_A – permanent crop	02 – plantation
		03 – orchard
		05 – ornamental plant nursery
Grassland	PTTR_A – grassy vegetation and arable farming	01 – grassy vegetation (selection of those not in built-up areas)
Other areas	PTGN_A – unused land	01 – scree, pile or rock rubble
		02 – stony ground
		03 – sandy or gravel ground
		04 – other unused land
	PTWZ_A – excavation and dumping ground	01 – excavation
		02 – heap
	PTSO_A – landfill	01 – municipal waste disposal site
		02 – industrial waste disposal site
	PTNZ_A – remaining undeveloped area	01 – land under technical equipment or construction sites
	PTRK_A – shrubby vegetation	01 – mountain pine (selection of those which do not have a recreational function)
		02 – shrubs (selection of those that do not have a recreational function)
	PTLZ_A – forest and wooded area	03 – wooding (selection of those which do not have a recreational function)

Class 1 – residential areas – includes areas with residential, commercial and service and agricultural buildings, together with infrastructure functionally linked to the buildings, e.g. playgrounds, yards, car parks, small green areas, courtyards, shelters, livestock buildings, etc.

Class 2 – industrial areas – includes buildings and industrial and storage areas.

Class 3 – communication areas – includes areas occupied by roadways, tracks, paved squares and airport roads, together with traffic service equipment, e.g. pavements, siding stations, ramps, aircraft parking lots.

Class 4 – forests – includes both forests, as well as groves, coppices and forest nurseries.

Class 5 – recreation and leisure areas – includes mainly allotment gardens and green areas in built-up sites.

Class 6 – arable land and permanent crops – includes areas occupied by field crops, plantations and orchards.

Class 7 – grassland – includes meadows and pastures.

Class 8 – other areas – includes unused land, excavation and dumping grounds, landfills, other undeveloped areas, wooded areas and shrubby vegetation outside parks or greenery serving as recreation and leisure areas.

In addition, the buildings shown in the flood risk maps have a specific function, from which the type of economic activity also derives.

7.3. PROTECTED AREAS

Flood risk maps show the protected areas listed in the Water Law Act (article 170, paragraph 2, point 4) and the Regulation (including the areas indicated in Annex IV, point 1(i), (iii) and (v) of Directive 2000/60/EC (WFD)), i.e.:

- surface water and groundwater abstractions – including those for human consumption (designated under article 7 of RDW);
- water abstraction protection zones;
- bathing waters included in the list referred to in article 44, paragraph 2 of the Water Law Act;
- forms of nature protection: national parks, nature reserves, Natura 2000 areas divided into special areas of habitat protection (SOO) and special bird protection areas (OSO);
- zoos.

These objects shall be retrieved from the BDOT10k or relevant institutions dealing with the issue, as listed in Chapter 5.4.

In the case of water abstraction protection zones, it may be problematic to assign the type of abstraction (surface water or groundwater) to which the zone applies – it is necessary to analyse the zone area (small, regular-shaped polygons usually apply to groundwater abstractions) and the occurrence of zones containing cut out small zones (the types should be compatible). In addition, the abstraction type assigned in the water abstraction protection zone layer should correspond to the abstraction type of the objects included in the FRM water abstraction data set.

7.4. FACILITIES THAT POSE A THREAT TO THE ENVIRONMENT IN THE EVENT OF FLOODING, INCLUDING THOSE THAT MAY ADVERSELY AFFECT HUMAN HEALTH

According to the Water Law Act (Article 170, paragraph 2, point 3) flood risk maps present installations which, in the event of flooding, may cause significant pollution of particular natural elements or the environment as a whole.

These are installations for which it is required to obtain an integrated permit within the meaning of Article 181, paragraph 1, point 1 of the Act of 27 April, 2001. – Environmental Protection Law (in accordance with the division from Annex 1 to Directive 2010/75/EU of the European Parliament and of the Council of 24 November, 2010 on industrial emissions (IED) in the following categories of industrial activities:

a) energy industry;
b) production and processing of metals;
c) mineral industry;
d) chemical industry;
e) waste management;
f) other activities including
   - production and processing of paper and wood,
   - intensive rearing or breeding of poultry and pigs,

– production and processing of plant and animal raw materials.

An integrated permit is required to run an installation, the operation of which, due to the type and scale of its activity, may cause significant pollution of particular natural elements or the environment as a whole. The 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 of 27 August, 2014. (Journal of Laws of 2014, item 1169).

Moreover, the risk maps present industrial plants, the installations of which do not require an integrated permit, and which may pose a threat, including plants posing a hazard of a serious industrial accident within the meaning of article 3, item 48a and 248, section 1 of the Act of April 27, 2001 – Environmental protection law (in accordance with Directive 2012/18/EU of the European Parliament and of the European Council of 4 July, 2012 on the control of major-accident hazards involving dangerous substances, also called the Seveso III Directive), i.e.:

a) facilities with a higher risk of a major industrial accident and
b) facilities with a high risk of a major industrial accident.

The above division takes into account the type and quantity of hazardous substances present in the facilities, which pose a threat to the environment, but also to human health. This is specified in the Regulation of the Minister of Development on the types and quantities of dangerous substances present in a facility, determining the classification of a facility as an establishment with increased or high risk of a major industrial accident of 29 January, 2016. (Journal of Laws of 2016, item 138).

All available data obtained from the indicated sources must be used to locate the industrial plants and the data must then be verified for each OZP in order to obtain the full information on the industrial plants located in the OZP required by the FRM. This will result in a set of industrial plants covering

- plants holding an integrated IPPC permit (i.e. according to the Regulation *installations which may, in the event of flooding, cause significant pollution of particular natural elements or of the environment as a whole, for the operation of which it is required to obtain an integrated permit referred to in article 181, paragraph 1, point 1 of the Act of 27 April, 2001 – Environmental Protection Law*),
- plants listed in the register of facilities with a large/increased risk of a major accident (i.e. according to the Regulation, *establishments posing a threat of a major industrial accident within the meaning of article 3, point 48a of the Act of 27 April, 2001 – Environmental Protection Law*),
- other facilities which neither hold an IPPC permit nor are listed in the register of facilities with a high/increased risk of a major accident (i.e. according to the Regulation, *industrial establishments with installations that do not require an integrated permit referred to in article 181, paragraph 1, point 1 of the Act of 27 April, 2001 – Environmental Protection Law, and which may pose a threat*).

In the case of large industrial plants it may be problematic to present objects on maps when, for example, integrated permits may cover several different industry categories. Then, if one plant is represented by several points of the same industry category (several installations with separate permits in the same industry category), only one point should be left. In the case when one plant is represented by several points of different industry category, it is advisable to spread points in space for their identification).

In addition, the flood risk maps show, in accordance with the Regulation, the potential sources of water pollution, i.e.:

1) wastewater treatment plants;
2) wastewater pumping stations;
3) landfills;
4) cemeteries.

All available data obtained from the indicated sources should be used to locate the above mentioned objects and then for each OZP data should be verified in order to obtain full information on the above mentioned objects located in the OZP, required for FRM. The above work will be carried out for the OZP – in this way for each designated OZP verified information on the objects concerning potential pollution sources will be obtained.

In the case of landfills, for example, the following procedure should be followed in a view of the quality of the source data (also with regard to national uniformity):

– The surface layer of landfills developed on the basis of BDOT should be verified for the TYPE attribute of the landfill, based on the data from the Voivodeship Inspectorate for Environmental Protection (WIOŚ) and the point layer of landfills from the Pressure identification (2018),
– Data from the WIOŚ and the Pressure identification (2018) should be verified and submitted
  in a polygonal form, based on the orthophotomap.

7.5. CULTURAL HERITAGE AREAS AND OBJECTS

According to the Regulation, the following cultural heritage sites are presented on flood risk maps:

1) immovable historic areas and buildings, in particular covered by the forms of monument protection, referred to in article 7, point 1 of the Act of 23 July, 2003 on the protection and care of monuments (Journal of Laws of 2017, item 2187, as amended);
2) monuments included in the World Heritage List, referred to in article 11, point 2 of the Convention on the Protection of the World Cultural and Natural Heritage, adopted in Paris on 16 November, 1972 by the United Nations General Conference for Education, Science and Culture at its 17thsession (Journal of Laws of 1976, no. 32, item 190);
3) extermination monuments, referred to in article 2 of the Act of May 7, 1999 on the protection of the sites of former Nazi death camps (Journal of Laws of 2015, item 2120, as amended);
4) open-air museums and museums entered in the National Register of Museums, referred to in article 13 of the Act of 21 November, 1996 on museums (Journal of Laws of 2018, item 720, as amended);

5) libraries with collections that constitute the national library resource, referred to in article 6, paragraph 1 of the Act of 27 June, 1997 on libraries (Journal of Laws of 2018, item 574, as amended);
6) archives with collections that constitute the national archival resource, referred to in article 2, paragraph 1 of the Act of 14 July 1983 on the National Resource (Journal of Laws of 2018, item 217, as amended).

The source material for identification of the above mentioned objects are mainly the resources of the National Heritage Institute, including, among other things, immovable monuments. These monuments can be in point, polygonal and linear form – the latter cannot be directly used as an FRM layer, therefore linear objects should be presented in a point form (a point generated in the middle of the line located on the OZP, created after being cut to FHM).
The material is indicated as supplementary material:

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 stock (Journal of Laws of 2017, item 1948, as amended);
3) list of state archives;
4) list of extermination monuments indicated in the Act of May 7, 1999 on the protection of the sites of former Nazi death camps (Journal of Laws of 2015, item 2120, as amended);
5) State Register of Museums.

Identified cultural heritage objects/areas that have several functions (e.g. immovable monument and museum) are duplicated in the numerical version of FRM. For the purpose of cartographic presentation the following hierarchy of functions is adopted in these cases:

1	P	memorial
2	M	museum, open-air museum
3	A	archive
4	B	library
5	Z	immovable museum

7.6. METHODS OF CALCULATING AND PRESENTING THE VALUES OF POTENTIAL FLOOD DAMAGES

The calculation of potential flood damages is carried out for seven land use classes:

1) Class 1 – residential areas;
2) Class 2 – industrial areas;
3) Class 3 – communication areas;
4) Class 4 – forests;
5) Class 5 – recreation and leisure areas;
6) Class 6 – arable land and permanent crops;
7) Class 7 – grassland.

For class 8 – other areas and for surface water, potential flood damages are not calculated due to lack of use or insignificant management of these areas.

The BDOT10k vector data are the basis for delimiting and calculating the area of individual classes in a flood hazard area.

The methods of calculating the value of potential unit damages and the method of estimating potential damages for particular classes of land use in a flood hazard area are presented below.

Class 1 – residential areas

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

- direct damages – the most important are: damage to real estate, loss or damage to property, destruction or damage to technical infrastructure around buildings (yards, playgrounds, pavements, squares, livestock buildings);
- indirect damages – the most important of them are the expenses for cleaning up the damage.

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

The value of potential direct loss per unit in PLN/m^2 is calculated on the basis of the value of assets in housing estates and the value of the loss function, binding the depth of water with the loss of value for class 1. Within the area of housing development, the following are separated: private and municipal assets, as well as housing estate or functionally related infrastructure, including playgrounds, courtyards, car parks, small green areas, courtyards, shelters, livestock buildings.

Due to the lack of data and the lack of possibility of spatial separation of areas including municipal property and housing estate infrastructure, the private property value index defined for individual voivodeships as a measure for class 1 was conventionally adopted.

To determine the value of potential direct unit loss for class 1, the data of the National Bank of Poland (NBP) from 2016 and the Central Statistical Office (GUS) was used. The calculation was made using the method of determining property value indices in residential areas for provinces (Fig. 60) proposed by I. Godyń [2016].

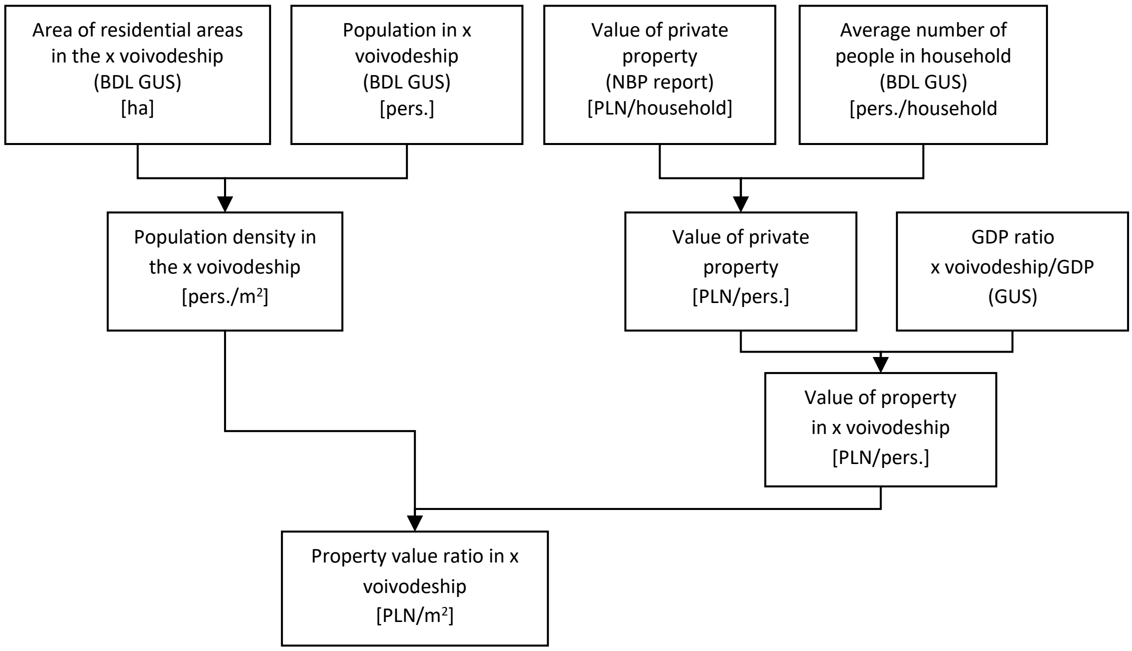


Fig. 60. Method of determining the private property value index for residential buildings [Godyń 2016].
Data: BDL GUS – Central Statistical Office Local Data Bank. Data for 2016; NBP report – National Bank of Poland 2017b; CSO – Central Statistical Office. GDP – current data for 2015.

According to the statistical survey of households' wealth, conducted within the Household Finance and Consumption Network (HFCN)[1] by the National Bank of Poland in 2016, tangible assets of households in Poland measured by the median amounted to 293 thousand PLN (for further calculations the median value was used due to the strong diagonality of the data distribution). Tangible assets constitute the vast majority of total household assets. The value structure of tangible assets is dominated by real estate being the main place of residence and assets resulting from conducting own business activity. Much smaller percentage is constituted by valuables and vehicles. Calculating all the components of the diagram above, the following values of property for particular voivodeships were obtained (Table 17).

Table 17. Values of private property in residential areas

Voivodeship	**Value of private property in residential areas in 2016 [PLN/m²]**
Lower Silesia	691.11
Kuyavia-Pomerania	421.51
Lublin	217.43
Lubusz	396.95
Łódź	393.64
Lesser Poland	514.05

[1] The HFCN is coordinated by the European Central Bank and involves central banks and statistical offices representing the eurozone countries, as well as Poland and Hungary. The research is conducted on the basis of an agreed methodology with a uniform scope of activities, the same definitions and similar data processing methods, which ensure the comparability of results in all European countries participating in the study.

Masovia	684.41
Opole	376.79
Subcarpathia	296.32
Podlaskie	239.64
Pomerania	594.46
Silesia	743.12
Holy Cross	258.51
Warmia-Masuria	281.61
Greater Poland	553.17
West Pomerania	559.78

The loss of property value in areas of housing estates, depending on water depth is shown in Fig. 61 and Table 18.

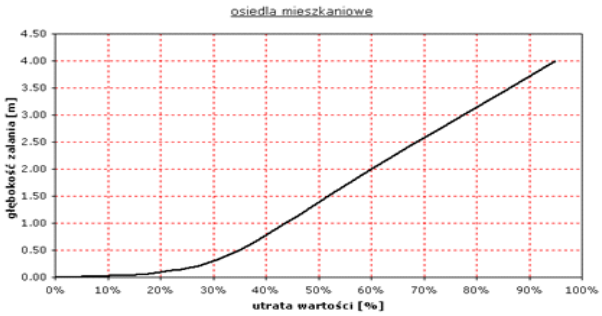


Fig. 61. Loss of property value in housing estates, depending on the depth of flooding [source: Methodology of developing flood risk maps, 2009]

Table 18. Loss of property value for housing estates with regard to depth ranges [source: Methodology of developing flood risk maps, 2009]

Section	Water depth (h) in metres	Impairment of assets f (h) in %
1	h < 0,5	20
2	0.5 < h <= 2	35
3	2 <h <= 4	60
4	h > 4	95

The indirect loss estimated according to J. Chojnacki [2000] as a percentage of the direct loss value was added to the direct loss value calculated above. The division was made due to the diversity of the value of damages, depending on the density of residential buildings.

The following indirect damages are assumed for class 1:

– 80% direct loss for dense construction;
– 40% direct loss for low-density housing.

Finally, the values of potential unit flood damages in class 1 are calculated for individual surface structures in this class, according to the formula below and assuming that dense development consists of concentrated and dense buildings (BDOT10k), while loose development of loose development (BDOT10k):

for dense construction: $Sp_{1g} = Sp_j + 80\%Sp_j$

for low-density housing: $Sp_{1l} = Sp_j + 40\%Sp_j$

where: $Sp_j = W * f(h_j)$; Sp_j – means the value of potential direct damages for class 1 and depth range *j* in (PLN/m^2); *W* – means the value of assets in class 1 (PLN/m^2); $f(h_j)$ – means the value of the loss function linking water depth *j* with impairment of assets in class 1 (%).

Class 2 – Industrial sites

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

- direct damages **–** the most important ones are: damage and/or loss of fixed and current assets, loss of documentation, archives;
- indirect damages **–** the most important are: cleaning expenses, expenses related to the transfer of movable property, production damages/interruption of the production process.

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

Individual direct damages are calculated on the basis of the value of assets for industrial areas and the value of the loss function linking water depth with loss of value for class 2. 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 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. The value of assets for industrial areas is presented in Table 19.

Table 19. Property values in industrial areas

Voivodeship	Value of assets in industrial areas in 2016 [PLN/m^2]
Lower Silesia	822.13
Kuyavia-Pomerania	750.65
Lublin	916.26
Lubusz	1201.97
Łódź	1256.78
Lesser Poland	1028.11
Masovia	1429.69
Opole	691.71
Subcarpathia	980.58
Podlaskie	803.29
Pomerania	1053.13
Silesia	928.73
Holy Cross	819.90
Warmia-Masuria	832.46
Greater Poland	1198.75
West Pomerania	457.21

Loss of property value in industrial areas, depending on water depth is shown in Fig. 62 and Table 20.

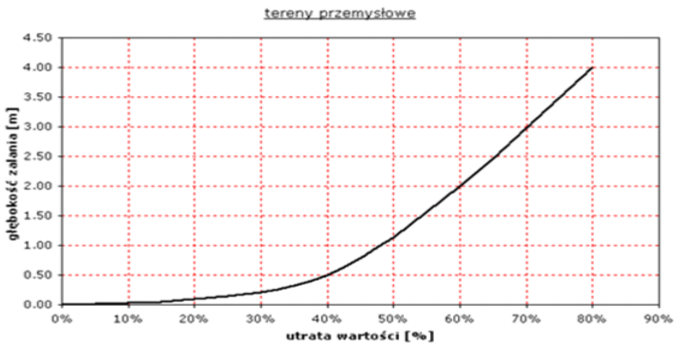


Fig. 62. Loss of value of assets in industrial areas, depending on the depth of flooding [source: Methodology of developing flood risk maps, 2009]

Table 20. Loss of property value for industrial areas by depth ranges [source: Methodology of developing flood risk maps, 2009]

Section	Water depth (h) in metres	Impairment of assets f (h) in %
1	h <= 0,5	20
2	0.5 < h <= 2	40
3	2 < h <= 4	60
4	h > 4	80

According to A. Symonowicz [Chojnacki, 2000 after Symonowicz, 1969], the amount of indirect damages in particular sectors of the economy can be estimated in the range of 50-100% of direct damages. An additional mark-up has been contractually accepted for industrial areas as an indirect loss in the form of 80% of the direct loss value.

Ultimately, the values of potential unit flood damages in class 2 are calculated for individual surface objects in this class according to the formula:

$$Sp_2 = Sp_j + 80\%\ Sp_j$$

where: $Sp_j = W * f(h_j)$; Sp_j – means the value of potential direct damages for class 2 and depth range j in (PLN/m^2); W – means the value of assets in class 2 in (PLN/m^2), $f(h_j)$ – means the value of the loss function linking water depth j with impairment of assets in class 2 (%).

Class 3 – Transport areas

The value of communication areas is calculated on the basis of indexation of the value of assets in communication areas, valid in the first planning cycle, specified in the Regulation of 21 December, 2012, issued by 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 on the development of flood hazard maps and flood risk maps (Journal of Laws, 2013, item 104)[2].

The indexation is 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 percentage terms in relation to 2008 (to

[2] This regulation expired on the date of entry into force of the regulation of the Minister of Maritime Economy and Inland Navigation of October 4, 2018 on the development of flood hazard maps and flood risk maps (Journal of Laws 2018, item 2031)

which the value of assets in the 2012 regulation referred to) and amounted to 64%. The value of transport areas from 2008 was indexed by the value of the index and amounts to PLN 717 PLN/m^2 for 2016.

Loss of property value in communication areas, depending on water depth is shown in Fig. 63 and Table 21.

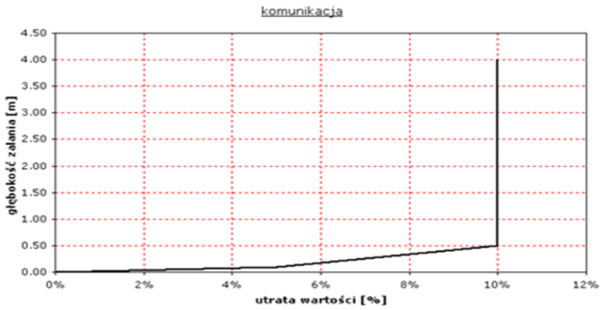


Fig. 63. Loss of value of assets in communication areas, depending on the depth of flooding [source: Methodology of developing flood risk maps, 2009]

Table 21. Loss of property value for communication areas with regard to depth ranges [source: Methodology of developing flood risk maps, 2009]

Section	Water depth (h) in metres	Impairment of assets f (h) in %
1	h <= 0.5	5
2	0.5 < h	10

The values of potential unit flood damages in class 3 are calculated for individual surface objects of class 3 separated by water depth according to the formula below:

$$Sp_{3j} = W * f(h_j)$$

where: Sp_{3j} – means the value of potential unit damages for class 3 and depth range j in (PLN/m^2); W – means the value of assets calculated for class 3 (PLN/m^2); $f(h_j)$ – means the value of the loss function linking water depth j with impairment of assets in particular classes in (%).

Class 4 – Forests

The potential unit loss for this class is difficult to determine. Flood damages depend primarily on the duration of the flood, the age of the stand, the type of natural habitat, the condition of the 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 – non-productive assets, e.g. damages in the public functions of the forest, e.g. protective role of forests.

For the purpose of flood risk mapping, the potential unit loss for this class is determined based on data from the General Directorate of State Forests and the German publication LTV [2003].

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 publication of the *National Flood Damage Evaluation Methods,* which estimates the loss of 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, constant loss values are assumed for the whole country, independent of water depth.

Class 5 – Recreational and leisure areas

The value of potential unit loss for recreation and leisure areas is calculated on the basis of indexation of the unit value of potential loss, applicable in the first planning cycle, specified in the Regulation of 21 December, 2012. The value of the potential unit loss for recreational and leisure areas is calculated on the basis of the indexation of the unit value of the potential loss applicable in the first planning cycle as specified in the Regulation of 21 December, 2012 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 on the development of flood hazard maps and flood risk maps (Journal of Laws 2013, item 104)[3]. The value of 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 amounted to 64%. The value of recreation and holiday areas from 2008 was indexed by the value of the index and amounts to 8 PLN/m^2 in 2016.

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

Class 6 – Arable land and permanent crops

Depending on how the floods affect, potential flood damages in class 6 can be divided into two types:

- direct damages – the most important of these are: crop damages, soil destruction, e.g. by flushing processes, erosion, disturbance of water conditions in the soil, soil pollution;
- indirect damages – the most important of these are: expenditure on cleaning up the damage, damages in animal production, e.g. a reduction in yields has an impact on additional expenditure or a decrease 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. Analysing the damages from historical floods, it can be concluded that there is a regional variation in the amount of crop damages in Poland. Therefore, it will be reasonable, as indicated by Godyń [2015], to calculate the agricultural production index by voivodeship. The value of agricultural production is calculated in the following steps using GUS data:

1) determining the agricultural output for crop production, reduced by meadow hay;
2) calculating the crop production for voivodeships on the basis of the agricultural output structure;
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.

Since the volume of agricultural production is highly dependent on meteorological conditions in a given year, the average, in this case from the last 3 years, should be used to assess the production

[3] This regulation expired on the date of entry into force of the regulation of the Minister of Maritime Economy and Inland Navigation of October 4, 2018 on the development of flood hazard maps and flood risk maps (Journal of Laws 2018, item 2031)

value. Such a period is recommended by the Ministry of Agriculture to committees appointed by voivodes to assess damages in case of natural disasters [Godyń 2015]. The value of agricultural production was calculated for the period 2013-2014, due to lack of data for 2015.

To calculate the unit loss for arable land, the table [Penning-Rowsell et al., 2013 – Fig. 64 for RISC-KIT 2015] showing the amount of damages for individual, crops depending on the month in which flooding may occur was used.

Fig. 64. Loss of harvest expressed as a percentage for selected crops and grassland in the case of flooding lasting less than 1 week [used: Penning-Rowsell et al., 2013].

Each of the four loss ranges (>66%; 33-66%; 1-33%; no damages) has been weighted accordingly:

- >66% – weight 3;
- 33-66% – weight 2;
- 1-33% – weight 1;
- no damages – weight 0.

Then the average for winter, spring, root, oil and legume crops was calculated. The obtained value was 1.58. Taking the upper value of the interval for weight 2, the potential loss for crops for the whole year was calculated and amounted to 52%.

According to A. Symonowicz [Chojnacki, 2009 after Symonowicz, 1969], the amount of indirect damages in agriculture does not exceed 20% of direct damages, therefore eventually potential flood damages in class 6 (Sp_6) are defined as:

$$Sp_6 = Sp + 20\%Sp$$

where Sp – means the value of potential direct damages for class 6 in PLN/m^2.

The values of potential flood damages for arable land and permanent crops are presented in Table 22.

Table 22. Values of potential flood damages for arable land and permanent crops

Voivodeship	**Potential single-flooded unitary loss (PLN/m^2)**
Lower Silesia	0.31
Kuyavia-Pomerania	0.30
Lublin	0.33
Lubusz	0.31

Łódź	0.32
Lesser Poland	0.40
Masovia	0.37
Opole	0.34
Subcarpathia	0.26
Podlaskie	0.18
Pomerania	0.26
Silesia	0.33
Holy Cross	0.37
Warmia-Masuria	0.24
Greater Poland	0.30
West Pomerania	0.27

Class 7 – Grassland

Depending on how the floods affect, the potential flood damages in class 7 can be divided into two types:

- direct damages – the most important are: damages in biomass, destruction of soil, e.g. by flushing processes, erosion, disturbance of water conditions in soil, soil pollution;
- indirect damages – the most important of these are: expenditure on cleaning up the damage, damages in animal production, e.g. a reduction in harvest has an impact on additional expenditure or decrease in breeding.

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

As in the case of 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 dt by voivodeship was assumed and compared to the value of the average price in PLN/dt from the last 3 or 5 years (in the case of analysing 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 calculations for arable land and permanent crops, Fig. 64 was used. Each of the three ranges of damages for grassland (33-66%; 1-33%; without damages) was weighted accordingly:

- 33-66% – weight 2;
- 1-33% – weight 1;
- no damages – weight 0.

Then the average for meadows and pastures was calculated. The obtained value was, for meadows – 0.9; for pastures – 0.75. Assuming the upper value of the range for weight 1, the potential direct loss for meadows for the whole year was calculated respectively in the amount of 30%, for pastures – 25%. The amount of indirect damages was assumed to be 30% of direct damages. Ultimately, potential unit flood damages for individual voivodeships in class 7 (Sp_7) are defined as:

$$Sp_7 = Sp_{7Ł} + 30\%\ Sp_{7Ł} + Sp_{7P} + 30\%\ Sp_{7P}$$

where: $Sp_{7Ł}$ – means the value of potential direct damages for meadows in class 7 (PLN/m^2); p_{7P} – *means the value of* potential direct damages for pastures in class 7 (PLN/m^2).

The values of potential flood damages for grassland are presented in Table 23.

Table 23. Values of potential flood damages for grassland

Voivodeship	Potential flooding unit in 2016 (PLN/m^2)
Lower Silesia	0.08
Kuyavia-Pomerania	0.09
Lublin	0.09
Lubusz	0.08
Łódź	0.10
Lesser Poland	0.08
Masovia	0.08
Opole	0.10
Subcarpathia	0.06
Podlaskie	0.10
Pomerania	0.08
Silesia	0.10
Holy Cross	0.07
Warmia-Masuria	0.10
Greater Poland	0.09
West Pomerania	0.08

Ranges of potential flood damages

Flood risk maps in the cartographic version present values of potential unit damages 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 up to full zlotys. In the case of separating areas for which the potential loss in PLN is below 1 PLN, such area should be included in the adjacent area.

Summary values of potential flood damages

On the basis of the digital flood risk map Sp_i (spatial database) it is possible to calculate the total values of potential flood damages for any chosen area. 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:

$$Sp_i = \sum_{j=1}^{4} Sp_{ij} \cdot A_i \ \ for\ i = 1\ or\ 2$$

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

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

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

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

The method for calculating the potential loss aims **only at a framework spatial differentiation of areas in terms of the magnitude of the potential loss** and thus at identifying areas where flood risk reduction measures should be specifically continued or taken.

8. FHM AND FRM SPATIAL DATABASES

8.1. DATABASES

The spatial databases of FHM and FRM shall be prepared in *.shp format in the rectangular flat coordinate system (EN-1992). In addition, a database version shall be prepared in ESRI geobase format with tools for migration between data formats.

The database of flood hazard maps and flood risk maps includes

1) **Reference layers:**
   - natural watercourses and canals;
   - other watercourses;
   - surface water;
   - roads;
   - railroads;
   - voivodeship;
   - poviat;
   - municipality;
   - 1:10,000 scale sheet division of maps for the PL-1992 system;
2) **Layers of flood hazard maps:**
   - flood hazard area for rivers – a separate layer for each scenario: 10%, 1%, 0.2% and WZ;
   - water depth – separate layer for each scenario: 10%, 1%, 0.2% and WZ;
   - water flow velocity – separate layer for each scenario: 10%, 1%, 0.2%;
   - water flow directions – separate layer for each scenario: 10%, 1%, 0.2%;
   - maximum ordinates of the water level;

- ordinates of top of flood embankments in cross-sections;
- places where the water overflows through the flood embankment;
- place where the embankment was completely destroyed;
- flood embankments;
- chainage;
- maximum flow rate values.

3) Layers of flood risk maps:

- land use with calculated potential flood damages – separate layer for each scenario: 10%, 1%, 0.2% and WZ;
- land use – separate layer for each scenario: 10%, 1%, 0.2% and WZ;
- buildings;
- industrial plants;
- water abstractions;
- water abstraction protection zones;
- bathing waters;
- forms of nature conservation;
- culturally valuable areas;
- culturally valuable objects;
- zoos;
- cemeteries (potential pollution sources);
- landfill sites (potential pollution sources);
- wastewater treatment plants and pumping stations (potential pollution sources);
- cities.

Information about the current version of the map sheet in each of the FHM and FRM scenarios (e.g. 2015v1, 2017v1, 2018v1, 2019v1) is included in the frame-sheet layer (1:10,000 scale map sheet division).

A detailed description of the attribute structure of the flood hazard map database and flood risk maps is included in Annex 2 and consists of: names of layers, layer types, description of layers, data source and attributes (field name, field type, description, attribute source).

The final database is divided according to the types of floods: river, sea water and others. Each type of flood is a separate database.

The internal catalogue structure for other types of floods and sea water floods is analogous to that for fluvial floods.

8.2. METADATA

For all spatial data generated in the project, metadata should be prepared in accordance with the INSPIRE Directive and the guidelines of the European Commission for reporting from the Floods Directive.

The range of metadata compatible with the INSPIRE profile has been defined on the basis of the following documents:

- INSPIRE Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119 v1.3, 2013;
- Technical Guidelines for implementing dataset and service metadata based on ISO/TS 19139:2007 v2.0.1, 2017;
- Data Specification on Natural Risk Zones – Technical Guidelines v3.0, 2013;
- Floods Directive GIS Guidance on the reporting of spatial data, 2020.

Metadata should be prepared separately for:

1) FHM and FRM databases – according to the current INSPIRE metadata profile – for the following sets:

   a) FHM
   b) FHM_WZ
   c) FHM_BP*
   d) FRM_RL
   e) FRM _RL_WZ
   f) FRM _RL_BP*
   g) FRM _RS
   h) FRM _RS_WZ
   i) FRM _RS_BP*

   *metadata related to flood hazard maps and flood risk maps in the damage or destruction scenario of damming structures.

2) Data sets from INSPIRE Annex III, point 12 – Natural hazard zones, according to the current INSPIRE metadata profile (only for river and sea water floods):

   a) FHA_low
   b) FHA_medium
   c) FHA_high
   d) FRZ_low
   e) FRZ_medium
   f) FRZ_high

3) Preparing a report for the European Commission on the review and update of flood hazard maps and flood risk maps (applies to all types of floods).

Data sets indicated in points 1 and 2 shall be described with metadata in xml format, grouped thematically by river basin area.

The following table shows the INSPIRE metadata profile.

Metadata Regulation Section	Metadata element	Element	Description
1	**IDENTIFICATION**		
1.1	Resource title	Resource title	The characteristic and often unique name under which the resource is known. The value domain of this metadata element is any text.
1.2	Resource abstract	Resource abstract	This is a concise description of the content of the resource. The value domain of this metadata element is any text.
1.3	Resource type	Resource type	This is the type of resource described by the metadata. The value domain of this metadata element is defined in Part D.1.

Metadata Regulation Section	Metadata element	Element	Description
1.4	Resource locator	Resource locator	A resource's address specifies the link(s) to the resource or a link to additional information about the resource. The value domain of this metadata element is a character string, usually expressed as a uniform resource locator (URL).
1.5	Unique resource identifier	Unique resource identifier	A value that identifies a resource in a unique way. The value domain of this metadata element is the mandatory character string code, usually assigned by the data owner, and the character string namespace which uniquely describes the context of the identifier code (e.g. data owner).
1.6	Coupled resource	Coupled resource	If the resource is a spatial data service, then this metadata element shall specify, where appropriate, the target spatial data set(s) of the service using a unique resource identifier (URI). The value domain of this metadata element is the mandatory character string code, usually assigned by the data owner, and the character string namespace which uniquely describes the context of the identifier code (e.g. data owner).
1.7	Resource language	Resource language	The language(s) used in the resource. The value domain of this metadata element is limited to the languages defined in ISO 639-2.
2	**CLASSIFICATION OF SPATIAL DATA AND SPATIAL DATA SERVICES**		
2.1	Topic category	Topic category	This is a high-level classification diagram to support the grouping and thematically targeted search of available spatial data resources. The value domain of this metadata element is defined in Part D.2.
2.2	Spatial data service type	Spatial data services type	This classification supports the search for available spatial data services. A specific service can be assigned to only one category, The value domain of this metadata element is defined in Part D.3.
3	**KEYWORDS**		If the resource is a spatial data service, at least one keyword from D.4 shall be used. Where a resource is a spatial data set or a series of spatial data sets, one or more keywords, derived from the General Multilingual Environmental Thesaurus (GEMET), describing the relevant spatial data theme as defined in Annexes I, II or III to Directive 2007/2/EC, shall be used. The following metadata elements shall be provided for each keyword
3.1	Keyword value	Keyword value	A keyword value is a commonly used word, a formalised word or phrase used to describe a topic. While subject categories are too general for detailed queries, keywords help to make full text searches more detailed and allow structural keywords. The value domain of this metadata element is any text.
3.2	Originating controlled vocabulary	Standard source dictionary	If the keyword value comes from a controlled dictionary (thesaurus, ontology), for example GEMET thesaurus, a reference to the controlled source dictionary must be given. This reference shall include at least the title of the controlled source dictionary and the reference date (date of publication, date of last revision or creation).
4	**LOCATION**		The geographical location requirement laid down in Article 11(2)(e) of Directive 2007/2/EC shall be expressed by means of a metadata element in the form of a geographical delimiting rectangle.
4.1	Geographic bounding box	Geographical delimiting rectangle	This is the range of the resource in geographical space, expressed in a limiting rectangle. The bounding box shall be described by the meridians of the western boundary and the eastern boundary of the area and the parallels of the southern boundary and the northern boundary expressed in decimal degrees, with an accuracy of at least two decimal digits.

Metadata Regulation Section	Metadata element	Element	Description
5	**TIMELINE**		
5.1	Temporal extent	Time range	The time range defines the period covered by the content of the resource. This period can be expressed in one of the following forms: - date, - a range of dates expressed by the start date and end date of the range, - a combination of date and date range.
5.2	Date of publication	Date of publication	This is the date of publication of the resource, if available, or the date of entry into force. There may be more than one date of publication.
5.3	Date of last revision	Date of last update	This is the date of the last update in case the resource was updated. There should not be more than one last update date.
5.4	Date of creation	Date of creation	This is the date the resource was created. There should be no more than one creation date.
6	**QUALITY AND IMPORTANCE**		The requirements referred to in Articles 5(2) and 11(2) of Directive 2007/2/EC relating to the quality and validity of spatial data shall be met by the following metadata elements:
6.1	Lineage	Origin	This is a description of the history of the creation process or the overall quality of the spatial data set. Where appropriate, it may include a statement as to whether the data set has been subject to validation or quality assessment, whether it is the official version (if multiple versions exist) and whether it is legally binding. The value domain of this metadata element is any text.
6.2	Spatial resolution	Spatial resolution	Spatial resolution refers to the level of detail of the data set. It is specified as a set from zero to multiple lengths expressing resolution (usually for grid data and imaging derived products) or equivalent scales (usually for maps or their derived products). The equivalent scale is generally expressed by an integer which is the denominator of the scale. The length expressing the resolution is given by a numerical value resulting from the adopted unit of length.
7	**CONFORMITY**		The requirements referred to in Articles 5(2)(a) and 11(2)(d) of Directive 2007/2/EC relating to the compliance, and the degree of compliance, with implementing rules adopted pursuant to Article 7(1) of Directive 2007/2/EC shall be met by means of the following metadata elements:
7.1	Specification	Specification	This is a citation of the implementing rules adopted pursuant to Article 7(1) of Directive 2007/2/EC or other specification to which a particular resource corresponds. A resource may correspond to more than one implementing rule adopted pursuant to Article 7(1) of Directive 2007/2/EC or to another specification. This citation shall include at least the title and a reference date (date of publication, date of last revision or creation) of the implementing rules adopted pursuant to Article 7(1) of Directive 2007/2/EC or the specification concerned.
7.2	Degree	Degree	This is the degree of compliance of the resource with implementing rules adopted pursuant to Article 7(1) of Directive 2007/2/EC or other specifications. The value domain of this metadata element is defined in Part D.5.
8	**REQUIREMENTS FOR ACCESS AND USE**		The requirement for access and use shall cover separately or jointly: - set of conditions for access and use (8.1), - a set of restrictions on public access (8.2).
8.1	Conditions for access and use	Conditions for access and use	This metadata element shall specify the conditions for access to and use of spatial data sets and services and, where applicable, the relevant charges required under Articles 5(2)(b) and 11(2)(f) of Directive 2007/2/EC. The value domain of this metadata element is any text.

Metadata Regulation Section	Metadata element	Element	Description
			This element must contain values. If no conditions apply to access and use of the resource, the entry "no conditions" is required. If the conditions are unknown, "unknown conditions" shall be entered. This element should also provide information on paying the necessary fees to access and use the resource, if any, or refer to the uniform resource locator (URL) where information on fees is available.
8.2	Limitation on public access	Limitation on public access	Where member states restrict public access to spatial data sets and services on the basis of Article 13 of Directive 2007/2/EC, that metadata element should include information on those restrictions and the reasons for them. If there are no restrictions on public access, this fact should be condemned in this metadata element. The value domain of this metadata element is any text.
9	**ORGANISATIONS RESPONSIBLE FOR THE CREATION OF SPATIAL DATA SETS**		
9.1	Responsible party	Responsible party	This is a description of the organisation responsible for the creation, storage, distribution and management of the resource. This description should include - the name of the organisation in any text, - contact details (e-mail address) in the form of a string.
9.2	Responsible party roles	Responsible party roles	This is the role of the responsible organisation. The value domain of this metadata element is defined in Part D.6.
10	**METADATA ON METADATA**		For the purposes of Article 5(1) of Directive 2007/2/EC, the following metadata elements shall be provided:
10.1	Metadata point of contact	Metadata point of contact	This is a description of the organisation responsible for creating and storing metadata. This description should include - the name of the organisation in any text, - contact details (e-mail address) in the form of a string.
10.2	Metadata date	Metadata date	This is the date that determines when the metadata record was created or updated. This date shall be expressed in accordance with ISO 8601.
10.3	Metadata language	Metadata language	This date shall be expressed in accordance with ISO 8601.

For the purpose of reporting to the European Commission on the review and updating of flood hazard maps and flood risk maps, metadata should be produced in accordance with the European Commission's Floods Directive GIS Guidance on the reporting of spatial data (2020), described in the chapter "Flood Hazard Maps and Flood Risk Maps". The metadata range for FHMs and FRMs is included in the FHRM_LinkToMS diagram and includes the information indicated in the table below.

Name of the table	Attribute name	Description
FHRM_LinkToMS	floodHazardRiskMapsID	
FHRM_LinkToMS_Management AreaIdentifier	floodHazardRiskMapsID	
	managementAreaIdentifierID	Unique identifier code for units of management.
FHRM_LinkToMS_Management AreaIdentifier_uomIdentifier	managementAreaIdentifierID	
	uomIdentifier	Use relevant UOMcode reported under the reporting obligation for unit of management and competent authorities.
FHRM_LinkToMS _MapInformation	mapInformationID	
	floodHazardRiskMapsID	Unique identifier code for relevant areas of flood risk.
	description	Give short description of the map content – e.g. flood scenarios, exposed elements... **EN:** Flood hazard map with water depth; Flood hazard map with water flow velocity;

Name of the table	Attribute name	Description
		Flood risk map – potential adverse consequences for human life and health and the value of potential flood damages; Flood risk map – potential negative consequences for the environment, cultural heritage and economic activity.
	category	The map category that the URL is displaying. Choose between the 6 overall categories or specify other value: Available codelist: - LowProbabilityHazard - MediumProbabilityHazard - HighProbabilityHazard - LowProbabilityRisk - MediumProbabilityRisk
FHRM_LinkToMS_Metadata	metadataID	
	serviceURLID	
	resourceTitle	Map/service title.
	spatialResolution	Spatial resolution must be specified by using the resolution value and the unit of measure. Based on the type of reported map the resolution refers to the following: - Map image: size of the pixel used to construct the image (e.g. 100 m) - Vector map: scale used to represent the map (e.g. 1:25,000).
	mapLanguage	Language of the map.
	pointOfContact_email	Provide the email for the contact point responsible for the link to the national FHRM maps.
	pointOfContact_responsible Organisation	Provide the name for the contact point responsible for the link to the national FHRM maps.
	temporalReference _dateOfCreation	Date in which the map was created. Specify month, day, year.
	temporalReference _temporalExtent	Provide the temporal coverage for the map, or the validity period. Specify an interval for start-end period by means the month, day, year (e.g. 01-01-2015–01-01-2017).
	temporalReference _dateOPublication	Date in which the map was published by means of the URL service. Specify month, day, year.
	temporalReference _dateOLastRevision	Date in which the map was updated or revised the last time. Specify month, day, year.
FHRM_LinkToMS_Metadata _otherMapLinks	metadataID	
	otherMapLinks	Report other relevant links where information about the FHRM map is available.
FHRM_LinkToMS_Metadata _spatialCoverage	metadataID	
	spatialCoverage	Spatial coverage refers to the geographical area that is presented on the map.
FHRM_LinkToMS _RelevantFLoodAreaIdentifier	relevantFLoodAreaIdentifierID	
	floodHazardRiskMapsID	
	boundingBox	In cases where the MS has not used either UoM, SubUnits or APSFR the MS needs to report a 'bounding box' where they have available national FHRM and report the link at this level.
FHRM_LinkToMS_RelevantFLood AreaIdentifier_apsfrIdentifier	relevantFLoodAreaIdentifierID	
	apsfrIdentifier	Unique EU code for the area of potential significant flood risk as reported under the Reporting obligation for Preliminary flood risk assessment.
FHRM_LinkToMS_ServiceURL	floodHazardRiskMapsID	
	serveceURLID	
	wfs	URL to the Web Feature Service
	wms	URL to the Web Map Service
	portal	URL to a Portal where the service is available.
	pdf	URL to the pdf file

Name of the table	Attribute name	Description
	other	URL to another kind of service

The indexes for metadata (for FHM and FRM in cartographic and numerical version) should be made in *.shp format containing sheets with assigned information about the type of data, its spatial range, timeliness of source data, type of model used and the Contractor (Tables 24 and 25). Metadata for FHM and FRM in cartographic and numerical version will be made in .xml format, divided into river basin areas and grouped thematically.

Index of flood hazard maps

- Layer: Index_FHM;
- Type of layer: polygon;
- Description: 1:10,000 scale sheetfed map area coverage in coordinate system PL-1992;
- Data source: aMZPiMRP.

Table 24 Attribute structure of the flood hazard maps index for metadata

Attribute	Field type	Description	Attribute source
GODLO	T(22)	Emblem of the map sheet in the 1992 layout	GUGIK
WSP_LG	T(254)	Coordinates [X;Y] of the upper left corner of the sheet	GUGIK
WSP_LD	T(254)	Coordinates [X;Y] of the lower left corner of the sheet	GUGIK
WSP_PG	T(254)	Coordinates [X;Y] of the top right corner of the sheet	GUGIK
WSP_PD	T(254)	Coordinates [X;Y] of the lower right corner of the sheet	GUGIK
WYKONAWCA	T(38)	Contractor	aMZPiMRP
KL_MOD	T(5)	Type of model used	aMZPiMRP
AKT_BDOT	T(50)	BDOT topicality	aMZPiMRP
AKT_NMT	T(50)	DTM topicality	aMZPiMRP
UWAGI	T(254)	Comments	aMZPiMRP
MZP_10	T(50)	Name of flood hazard map with water depth 10% – FHM with depth 10%	aMZPiMRP
MZP_1	T(50)	Name of flood hazard map with water depth 1% – FHM with water depth 1%	aMZPiMRP
MZP_02	T(50)	Name of flood hazard map with water depth 0.2% – FHM with 0.2% depth	aMZPiMRP
MZP_WZ	T(50)	Name of flood hazard map with water depth WZ – FHM with water depth WZ	aMZPiMRP
MZP_P10	T(50)	Name of the flood hazard map with a water flow velocity of 10% – FHM with a flow velocity of 10%	aMZPiMRP
MZP_P1	T(50)	Name of the flood hazard map with a water flow velocity of 1% – FHM with a f of 1%	aMZPiMRP
MZP_P02	T(50)	Name of flood hazard map with water flow velocity 0.2% – FHM with 0.2%	aMZPiMRP

Component of flood risk maps

- Layer: Index_FRM;
- Type of layer: polygon;
- Description: 1:10,000 scale sheetfed map area coverage in coordinate system PL-1992;
- Data source: aMZPiMRP.

Table 25: Attribute structure of the flood risk map index for metadata

Attribute	Field type	Description	Attribute source
WSP_PD	T(22)	Emblem of the map sheet in the 1992 layout	GUGIK
WYKONAWCA	T(254)	Coordinates [X;Y] of the upper left corner of the sheet	aMZPiMRP
KL_MOD	T(254)	Coordinates [X;Y] of the lower left corner of the sheet	aMZPiMRP

AKT_BDOT	T(254)	Coordinates [X;Y] of the top right corner of the sheet	aMZPiMRP
AKT_NMT	T(254)	Coordinates [X;Y] of the lower right corner of the sheet	aMZPiMRP
UWAGI	T(38)	Contractor	WYKONAWCA
MRP_RL_10	T(5)	Type of model used	aMZPiMRP
MZP_RL_1	T(50)	BDOT topicality	aMZPiMRP
MRP_RL_02	T(50)	DTM topicality	aMZPiMRP
MRP_RL_WZ	T(254)	Comments	aMZPiMRP
MRP_RS_10	T(50)	Name of flood risk map – potential adverse consequences for human life and health and value of potential flood damages 10%	aMZPiMRP
MRP_RS_1	T(50)	Name of the flood risk map – potential adverse consequences for human life and health and value of potential flood damages 1%	aMZPiMRP
MRP_RS_02	T(50)	Name of the flood risk map – potential adverse consequences for human life and health and value of potential flood damages 0.2%	aMZPiMRP
MRP_RS_WZ	T(50)	Name of the flood risk map – potential adverse consequences for human life and health and the value of potential flood damages WZ	aMZPiMRP
WSP_PD	T(50)	Name of flood risk map – potential negative consequences for the environment, cultural heritage and economic activity 10%	aMZPiMRP
WYKONAWCA	T(50)	Name of flood risk map – potential negative consequences for the environment, cultural heritage and economic activity 1%	aMZPiMRP
KL_MOD	T(50)	Name of the flood risk map – potential negative e consequences for the environment, cultural heritage and economic activity 0.2%	aMZPiMRP
AKT_BDOT	T(50)	Name of the flood risk map – potential negative consequences for the environment, cultural heritage and economic activity WZ	aMZPiMRP

In addition, the FHM and FRM topicality indexes for river sections (in Task 1.3.8) and map sheets in the scale 1:10,000 (in Task 1.3.9) should be made.

9. CARTOGRAPHIC VERSION OF FHM AND FRM

The cartographic versions of FHM and FRM are prepared in the form of graphic files in sheets (emblems) corresponding to sheets of topographic maps at a scale of 1:10 000, in a rectangular flat coordinate system EN-1992.

Cartographic versions are prepared in the following formats:

- pdf (version with non-blocking description);
- geotiff (map content with georeferencing, without non-blocking information).

Each sheet is edited with regard to the content of the map – point symbols and their labels, names of flowing waters and direction of the run-off, names of localities, names of water reservoirs; as well as the non-blocking description – coordinates of cartographic nets and the content of an overview map of administrative division.

Cartographic versions of FHM and FRM are developed separately for each of the four flood scenarios (see Chapter 4). For each of the scenarios the following types of maps are made:

1) Flood hazard maps in two sets of themes:
   a) flood hazard map with water depth – presenting the flood hazard areas and specifying four water depth zones (with limit values of 0.5 m; 2 m; 4 m);
   b) flood hazard map with water flow velocity (developed only for the areas of cities with the seat of the voivodeship self-government authorities or a voivode, towns with poviat rights, as well as other towns with more than 100,000 inhabitants) – presenting flood hazard areas with four water flow velocity zones (limit values: 0.5 m; 1 m; 2 m) and water flow directions;
2) Flood risk maps in two sets of themes:
   a) Flood risk maps – potential adverse consequences for human life and health and the value of potential flood damages;
   b) Flood risk map – potential negative consequences for the environment, cultural heritage and economic activity.

All types of cartographic versions of flood hazard maps are listed in Table 26.

An overview of all types of cartographic versions of flood risk maps is presented in Table 27.

Table 26. Types of cartographic versions of flood hazard maps

N.	Map title	Name of the pdf file with the cartographic version [SHEET EMBLEM_ [scenario indication_ version]	Example
1	FLOOD HAZARD MAP WITH WATER DEPTH AREAS WHERE THE PROBABILITY OF FLOODING IS MEDIUM – 1% (ONCE EVERY 100 YEARS)	Emblem_ZG_1_version	N34062Ab1_ZG_1_2019v1.pdf
2	FLOOD HAZARD MAP WITH WATER DEPTH AREAS WHERE PROBABILITY OF FLOODING IS HIGH – 10% (ONCE EVERY 10 YEARS)	Emblem_ZG_10_version	N34062Ab1_ZG_10_2019v1.pdf
3	FLOOD HAZARD MAP WITH WATER DEPTH AREAS WHERE PROBABILITY OF FLOODING IS LOW – 0.2% (ONCE EVERY 500 YEARS)	Emblem_ZG_02_version	N34062Ab1_ZG_02_2019v1.pdf
4	FLOOD HAZARD MAP WITH WATER DEPTH AREAS EXPOSED TO FLOODING IN THE EVENT OF TOTAL DESTRUCTION OF THE EMBANKMENT	scenario of total destruction of the embankment	
		Emblem_ZG_1WZ_version	N33060Aa1_ZG_1WZ_2019v1.pdf
5	FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AREAS WHERE THE PROBABILITY OF FLOODING IS MEDIUM – 1% (ONCE EVERY 100 YEARS)	Emblem_ZP_1_version	N34062Ab1_ZP_1_2019v1.pdf
6	FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AREAS WHERE THE PROBABILITY OF FLOODING IS HIGH – 10% (ONCE EVERY 10 YEARS)	Emblem_ZP_10_version	N34062Ab1_ZP_10_2019v1.pdf
7	FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AREAS WHERE THE PROBABILITY OF FLOODING IS LOW – 0.2% (ONCE EVERY 500 YEARS)	Emblem_ZP_02_version	N34062Ab1_ZP_02_2019v1.pdf

Table 27. Types of cartographic version of flood risk maps

N.	Map title	Name of the tiff file with the cartographic version [SHEET EMBLEM_ [scenario indication_ version]	Example
1	FLOOD RISK MAP – POTENTIAL ADVERSE CONSEQUENCES FOR HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS WHERE THE PROBABILITY OF FLOODING IS MEDIUM – 1% (ONCE EVERY 100 YEARS)	Emblem_RL_1_version	N34062Ab1_RL_1_2019v1.pdf
2	FLOOD RISK MAP – POTENTIAL ADVERSE CONSEQUENCES FOR HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS WHERE THE PROBABILITY OF FLOODING IS HIGH – 10% (ONCE EVERY 100 YEARS)	Emblem_RL_10_version	N34062Ab1_RL_10_2019v1.pdf
3	FLOOD RISK MAP – POTENTIAL ADVERSE ECONSEQUENCES FOR HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS WHERE THE PROBABILITY OF FLOODING IS LOW – 0.2% (ONCE EVERY 500 YEARS)	Emblem_RL_02_version	N34062Ab1_RL_02_2019v1.pdf
4	FLOOD RISK MAP – POTENTIAL ADVERSE CONSEQUENCES FOR HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS EXPOSED TO FLOODING IN THE EVENT OF TOTAL DESTRUCTION OF THE EMBANKMENT	scenario of total destruction of the embankment Emblem_RL_1WZ_version	N33060Aa1_RL_1WZ_2019v1.pdf
5	FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WHERE THE PROBABILITY OF FLOODING IS MEDIUM – 1% (ONCE EVERY 100 YEARS)	Emblem_RS_1_version	N34062Ab1_RS_1_2019v1.pdf
6	FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WHERE THE PROBABILITY OF FLOODING IS HIGH – 10% (ONCE EVERY 100 YEARS)	Emblem_RS_10_version	N34062Ab1_RS_10_2019v1.pdf
7	FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WHERE THE PROBABILITY OF FLOODING IS LOW – 0.2% (ONCE EVERY 500 YEARS)	Emblem_RS_02_version	N34062Ab1_RS_02_2019v1.pdf
8	FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS EXPOSED TO FLOODING IN THE EVENT OF TOTAL DESTRUCTION OF THE EMBANKMENT	scenario of total destruction of the embankment Emblem_RS_1WZ_version	N33060Aa1_RS_1WZ_2019v1.pdf

A detailed description of all types of maps, including titles and file names, is provided in Annex 3 *Description of the cartographic versions of flood hazard maps and flood risk maps*.

Tool to generate cartographic version of FHM and FRM

A Python application (version 2.6.5) is used to automatically save the cartographic version of FHM and FRM, which uses the API (arcpy) elements of ESRI ArcGIS 10.0 software.

The application allows to save ready map projects (files with the .mxd extension) to various graphic formats (.tif, .bmp, .pdf, .jpg, .gif, .ai, .emf, .eps, .png, .svg, and geotiff).

It has a graphical user interface (Fig. 65), by means of which you can easily define the parameters for saving files (Fig. 66, let. c). During operation, the application scans the indicated folder (Fig. 66, let. a) for *.mxd files and saves their graphic form in the result folder (Fig. 66, let. b). In order to save graphics with georeference from graphic format menu (Fig. 66c), select “GEOTIFF” option. The resulting graphic file will be limited to the map frame fixed in *.mxd file and the remaining pixels will be filled in white. To obtain files without a white frame, use “GEOTIFF_ MZPiMRP” option and indicate as source the directory with *.mxd files with suffix “_GEOTIFF”.

The automatically generated project *.mxd represents the spatial range of the corresponding FHM and FRM sheet in the current coordinate system, together with the non-blocking elements of the sheet and the map content. Moreover, on each FHM and FRM sheet, in accordance with the rules in force, cartographic editing is carried out – the distribution of labels of maximum ordinates of water level, ordinates of embankment tops, names of towns, chainage labels or names of surface waters with the direction of their flow. The cartographic editorial team also edits the non-blocking description – proper distribution of cartographic grid coordinates and descriptions inside the frame with administrative division.

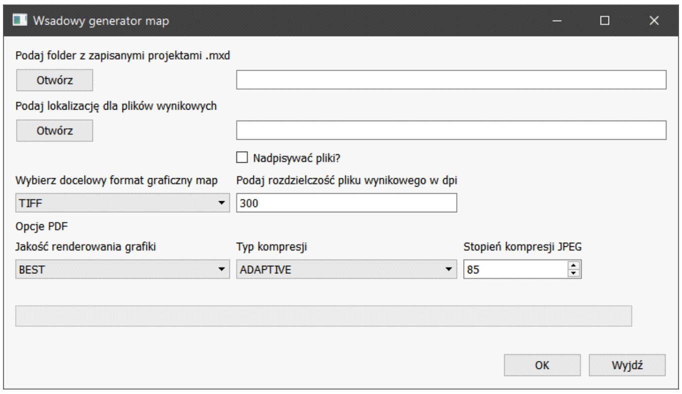


Fig. 65. Example of graphic user interface for FHM and FRM recording applications.

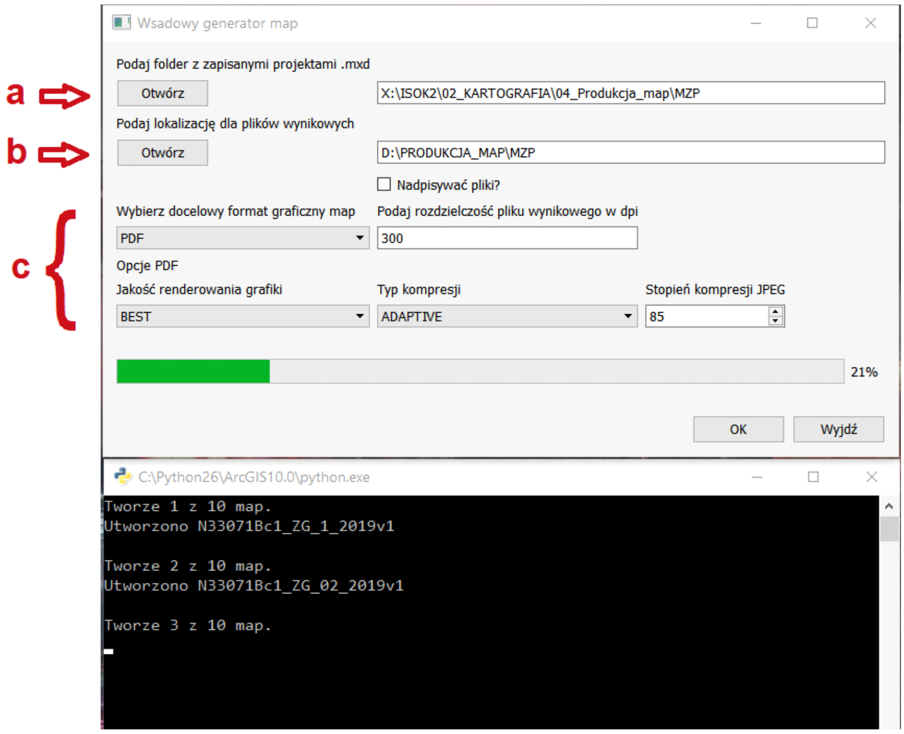


Fig. 66. Example of creating a cartographic version of FHM.

10. CHANGES IN THE DEVELOPMENT OF FHM AND FRM IN THE 2nd PLANNING CYCLE WITH REGARD TO HOW THE FHM AND FRM IN THE 1st CYCLE ARE DEVELOPED

The changes introduced in the preparation of flood hazard maps and flood risk maps in the second planning cycle are aimed at improving the process of map preparation, their publication and reporting to the European Commission, taking into account the timeliness and quality of available data. They result from experience in mapping and their publication in the first planning cycle.

The amendments concern in particular:

1) developing flood scenarios;
2) updating the input data for FHM development;
3) hydrodynamic modelling methodology;
4) designating flood hazard areas;
5) attributing structure of FHM layers;
6) elements of the cartographic version of the FHM;
7) updating the input data for FRM development;
8) attributing structure of FRM layers;
9) elements of the cartographic version of FRM.

10.1. DEVELOPMENT OF FLOOD SCENARIOS

Flood scenarios in the first planning cycle were developed in accordance with the Water Law Act of 18 July, 2001. (Journal of Laws of 2012, item 145, as amended and Journal of Laws of 2014, item 850), while in the second planning cycle – in accordance with the Water Law Act of 20 July, 2017. (Journal of Laws of 2020, item 310).

The Water Law Act of 2017 introduced a change in the name of the basic scenarios (I – III) and an additional scenario, i.e. areas exposed to the risk of flooding in the event of dam failure (Scenario V in the second planning cycle).

In addition, 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) introduced changes to the scenario of destruction or damage to the embankment/storm embankment.

In the first planning cycle the scenario of destruction or damage of the embankment was performed in two variants:

a) Destruction or damage of the embankment in selected section (for a flow with a 1% probability of occurrence),

b) Total destruction or damage of the embankment (for flow with 1% probability of occurrence).

The current Regulation establishes that the designation of flood-prone areas in the event of damage or destruction of the embankment shall take into account the total destruction of the embankment or storm barrier.

The scenario of embankment destruction in selected section, developed within the framework of the first planning cycle, did not allow a comprehensive presentation of the risk involved with embankment failure – because it is not possible to analyse all potential embankment damage sites. On the other hand, the scenario of total destruction of the embankment allows to determine the flood hazard in any location.

To develop a scenario of total destruction of flood embankments) two methods are used in the second planning cycle:

1) method I – using the maximum water level ordinates, resulting from modelling for scenario II (areas where the probability of flooding is average and amounts to 1%, i.e. once every 100 years). The ordinates of the water level calculated for the riverbed zone are transferred to the parallel area behind the flood embankment;
2) method II – carrying out hydraulic modelling in case of "flat" and vast river valleys or rivers, where the area on the embankment is significantly below the embankment. Modelling is carried out on the basis of the models prepared under scenario II (undetermined movement), after previous removal of the embankments (unilateral removal of the right and left embankments separately).

10.2. UPDATE OF INPUT DATA FOR THE DEVELOPMENT OF FHM

In the second planning cycle, as in the first cycle, the most up-to-date data available for the area are used to develop the FHM. In the case of maps developed in cycle I, the need to update the FHM, including the timeliness of the input data is determined at the review stage. Where new FHMs are developed, the most recent data available for the area is used. All necessary data and their timeliness in the first and second planning cycle are summarised in Table 28.

Table 28. Summary of input data necessary to develop the FHMs in the first and second planning cycle.

No.	Data	Name of institution/resource	Format	Update of data	
				First planning cycle	Second planning cycle
1	Orthophotomaps (field pixel size: 0.5 m; 0.25 m, 0.1 m)	Head Office of Geodesy and Cartography	*tif	2010-2013	2010-2018
2	State Border and Area Register of National Territorial Divisions (PRG)		*shp	2013	2018
3	National Register of Geographical Names (PRNG)		*shp	2013	2018
4	Topographical Object Database BDOT10k		*shp	2005-2013	2018
5	Digital Terrain Model (DTM) and Digital Surface Terrain Model (DSTM)		*xyz, *asc, *tif, *las, TIN *	2011-2014	2010-2018
6	Map index 1:10,000		*shp	2013	2013
7	Hydrological and meteorological data	Institute of Meteorology and Water Management – National Research Institute	*doc, *xls, *pdf, *pdf, *tif, *jpg and others*	1951-2010	1986-2016 (majority of stations)
8	Flood hazard areas for rivers, water depths, water velocities, water flow directions, maximum water level ordinates, embankment top ordinates in cross-sections, embankment damage or destruction sites, embankment overflow sites	In the first planning cycle: IMGW-PIB In the second planning cycle: IMGW-PIB/ARCADIS/MGGP	*shp	2012-2013	2018-2019

No.	Data	Name of institution/resource	Format	Update of data	
				First planning cycle	Second planning cycle
9	Current reservoir water management instructions/reservoir project or post-project documentation	State Water Holding Polish Waters Regional Water Management Boards	*xyz, *shp, *dwg, *asc, *dat, *pdf, *.doc	-	1998-2017
10	Data on flood embankments and water facilities	Voivodeship Water Management Boards of Meliorations and Water Facilities; Regional Water Management Boards State Water Holding Polish Waters	*xls, *doc, *jpg and others *	2011-2013	2018-2019
11	Execution/post-construction projects, data on investments having a significant impact on the extent of flooding		*xyz, *shp, *dwg, *dat, *pdf, *.doc	-	2009-2019
12	Results of the RZGW survey	State Water Holding Polish Waters	*.xls	-	2010-2019
13	Results of the ZMiUW survey		*.xls	-	2009 (10/11)-2019
14	Results of the General Directorate for National Roads and Motorways (GDDKiA)/PZD/WZD) survey		*.xls	-	2009-2019
15	Results of the railway authorities survey		*.xls, *.pdf, *.jpg	-	2009-2019
16	Results of the Maritime Offices survey		*.xls	-	2009/10-2019
17	Wet riverbed cross-sections with photo documentation and inventory of hydrotechnical and communication structures – developed within the ISOK project		*shp, *xls, *txt, *jpg, *pdf	2012-2013	2012-2013
18	Wet riverbed cross-sections with photo documentation and inventory of hydrotechnical structures, communication structures and flood embankments – developed within the aMZPiMRP project		*shp, *xls, *jpg, *pdf	-	2018-2019
19	Analysis of the current flood protection system for the development of flood risk management plans for river basin areas and water regions		*xls, *shp, *doc *	-	2013
20	Project data: Identification of pressures in water regions and river basin areas – Part I: Creating a national database on hydromorphological changes		geobase	-	2017
21	Map of Hydrographic Division of Poland MPHP10k		*shp	2010	2017
22	Execution/post-construction projects, data on investments having a significant impact on the extent of flooding	General Directorate for National Roads and Motorways/PZD/WZD Railway Authorities District Road Authorities Municipal Road Authorities Municipal Offices	*xyz, *shp, *dwg, *dat, *pdf, *.doc	-	2009-2019

In the second planning cycle a new methodology was applied to develop geodetic and hydrological data. In addition, in the second planning cycle, information on changes in the timeliness of the input data resulting from the survey and inventory of investments affecting the extent of flood hazard areas, as well as the applicable instructions for water management in reservoirs and project or post-project documentation of reservoirs were taken into account.

10.2.1. CHANGES IN GEODETIC DATA

Both in the first and second planning cycle direct measurements of wetland riverbed cross-sections and engineering objects were made in the National Geodetic Coordinate System 1992 (PUWG 1992) and in the Kronstadt 86 geodetic height system (PL-KRON86-NH). The main differences in methodological assumptions of the new geodetic data are presented in Table 29.

Table 29: Differences in development of new geodetic data between the first and second planning cycles.

No.	Differences in the execution of geodetic measurements	First planning cycle	Second planning cycle
1	Location of cross-sections	At distances not exceeding 500 m in a mountainous area and not exceeding 1500 m in a lowland area. In a 2D modelling area every 250 m.	At distances of no more than 500 m. In the area of 2D modelling every approx. 250 m.
2	Width of riverbed cross-sections	The riverbed cross-sections were measured in such way that, apart from the riverbed itself, they included a 5 m wide belt of land counting to the right and left of the upper edge of the riverbed edge slope towards the outside from the axis of the riverbed.	The riverbed cross-sections were measured in such way that, apart from the riverbed itself, they included a 20 m wide belt of land counting to the right and left of the upper edge of the riverbed edge slope towards the outside from the axis of the riverbed.
3	Location of riverbed cross-sections above engineering structures	Measurement of the riverbed cross-section in the top line of the object position.	Riverbed cross-sections located in the line above the upper position of the bridge facilities measured at a distance close to the width of the bridge light, in a place representative of the riverbed in this section.
4	Location of riverbed cross-sections in reservoirs and lakes	No measurement	Riverbed cross-sections were made in flow reservoirs and flow lakes perpendicularly to the river axis. In this case, the measurement of cross-sections on the stream before entering the lake and after the outflow from the lake was also considered. In the case of lakes or embanked reservoirs, the riverbed cross-section was ended about 10 m beyond the embankment or side dam. It was possible to reflect the bathymetry of lakes on the basis of the Polish Lake Atlas. Moreover, it was allowed to reflect the capacity of the reservoirs on the basis of the reservoir capacity curve from the Water Management Manual.
5	Location of riverbed cross-sections at the lower stand of hydrotechnical structures	For facilities with a fixed slope and threshold height greater than or equal to 1.0 m. Additionally, in the situation where the ordinates of the upper post bottom were lower than the ordinate of the overflow threshold top by at least 1.0 m, a cross-section was additionally mapped in the line of the structure of the object (i.e. in the overflow line)	For steps and weirs with fixed slope and overflow threshold height $H \geq 1{,}5$ m and for all anti-debris barriers
6	Additional measurements on damming structures	In the situation where the ordinates of the upper post bottom were lower than the ordinate of the overflow threshold top by at least 1.0 m, the cross-section was additionally mapped in the line of the object construction (i.e. in the overflow line); Determining the main points of the cross-sections by the modeller, in the case of	No measurement

No.	Differences in the execution of geodetic measurements	First planning cycle	Second planning cycle
		wide and deep rivers, on which the boat measurement was carried out using hydroacoustic or classical methods (depth above 1 m).	
7	Measurements of objects located at short distances from each other	No guidelines	In the case of a sequence of consecutive bridge objects (footbridges, culverts) at distances of less than 100 m, the first and last of the objects were measured. Notwithstanding the above, for each of the objects a picket was measured at the lowest point of the riverbed/culvert and the light size/diameter of the culvert was determined

In addition to new geodetic measurements, both in the first and second planning cycle, the geodetic data from other projects and flood protection studies are used.

In the first cycle geodetic measurements from the flood protection studies were used only in the area of the proper riverbed of the modelled rivers, valley cross-sections were obtained on the basis of the current DTM. Additional data sources included:

- wet riverbed cross-sections carried out as a part of the “Comprehensive flood protection of Żuławy – until 2030” project (RZGW in Gdansk, measurements made in 2012);
- geodetic measurements from the flood protection study of the Kłodzko Basin with particular emphasis on the city of Kłodzko (Regional Water Management Board in Wroclaw, measurements made in 2002);
- study of protection against flooding of the drainage basin of the Kłodzko Nysa river basin below the Bardo water signpost (RZGW in Wroclaw, measurements made in 2004);
- Study of flood protection in the Bystrzyca river basin (RZGW in Wroclaw, measurements made in 2006);
- Study of flood protection in the Kaczawa river basin (RZGW in Wroclaw, measurements made in 2004);
- Study of flood protection in the Górny Bóbr river basin (RZGW in Wroclaw, measurements made in 2004);
- Study of flood protection in the Kwisa river basin (RZGW in Wroclaw, measurements made in 2004).

In the second planning cycle, geodetic measurements were made for newly developed river sections and some of the updated river sections for which a review of the input data revealed the need for updating. Additionally, ready geodetic data were used:

- riverbed sections: Brennica, Przemsza river basin (RZGW in Wroclaw: measurements made in 2010, 2014 and 2016; MGGGP: measurements made in 2018 in sections 0.000-4.888
and 12.200-15.000);
- as-built sections acquired as a part of the modernisation of the Wroclaw Water System (measurements made in 2018);
- riverbed cross-sections obtained under API development (measurements made in 2015);

- wet riverbed cross-sections made as part of the "Comprehensive flood protection of Żuławy – until 2030" project, including the stage 2015 (Regional Water Management Board in Gdansk, measurements made in 2012);
- wet riverbed cross-sections with photo documentation and inventory of hydrotechnical and communication structures – developed under the ISOK project (measurements made in 2012-2013);
- Riverbed and bridge cross-sections for the Lower Vistula section made as a part of the "Analysis of the adaptation of the Vistula River from Wloclawek to the mouth of the Gulf of Gdansk large and small cascade – modelling" (measurements made in 2016-2017);
- riverbed cross-sections and water structures, digital terrain model, orthophotomaps, the Nysa Łużycka river (measurements made in 2009-2010);
- bridge cross-sections and water structures of the Nysa Kłodzka – Nysa Kłodzka basin and its tributaries (measurements made in 2017).

10.2.2. CHANGES IN THE DEVELOPMENT OF HYDROLOGICAL DATA

Differences in the methodology of developing hydrological data in the first and second planning cycle refer to:

1) annual maximum flow rates with a set probability of exceedance in controlled catchments for water gauge station cross-sections,
2) hypothetical waves for the cross-section of water gauges.

Within cycle I maximum annual flows with a specified probability of exceedance for the catchment areas controlled in the cross-sections of water gauge stations were calculated in accordance with the methodology in force at IMGWM-PIB with the use of the FlowsMax 2011 programme (Regulation No. 57/2011 of the IMGW-PIB Director of 20 October, 2011 on calculation of maximum flows with a specified probability of exceedance). Calculation of maximum annual flows with a given probability of exceeding was carried out by means of selection of probability distribution, the parameters of which were estimated with the highest reliability method. The following distributions of the description of maximum annual flows were adopted: Persona III type, Log-normal Gumbel (Fisher-Tippett I type), GEV (Generalised Extreme Values).

The input data were the maximum annual flows observed at the water gauge stations from the years 1951-2010. In the case of observation series shorter than the assumed 60 years, further analyses were carried out for a period of at least 30 years, due to the assumption that the number of observations is to constitute a long series of flows and cannot be less than 30 years. The study of the homogeneity of strings played an informative role in the examined strings, and in the case of indicating the heterogeneity of the examined strings, the time series was analysed, in particular the factors influencing the course of the execution of the examined flows (random variables), and the elements of strings were checked for possible errors. Corrected measurement sequences were the basis for further calculations. The compatibility study of maximum annual flows was carried out in relation to the following distributions: a) Persona III type, b) Log-normal c) Gumbel (Fisher-Tippett
I type), d) GEV (Generalised Extreme Values). The estimation of unknown decomposition parameters was performed using the highest reliability method. In Person III type distribution and Log-norm for given lower limit (value smaller than the last word of decreasing order of distribution string) the parameter was selected so that Akaike information criterion was

minimized. One-sided confidence interval for the quantile distribution of maximum annual flows was determined using Rao-Cramer information imbalance on the basis of estimators determined by the highest reliability method. For catchments where the sea impact was taken into account, the water level with a certain probability of exceedance was determined by additionally analysing the increase in level caused by the sea impact in the estuaries – the wave run on the estuary sections of rivers. Wave heights in estuarial river sections were determined. A safety margin was adopted, which includes: oscillations/variations of 5 cm + 10 cm wavelength. In case there is a port additionally protected by a breakwater in the estuary these values were reduced.

In the second planning cycle flows with a defined probability of exceedance are calculated on the basis of the methodology for calculating flows and maximum precipitation with a defined probability of exceedance for controlled and uncontrolled catchment areas and identification of precipitation to outflow transformation models, prepared by the Polish Hydrologists Association (2017). The initial (default) Pearson III type distribution is assumed. In justified cases other distributions may be used.

The input data are the maximum annual flows observed at the water level stations from 1986-2016. The flows have been updated and are subject to a homogeneity test of the time series of maximum annual flows using the Mann-Kendall test to check for the non-existence of a monotonic trend with a correction for the occurrence of recurring elements. If a non-homogeneity of the tested sequence is found, the time series is analysed, in particular the factors influencing the course of the tested flows (random variables), and the elements of the sequences are checked for possible errors. Corrected measurement strings are again subjected to the homogeneity test. In the absence of errors, a homogeneous sequence of at least 30 years is extracted from the entire sample, which is the basis for further calculations. In special cases, the quality of Pearson III type distribution shall be compared with that of other theoretical non-compliant distributions. Verification of inconsistencies of theoretical distributions with empirical distributions shall be carried out by means of compliance tests. The AIC criterion allows for the selection of one of the most reliable functions from the group of considered non-compliant distributions. This criterion is the basis for indicating cases in which it was justified to adopt a different probability distribution than the default one. This is used in cases where other distributions better describe the statistical properties of maximum flow sequences.

Hypothetical waves in the first planning cycle for cross-sections of water signalling stations were developed using the method of the Department of Hydrology and Water Management of the Warsaw University of Technology [“Examples of hydrological calculations for water-melioration studies. Study Paper no. 126. CBSiPWM”, Warsaw, 1971]. The basis for the study of hypothetical waves were flow hydrographs from a multi-annual observation period and extraordinary observations. It is recommended to choose at least 6 of the largest floods including extraordinary observations, which are the basis for the construction of hypothetical waves. The data required for each of the floods: (i) the hydrograph of flows from the flooding period, (ii) a compilation of extraordinary observations covering the flooding period, (iii) the initial flow (wave base) – the flow from which a continuous and intense increase in flows begins, (iv) the maximum flow of the flood, (v) the time of the wave rise (time from the beginning of the wave to its culmination).
The parameters describing the waves are:

Q0 – initial flow, m³/s
Qs – maximum flow of the flood, m³/s
Ts – time of wave rise, hr.
The calculations were carried out in the following steps:

1. Selection of actual waves;
2. Standardisation of waves – carried out in two stages: with respect to time and flow;
3. Construction of reference wave based on standardised values of time and flow;
4. Calculation of hypothetical waves with maximum flow with a given probability of exceedance based on Qpp and reference hypothetical wave.

In the second planning cycle hypothetical hydrographs with peak flows corresponding to maximum annual flows with a given probability of exceeding in controlled and uncontrolled cross-sections are developed using mathematical models of precipitation to outflow transformation. In justified cases, the waves are developed using the Strupczewski method, on the basis of the observed historical abstraction waves. Typical hydrography with a specific probability of exceeding the culmination flow for watercourses leading water only after precipitation and with small retention, it takes shape:

$$Q_t = Q_{max.p}\left\{\left(\frac{t}{t_s}\right)^m e^{\left(\frac{m}{n}\right)\left[1-\left(\frac{t}{t_s}\right)^n\right]}\right\}$$

where:
Q_t – flow over time t since the beginning of the flood, m³/s,
$Q_{max.p}$ – maximum flow with a given probability of exceedance, m³/s,
t_s – time of the (rising) wave, hour,
t – the time counted from the accepted beginning of the call wave, an hour,
$m,\ n$ – wave form parameters,
e – the basis of the natural logarithm.
The time of the exceedance was determined according to “Update of methodology...”: the culmination time of a hypothetical hydrograph is functionally (power dependence) dependent on the size of the culmination flow. Developed Strupczewski waves (for p = 10%, p = 1% and p = 0.2%) can be presented as scaled (dimensionless) reference waves in a dimensionless system, where the value of 1 corresponds to the culmination flow time).

10.2.3. DATA ON INVESTMENTS AFFECTING THE EXTENT OF FLOOD HAZARD AREAS

The basis for reviewing and updating FHMs and FRMs developed in the second planning cycle and new maps is an inventory of investments affecting the extent of flood hazard areas. The inventory includes significant investments which were made in the period between the development of maps in the first and second cycle and were completed by the end of 2019. As a part of the inventory, comments to FHMs and FRMs made in the first planning cycle by municipalities, institutions and society were also analysed.

The data on investments that may have a significant impact on the change in flood hazard was the result of a survey of local government institutions and units (communes, poviat starosties):

- Regional Water Management Boards (RZGW),
- Regional Boards of Land Facilities and Water Management (ZMiUW),

- Maritime Offices (UM),
- Voivodeship Road Authorities (VRA),
- District Road Authorities (DRA),
- General Directorate for National Roads and Motorways (GDDKiA),
- Railway Authorities.

In addition, data on investments submitted during the Review and update of the WORP project were analysed. Within the framework of this project questionnaires were addressed to:

- municipalities: including municipal offices, town halls, town and commune offices;
- poviat starosties;
- land facilities and water management;
- voivodeship fire brigades and the National Fire Service Headquarters;
- water supply and wastewater plants;
- crisis management centres.

The results of the stocktaking are the basis for determining the timeliness of the input data for hydraulic modelling of newly developed maps and the timeliness of FHM made in the first planning cycle. In the case of a significant impact of the investment on the extent of the flood hazard area and outdated input data for modelling, these data are updated in accordance with the submitted investment documentation. The following activities are carried out:

- updating the ordinates of the digital terrain model;
- updating the valley cross-section geometry;
- taking into account new hydrotechnical facilities;
- changes in parameters of hydrotechnical objects.

10.3. CHANGES IN MATHEMATICAL HYDRODYNAMIC MODELLING

10.3.1. FLOODPLAINS SCHEMATIZATION

Changes in the floodplain schematization in hydraulic models mainly concern the way of reflecting the flow of water in embanked areas.

In the first planning cycle for the part of embanked rivers in model 1D, the calculations were limited to the area of the inter-embankment, and the ordinates determined in this way corresponded to the required capacity of the inter-embankment for flows with a certain probability of occurrence. This took place in cases when:

- there was no overflow of water through the embankment top,
- there was no overflow of water through the embankment top, but the water was flowing through the embankment from adjacent not embanked sections, if the overflow was over 2 km from the mouth of the river,
- there was an overflow of water through the embankment top, and at the same time a scenario of destruction or damage to the embankment in a 2D or hybrid model was performed or planned.

In the second planning cycle, in the case of water inflow into the area from not embanked sections or water overflowing through the embankment top, floodplains were determined obligatorily (without the possibility of limiting the active cross-section in the model to the width of the embankment spacing).

10.3.2. DETERMINATION OF ROUGHNESS COEFFICIENTS

Changes in relation to the first planning cycle included the way of assigning roughness coefficients in cross-sections. In the first planning cycle the preliminary values of roughness coefficients of Manning or Manning-Strickler were expertly accepted according to Ven Te Chow tables, taking into account the variability of shapes and dimensions of cross-sections, local obstacles in riverbeds, irregularities and curves of the horizontal river system. The most common method of defining roughness coefficients was the *High/Low flow zones* method with division into main riverbed and floodplain.

In the second planning cycle, the methods of defining and determining the values of the coefficients have been clarified. For individual land cover codes from BDOT10k and codes of watercourse bottom cover (assigned during geodetic measurements) specific values of roughness coefficients were assigned. Additionally, two methods of defining the transverse variability of the roughness coefficient in cross-sections were allowed:

1) medium roughness coefficient method with a division into main riverbed and floodplains (*High/Low flow zones)*, where roughness coefficients should be established separately for each of the terraces (left, right) and main riverbed. In each cross-section, the coefficient of roughness averaged over the mid-distance section of the terraces to the adjacent cross-sections shall be taken. Its value should be determined as a weighted average of the different land uses and the corresponding roughness coefficient values;
2) variable in cross-section roughness coefficient (*Distributed*) method, where the roughness coefficients corresponding to the coverage codes of the individual points of cross-section shall be taken. To determine the coverage codes in the main riverbed, geodetic measurements were used, while for flood terraces – BDOT10k.

The roughness coefficient values taken into account shall be subjected to the necessary correction in the process of calibration and verification of the models at the sections requiring this process.

In addition, in the second planning cycle, where coverage codes were not representative for the terrain between the cross-sections, additional cross-sections were introduced, whose shape and roughness coefficients for floodplains resulted from DTM and BDOT10k and from interpretation of information from orthophotomaps.

10.3.3. DEFINITION OF BOUNDARY CONDITIONS

The main change between the models developed in the first and second planning cycle is primarily the type of calculation used (steady/unsteady flow).

In the first planning cycle, fixed flow values (steady flow calculations) were given as upper and inner boundary conditions for the baseline scenarios for most rivers. Hydrographs of flows (steady flow calculations) were used in a few cases: for areas exposed to flooding from the sea, for scenarios of damage or destruction of embankments and protective structures of the technical belt.

In the second planning cycle, the calculations of all flood scenarios were carried out with an unsteady flow. Upper boundary conditions are defined in the form of hydrographs, based on hypothetical waves, whose culmination corresponded to the values of flows with a certain probability of occurrence. Internal boundary conditions (concentrated and distributed) are given in the form of flow hydrographs. If a precipitation-drainage model was developed for the modelled catchment, the results of this model were used to develop boundary conditions. A deviation from the application of transient traffic calculations in the second planning cycle was adopted for updated hydraulic models of the Oder river.

Lower boundary conditions in the first planning cycle are assumed in a fixed or variable form during the ordinate of the water level. The difference in defining the lower boundary condition between the first and second planning cycles results from the use of unsteady flow, as a result of which, for most rivers of the second cycle a hydrograph of water level ordinates for the receiver is introduced into the model as the lower boundary condition. The exception is the case of estuaries to rivers modelled in the first cycle, for which no update has been made.

10.3.4. INTRODUCTION OF WATER RESERVOIRS

An important change in the preparation of hydraulic models in the second planning cycle is the inclusion of the operation of water reservoirs in the hydraulic models. In the first planning cycle these objects were taken into account in a simplified manner. In cycle II water reservoirs are included in hydraulic models by reflecting the geometry of reservoir bowl and dams, calibration of capacity curves and implementation of the principles of controlling the outflow from reservoirs. The basis for including water reservoirs in hydraulic models is information contained in the current water management manuals.

10.3.5. CHANGES IN THE DEVELOPMENT OF 2D AND 1D/2D MODELS

The changes concerning the development of 2D and 1D/2D models between the first and second planning cycles are mainly related to:

- preparation of one-dimensional 1D models for hybrid 1D/2D modelling. In the second planning cycle in one-dimensional models the distances between the cross-sections should not exceed ca. 50 m. Additional cross-sections in the riverbed part were interpolated using MIKE 11 or equivalent procedures and outside the riverbed part were determined on the basis of DTM and BDOT10k. In the first planning cycle distances of about 250 m were used.
- taking into account buildings in the 2D model. In the first planning cycle the buildings were reflected in 2D models in the form of appropriate values of coefficients on the roughness grid. In the second planning cycle an additional possibility is to separate buildings from the digital surface terrain model (DSTM) or BDOT10k and implement them into the DTM developed for mathematical modelling (model bathymetry).

10.3.6. CALIBRATION AND VERIFICATION

The changes concerned the calibration parameters and the acceptable differences of these parameters.

In the first planning cycle the following elements were used:

- Correlation coefficient (R);
- Culmination error (ΔH_{max});
- Peak flow error (ΔQ_{max});
- Culmination shift (Δt_{max});
- Flood wave volume error (ΔV_{max}).

In the second planning cycle, apart from the above, the additional parameters are:

- Special correlation coefficient (R_s);
- Total square error (CBK);

In the first planning cycle the acceptable differences in calibration parameters were determined, while in the second planning cycle the parameter values were divided into 5 classes: “excellent”, “very good”, “good”, “quite good” and “unsatisfactory”. For the calibration for each criterion, the model must be rated “excellent”, “very good” or “good”. For the verification for each criterion, the model must be rated “excellent”, “very good”, “good” or “fairly good”. The table below summarises the limit values for calibration parameters in the first and second planning cycle. Changes in the acceptable differences in calibration and verification parameters between the first and second planning cycle are shown in Table 30.

Table 30: Changes in acceptable differences in calibration and verification parameters between the first and second planning cycles.

Acceptable parameter differences	First planning cycle	Second planning cycle
For calibration	R for Q and H> 0.98; ΔHmax = 10 cm; ΔQmax = 10%; Δtmax = 12h; ΔVmax = 10%	a "good" rating R for Q and H ≥ 0.8; ΔHmax = 15 cm; ΔQmax = 10%; Δtmax = 1.5h; ΔVmax = 10%; Rs for Q and H ≥ 0.85; CBK for Q and H < 10%
For verification	R for Q and H> 0.96; ΔHmax = 20 cm; ΔQmax = 10%; Δtmax = 12h; ΔVmax = 10%	a "pretty good" rating R for Q and H> 0.7; ΔHmax = 20 cm; ΔQmax = 25%; Δtmax = 2h; ΔVmax = 25%; Rs for Q and H ≥ 0.7; CBK for Q and H < 25%

Information on changes in the development of hydraulic models between the first and second planning cycles is presented in Table 31.

Table 31: Differences in the development of hydraulic models between the first and second planning cycles.

N.	Differences in the preparation of hydraulic models	First planning cycle	Second planning cycle
1	Schematization of floodplains behind	The active cross-section can be limited to the width of the embankment spacing in	In the case of water inflow to the site from unencapsulated sections or overflow of

N.	Differences in the preparation of hydraulic models	First planning cycle	Second planning cycle
	embankments	specific cases.	water through the embankment top, delimitation of floodplains as separate water flow routes.
2	Determination of roughness coefficients	Preliminary values of the Manning or Manning-Strickler roughness coefficients expertly accepted according to Ven Te Chow tables	Initial values of roughness coefficients on the basis of values assigned to land cover codes (on the basis of BDOT10k) and to the bottom cover codes (on the basis of geodetic measurements). Possible 2 methods of defining the lateral variability of the roughness coefficient in cross-sections (*High/Low flow zones and Distributed*)
3	Type of calculation and way of defining upper and lower boundary conditions	For baseline scenarios, steady motion calculations and boundary conditions in the form of constant Q-values or unsteady flow and boundary conditions in the form of hypothetical hydrographs that culminated in flow values with a defined probability of occurrence for scenarios IV and V.	Transient traffic calculations for all flood scenarios; upper and inner boundary conditions in the form of hypothetical hydrographs which culminated in flow values with a certain probability of occurrence.
4	Way of defining the lower boundary conditions	Fixed water level ordinate or hydrograph of water level ordinates.	Hydrograph of water level ordinates (in estuary sections) or fixed water level ordinate in case of estuaries to rivers modelled in cycle I for which no update has been made
5	Introduction of water reservoirs	Water reservoirs taken into account in a simplified manner	Introducing and incorporating the operation of water reservoirs in hydraulic models in accordance with current water management instructions
6	Preparation of 1D models for 1D/2D hybrid modelling.	The distances between the cross sections did not exceed about 250 m.	The distances between the cross sections did not exceed approx. 50 m.
7	Taking into account buildings in the 2D model	The corresponding values of the coefficients on the roughening grid.	Appropriate values of coefficients on the roughness grid or extracting buildings from the numerical land cover model (NMPT) or BDOT10k and implementing them into the model bathymetry.
8	Calibration and verification parameters	Correlation coefficient (R); Climbing state error (ΔHmax); Peak flow error (ΔQmax); Offset of the culmination (Δtmax); Error in the volume of the abstraction wave (ΔVmax).	Correlation coefficient (R); Special correlation coefficient (Rs); Total square error (CBK); Climbing state error (ΔHmax); Peak flow error (ΔQmax); Offset of the culmination (Δtmax); Error in the volume of the abstraction wave (ΔVmax).
9	Permissible differences in calibration parameters	R for Q and H> 0.98; ΔHmax = 10 cm; ΔQmax = 10%; Δtmax = 12h; ΔVmax = 10%	When calibrating for each criterion, the model must be rated "excellent", "very good" or "good".
10	Permitted differences in verification parameters	R for Q and H> 0.96; ΔHmax = 20 cm; ΔQmax = 10%; Δtmax = 12h; ΔVmax = 10%	For verification of each criterion, the model must be rated "excellent", "very good", "good" or "fairly good".

10.4. DETERMINATION OF FLOOD HAZARD AREAS

The main changes in the delimitation of flood hazard areas between the first and second planning cycles concern the generation of the digital water surface model (DWSM) raster, the delimitation of flood hazard areas and depth zones. Synthetic information on methodological changes is presented in Table 32.

Table 32. Changes in the delimitation of flood hazard areas between the first and second planning cycles.

First planning cycle	Second planning cycle
Generating a numerical water surface model (NMPW) raster	
Interpolation using ANUDEM algorithm (Hutchinson 1989 – Topo To Raster function in ArcGIS) Triangulation process (TIN model) with conversion to raster	Interpolation by TIN. Interpolation controlled by appropriate section density and selection of cross-section lengths. Taking into account, in the process of DWSM generation, linear objects separating the main riverbed from floodplains.
Designation of flood hazard areas and depth zones	
In the process of generalization of vector water depth classes, the polygons with an area of less than 200 m² are aggregated to adjacent, larger polygons. If there is no neighbour, the polygon not meeting the surface criterion is removed. An analogous approach is used for small (less than 200 m²) “holes” and “islands” within the depth classes.	In the process of generalization of vector water depth classes, the polygons with an area of less than 400 m² are aggregated to adjacent, larger polygons. In case of lack of a neighbour, the polygon not meeting the surface criterion is removed. An analogous approach is used for small (less than 400 m²) “holes” and “islands” within the depth classes.
Not applicable.	Supplementation of flood hazard areas in the areas of planned polders (as a result of the notification of the RZGW).
Smoothing of borders with the Smooth Polygon tool using the PEAK (Polynomial Approximation with Exponential Kernel) algorithm; smoothing of lines by using the square function and the weighted average for coordinates of all input points along the length of the so-called “moving segment” corresponding to the smoothing tolerance. The smoothing tolerance was experimentally assumed as 20 m. The maximum point displacement it can cause does not exceed 5 m. Repeat the process of elimination of polygons (aggregation to larger neighbours) of less than 200 m²	Simplification of the geometry of depth and flood hazard areas (elimination of “teeth” and “loops” structures). The edge of the polygon is smoothed in order to eliminate the effect of sharp bends. Subsequently, the depth polygon is generalised. The generalization parameters are selected in such way as to limit the size of vector data while maintaining data quality. Generalization of depth polygons to reduce the size of files and number of vertexes using the ET Geowizard – Generalize Polygons tool with parameter 0.5 or using 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 ISOK is no more than 0.5 meters.

10.5. UPDATE OF THE ATTRIBUTE STRUCTURE OF FHM DIGITAL LAYERS

The main changes in the attribute structure of the layers used in the first and second planning cycle result from the separation of databases for different types of floods in the second planning cycle (separation of the database for FHM from the sea water) and a change in the assumptions for developing an embankment destruction scenario (only the embankment destruction scenario remains).

The main changes in the attribute structure of the layers between cycle I and II are shown in Table 33. These relate to the reference layers and the MPP layers.

Table 33 Changes in the attribute structure between the first and second planning cycles.

Layer	First planning cycle	Second planning cycle
Reference layers		
watercourses_canals	– data source: BDOT/BDOT10k (name and identifier from BDOT) – no connection to the MPHP database (no identifiers and name)	– data source: MPHP 1:10,000 – (name and identifier from MPHP) – no connection to the PRNG and BDOT/BDOT10k database

Layer	First planning cycle	Second planning cycle
		(no identifiers and name) – extended classification in attribute TYPE – WIDTH attribute in 4 compartments – extended PERFORMANCE attribute
watercourses_other	– data source: BDOT/BDOT10k – TYPE attribute – WIDTH attribute – PERIODITY attribute	– data source: MPHP 1:10,000 – no connection to the BDOT/BDOT10k database (no badges)
surface waters	– data source: BDOT/BDOT10k (name and identifier from BDOT) – no link to the MPHP database (no identifiers and name)	– data source: BDOT10k (objects related to BDOT10k via IIP identifiers) – Binding to MPHP database attributes ID_HYD_R, NAME_MPHP – no connection to the PRNG database (no identifiers and name)
roads	– data source: BDOT/BDOT10k (name and identifier from BDOT	– data source: BDOT10k (objects related to BDOT10k via IIP identifiers)
railways	– data source: BDOT/BDOT10k (name and identifier from BDOT)	– data source: BDOT10k (objects related to BDOT10k via IIP identifiers)
voivodeship		– objects related to PRG through IIP identifiers
poviat		– objects related to PRG through IIP identifiers
municipality		– objects related to PRG through IIP identifiers
box_sheet		– attributes defining the version of the FHM and the FRM
Layers of FHM		
area_threats_pow_rivers	– areas for individual scenarios on one layer, embankment destruction scenario	– areas for each scenario divided into separate layers – no integrated layer_area_zagr_pow _reg_water – no integrated layer_area_zagr_ob basins – no attribute TYP_P_ZR – type floods due to source
depth_WZZ, velocity_WZ, flow_directions_WZ,	– soil depth_W1, soil depth_W2, soil depth_W3, water depth for the embankment damage scenario	– layers not having an equivalent in cycle I
max_previous_waters	– no name from MPHP database – ordinate for the embankment damage scenario	– no link to the PRNG database (no identifiers and name) – ordinate for the WZ script – attribute TERASA_ZAL
floodplains_front	– no name from MPHP database	– no link to the PRNG database (no identifiers and name)
floodplains	– no link to the MPHP database (no badges) – no link to the PRNG database (no name)	– no connection to the BDOT10k database (no badges) – TYPE attribute – no link to the PRNG database (no badges)
the_population_sites_water_1 0, the_placement_water_1, the_placement_water_02,	– no link to the MPHP database (no identifiers and name) – geometric representation of objects in the form of lines and points	– renaming of layers – no link to the PRNG database (no identifiers and name) – geometric representation of objects in the form of lines
total_destroy_value	– Destroy the valley,	– a layer with no equivalent in cycle I

Layer	First planning cycle	Second planning cycle
	– Destroy_damage_wallet_p – place of embankment damage in case of embankment failure	

10.6. DIFFERENCES IN THE DEVELOPMENT OF THE CARTOGRAPHIC VERSION OF FHM

The differences in the development of the cartographic version of the FHM between the first and second planning cycles concern the elements that make up the content of the map, explanations of signs and extra-lock elements. The differences are presented in Table 34.

Table 34: Changes between the first and second planning cycles concerning the elements that make up the content of the map, sign explanations and extra-bank elements for all types of MHPs.

First planning cycle	Second planning cycle
Differences in the elements that make up the map content	
– side dam included with embankments	– side dam is specified
– embankment top ordinate	– top ordinate of the embankment or lateral dam
– the place of hypothetical destruction or damage of the embankment (for the "flood-prone areas in event of embankment failure" scenario)	– place of destruction of the embankment or side dam (for maps in the scenario of total destruction of the embankment)
– the place of overflow of water, in particular through the flood embankment	– the place where the water spills through the flood embankment or side dam
Differences in sign explanations	
The sign was not present	zapora boczna
75,15 rzędna korony wału przeciwpowodziowego	75,15 rzędna korony wału przeciwpowodziowego lub zapory bocznej
miejsca przelania się wód w szczególności przez wał przeciwpowodziowy	miejsce przelania się wody przez wał przeciwpowodziowy lub zaporę boczną
całkowite zniszczenie wału przeciwpowodziowego	miejsce zniszczenia wału przeciwpowodziowego lub zapory bocznej
obszar zagrożenia powodziowego, przy wyznaczaniu którego przyjęto przepływ o średnim prawdopodobieństwie wystąpienia powodzi wynoszącym raz na 100 lat (Q 1%)	obszar zagrożenia powodziowego, przy wyznaczeniu którego przyjęto przepływ o prawdopodobieństwie wystąpienia 1% (raz na 100 lat)
sieć rzeczna	cieki naturalne i kanały
Differences in non-blocking elements	
Map title: FLOOD HAZARD MAP WITH WATER DEPTH AREAS WITH A MEDIUM PROBABILITY OF FLOODING ONCE EVERY 100 YEARS (Q 1%)	Map title: FLOOD HAZARD MAP WITH WATER DEPTH AREAS WITH A MEDIUM PROBABILITY OF FLOODING OF 1% (ONCE EVERY 100 YEARS)

First planning cycle	Second planning cycle
FLOOD HAZARD MAP WITH WATER DEPTH AREAS WITH A HIGH PROBABILITY OF FLOODING ONCE EVERY 10 YEARS (Q 10%) FLOOD HAZARD MAP WITH WATER DEPTH AREAS WITH A LOW PROBABILITY OF FLOODING ONCE EVERY 500 YEARS (Q 0.2%) FLOOD HAZARD MAP WITH WATER DEPTH AREAS EXPOSED TO FLOODING IN CASE OF TOTAL DESTRUCTION OR DAMAGE TO THE EMBANKMENT Additionally, above the logotypes there is an information: Scenario of total destruction of flood embankments FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AND DIRECTIONS OF WATER FLOW AREAS WHERE THE LEGAL SIMILARITY OF THE OCCURRENCE OF FLOODS IS MEDIUM AND IS ONCE EVERY 100 YEARS (Q 1%) FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AND DIRECTIONS OF WATER FLOW AREAS WITH A HIGH PROBABILITY OF FLOODING ONCE EVERY 10 YEARS (Q 10%) FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AND DIRECTIONS OF WATER FLOW AREAS WITH A LOW PROBABILITY OF FLOODING ONCE EVERY 500 YEARS (Q 0.2%)	FLOOD HAZARD MAP WITH WATER DEPTH AREAS WITH A HIGH PROBABILITY OF FLOODING OF 10% (ONCE EVERY 10 YEARS) FLOOD HAZARD MAP WITH WATER DEPTH AREAS WITH A LOW PROBABILITY OF FLOODING OF 0.2% (ONCE EVERY 500 YEARS) FLOOD HAZARD MAP WITH WATER DEPTH AREAS EXPOSED TO FLOODING IN THE EVENT OF TOTAL DESTRUCTION OF THE EMBANKMENT FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AREAS WITH A MEDIUM PROBABILITY OF FLOODING OF 1% (ONCE EVERY 100 YEARS) FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AREAS WITH A HIGH PROBABILITY OF FLOODING OF 10% (ONCE EVERY 10 YEARS) FLOOD HAZARD MAP WITH WATER FLOW VELOCITY AREAS WITH A LOW PROBABILITY OF FLOODING OF 0.2% (ONCE EVERY 500 YEARS)
– data frame defined as a “sheet layout” with the range of the main data frame marked, – sheet division of topographic maps at a scale of 1:10,000, in a rectangular flat coordinate system EN-1992, – a basic three-stage territorial division of the country.	– data frame defined as “sheet layout” with the range of the main data frame marked, – sheet division of topographic maps at a scale of 1:10,000, in a rectangular flat coordinate system EN-1992, – a basic three-stage territorial division of the country, – the area of activity of organisational units of the State Water Holding Polish Waters: regional water management boards and catchment area boards.
– logotypes: Innovative Economy sign (National Cohesion Strategy), National Water Management Board, European Union sign (European Regional Development Fund, National Fund for Environmental Protection and Water Management sign, Institute of Meteorology and Water Management – National Research Institute sign	– Logotypes: sign of the European Fund (Infrastructure and Environment), sign of the State Water Holding Polish Waters, sign of the European Union (Cohesion Fund),
– lack of information	– information on the authorities competent to draw up and map approvals
– information on the map's contractor directly next to the logotype	– information about the map contractor under logotypes
– reservation on the reproduction and use of the map	– lack of information
Differences in file formats	
– for files with extra-branch descriptions tif format	– for files with extra-brand descriptions, the format has been changed to pdf

10.7. UPDATE OF INPUT DATA FOR FRM DEVELOPMENT

All flood risk maps developed in the first planning cycle are subject to updating due to input data update. In the second planning cycle the following data were used with topicality years: 2018-2019. A comparison of the materials used and their timeliness is presented in Table 35.

Table 35 Comparison of data used for the purpose of FRM.

Input data for FRM development – summary of differences							
N.	**Data**	**First planning cycle**			**Second planning cycle**		
		Name of institution	**Format**	**Data update**	**Name of institution**	**Format**	**Data update**
1	Land use	GUGiK	shp	2011-2014	GUGiK	shp	2018
2	Number of inhabitants	MSW	txt	2012	GUS	.xlsx,.txt, .docx, .shp, . pdf	2018
3	Address points	GUGiK	.shp, .dbf	2005-2013	GUGiK	.xml	2018
4	Housing and buildings of social importance (hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, social welfare homes, nursing homes, hospices, penitentiaries, correctional facilities, detention centres, police units, fire protection units, border guard units)	GUGiK	shp	2005-2013	GUGiK	shp	2018
5	Social welfare homes, 24-hour care facilities	UW	xls, doc	2012	UW	.shp, .xlsx, docx	2018
6	Hospices	NFZ	.xls	2012	NFZ	.xlsx	2018
7	Penitentiaries, custodial facilities	CZSW	.xls	2012	CZSW	.xlsx	2018
8	Correctional facilities	MS	.xls	2012	MS	.xlsx	2018
9	Groundwater abstractions	PIG-PIB	.xls .shp	2012	PIG PIB PGW WP	.xlsx, .shp	2019 2018
10	Surface water abstractions	RZGW	shp	2013	GUGiK PGW WP	shp shp	2018 2018
11	Protection zones of water abstractions		shp	2013	PGW WP	shp	2018
12	Swimming pools	PIS-GIS	xls .shp	2011	PIS-GIS	.shp,	2018
13	Boundaries of Natura 2000 sites, including boundaries of special bird protection areas and special areas of habitat protection	GDOŚ	shp	2012	GDOŚ	shp	2018
14	National park borders	GDOŚ	shp	2012	GDOŚ	shp	2018
15	Borders of nature reserves	GDOŚ	shp	2012	GDOŚ	shp	2018
16	Fixed monuments	MKiDN	pdf	2012	NID	shp	2018
17	Sites inscribed on the UNESCO World Heritage List	UNESCO MKiDN	doc shp	2012	NID	shp	2018
18	Extermination monuments	MKiDN	pdf	2012	MKiDN	pdf	2019
19	Open-air museums and museums listed in the National Register of	MKiDN	.xlsx .shp	2012	MKiDN	.xlsx	2018

Input data for FRM development – summary of differences							
N.	**Data**	**First planning cycle**			**Second planning cycle**		
		Name of institution	**Format**	**Data update**	**Name of institution**	**Format**	**Data update**
	Museums						
20	Libraries forming the national library stock	MKiDN	.xlsx .shp	2012	MKiDN	pdf	2019
21	Archives forming the national archive stock	MKiDN	.xlsx	2012	MKiDN	pdf	2018
22	Zoos	GUGiK	shp		GUGiK	shp	2018
23	Industrial plants	GUGiK	shp	1993-2010	GUGiK PGW WP	shp shp	2018 2018
24	Industrial plants with a high and increased risk of a major industrial accident	GIOŚ	doc	2012	GIOŚ WIOŚ KG PSP	xlsx xlsx, .docx .pdf, .rtf	2018 2018 2018
25	IPPC installations (register of installations with integrated permits)	GIOŚ	.mdb	2012	register of installations holding integrated permits	.xlsx	2018
26	Cemeteries	GUGiK	shp	1993-2010	GUGiK	shp	2018
27	Landfills	GIOŚ	.mdb, .xls	2009-2011	GUGiK PGW WP WIOŚ	shp shp .shp, .xlsx, .mdb, .docx, .pdf	2018 2018 2018
28	Wastewater treatment plants	GIOŚ	.xls	2009-2011	WIOŚ PGW WP GUGiK	.shp, .xlsx, .pdf shp shp	2018 2018 2018
29	Wastewater pumping stations	GUGiK	shp	1993-2010	GUGiK	shp	2018
30	Flood damages	IMGW-PIB	shp	2013	IMGW-PIB/ARCADIS/MGGP consortium	shp	2019
31	Places	GUGiK	shp	2013	GUGiK	shp	2018

10.7.1. CHANGES IN LAND-USE DATA

Spatial data on land use were crucial in the project implementation. These data are the resource of the Head Office of Geodesy and Cartography and come from **the Topographic Object Database (BDOT10k)**. This database is a vector (object) database containing the spatial location of topographic objects together with their characteristics. The comparison of land use data used in the first and second planning cycle is presented in Table 36.

Table 36 Comparison of data used for the purpose of FRM.

Land-use class				
Land-use class	**First planning cycle**	**Attribute**	**Second planning cycle**	**Attribute**
Residential areas	PKZB_A – concentrated, dense or loose development areas	01 – block buildings	PTZB_A – housing	01 – multi-family housing
		02 – downtown type buildings		02 – single-family housing
		03 – single-family housing		04 – commercial and service buildings
		05 – other buildings		05 – other buildings

Land-use class				
Land-use class	**First planning cycle**	**Attribute**	**Second planning cycle**	**Attribute**
		(concentrated, dense or loose development, not qualified for other types of development, e.g. playgrounds, car parks, green areas, courtyards, shelters, livestock buildings, commercial and service development, sacral buildings, public administration, etc.)		
Industrial areas	PKZB_A – concentrated, dense or loose development areas	04 – industrial and warehouse buildings	PTZB_A – housing	03 – industrial and storage buildings
	PKNT_A – other undeveloped areas	01 – land under technical or construction equipment	PTNZ_A – remaining undeveloped area	02 – industrial and storage site
		03 – waste disposal site		
		04 – heap		
		05 – excavation, post-explosion pit		
		06 – other industrial and storage areas		
Communication areas	PKTK_A – areas under roads, railways and airports	01 – area under the road	PTKM_A – area under roads, railways and airports	01 – area under the road
		02 – area under the trackside		02 – area under the trackside
		03 – area under the road and the trackside		03 – area under the road and the trackside
		04 – area under the airport road		04 – area under the airport road
	PKNT_A – other undeveloped areas	02 – square with hard surface	PTPL_A – square	01 – square
		07 – square without surface		
Forests	PKLA_A – forest or wooded areas	01 – forest	PTLZ_A – forest and wooded area	01 – forest
		02 – grove		02 – grove
			PTUT_A – permanent crop	04 – forest nursery
Leisure and recreation areas	PKUT_A – area of permanent crops	03 – allotment gardens	PTUT_A – permanent crop	01 – allotment garden
	KUAA_A	KU SK 01 – area of sports and recreation centre	PTTR_A – Grassy vegetation and arable farming	01 – grassy vegetation (selection of those located in built-up areas or on the basis of KUSK_A usage complexes)
		KU SK 02 – holiday home complex	PTLZ_A – forest and wooded area	03 – wooding (selection of those which perform a recreational function on the basis of KUSK_A complexes)
		KU SK 03 – park	PTRK_A – shrubby vegetation	02 – shrubs (selection of those that serve a recreational function)
		KU SK 04 – botanical garden		
		KU SK 05 – zoo		
		KU HO 02 – resort area		
		KU HO 03 – camping		
		KU HO 04 – Tourist hostel		

Land-use class				
Land-use class	**First planning cycle**	**Attribute**	**Second planning cycle**	**Attribute**
		area		
agricultural land – arable land	PKTR_A – areas of grass vegetation and agricultural crops	01 – crops on arable land	PTTR_A – grassy vegetation and arable farming	02 – cultivation on arable land
	PKUT_A – areas of permanent crops	01 – orchard	PTUT_A – permanent crop	02 – plantation
		02 – plantation		03 – orchard
				05 – ornamental plant nursery
agricultural land – grassland	PKTR_A – areas of grass vegetation and agricultural crops	02 – grassy vegetation	PTTR_A – grassy vegetation and arable farming	01 – grassy vegetation (selection of those not in built-up areas)
other areas	PKLA_A – forest or wooded areas	03 – other tree plantings	PTGN_A – unused land	01 – scree, landfill or rock rubble
	PKKR_A – shrubby vegetation areas	01 – bushes		02 – stony ground
		02 – mountain pine scrubs		03 – sandy or gravel ground
	GDPR_A – uncovered land areas	01 – sandy or gravel ground		04 – other unused land
		02 – stony ground	PTWZ_A – excavation and dumping ground	01 – excavation
		03 – scree, landfill, rock rubble		02 – heap
		04 – other exposed land	PTNZ_A – remaining undeveloped area	01 – land under technical equipment or construction sites
			PTRK_A – shrubby vegetation	01 – pine (selection of those which do not have a recreational function)
				02 – shrubs (selection of those that do not have a recreational function)
			PTLZ_A – forest and wooded area	03 – wooding (selection of those which do not have a recreational function)

10.7.2. CHANGES IN DETERMINING THE POPULATION EXPOSED TO FLOODING

In the second planning cycle a change in the method of determining the number of inhabitants potentially affected by flooding was made. The characteristics of the method adopted in the first planning cycle and the method used in the second planning cycle are presented in Table 37.

Table 37. Changes between the first and second planning cycle concerning methods of determining the number of inhabitants potentially affected by flooding for FRM.

Estimated number of inhabitants potentially affected by flooding	
First planning cycle	**Second planning cycle**
In order to determine the estimated number of inhabitants, the flood risk maps show the number of people living (registered) in buildings located in a flood hazard area in a given city. The estimated number of inhabitants who may be affected by flooding was determined on the basis of address data contained in the Topographic Objects Database (BDOT) and data from the PESEL database, by linking the layer of	Two methods are used to determine the estimated number of inhabitants on flood risk maps. In the first place, the number of people inhabiting a given building is determined on the basis of data from the Central Statistical Office, i.e. the average number of people per dwelling in the commune and the NOBC register (information on the number of dwellings located at the given address). The

Estimated number of inhabitants potentially affected by flooding	
First planning cycle	**Second planning cycle**
address points to the number of people registered in a specific building.	address points are obtained from GUGiK resources from the Geoportal: http://mapy.geoportal.gov.pl/wss/service/SLNOFF/guest/slowniki-offline?wsdl. The number of people living at a given address is assigned to the address points, and then, by means of a spatial connection, the information is assigned to the residential building polygons with BDOT10k. Alternatively, when it is not possible to allocate the number of inhabitants to residential buildings using the first method, estimating the number of inhabitants in a building is based on the area of the building and the number of floors. To clarify the estimation of the number of persons In the buildings there are groups of single, double and multi-family residential buildings. Based on BDOT10k data, each building is assigned a number of households. In the case of multi-family buildings, the number of households is calculated on the basis of the building footprint of the BDOT, the number of floors (BDOT) and the average usable floor area of one apartment in m². The number of dwellings per one floor is calculated, and then the result is multiplied by the number of floors in the building.

10.7.3. CHANGES IN THE VALUE OF POTENTIAL FLOOD DAMAGES

Changes were also introduced to the value of potential flood damages presented in the flood risk maps. The data contained in the existing Regulation is based on the 2008 figures and needed to be updated. Details of the changes are included in Table 38.

Table 38. Changes between the first and the second planning cycle concerning estimation of potential values of flood damages for FRM.

Estimation of potential flood damages		
First planning cycle		**Second planning cycle**
Potential flood damages were based on 2008 figures. According to the Annex to the Regulation of the Minister of Environment, Minister of Transport, Construction and Maritime Economy, Minister of Administration and Digitization and Minister of Internal Affairs of 21 December, 2012 (item 104)		The values of potential flood damages [PLN/ m²] have been updated for 2016.
Value of potential damages by land use class		
Class 1 – residential areas		
Voivodeship	First planning cycle Value in PLN/m² in 2008	Second planning cycle Value in PLN/m² in 2016
Lower Silesia	422.24	691.11
Kuyavia-Pomerania	332.72	421.51
Lublin	164.54	217.43
Lubusz	276.30	396.95
Łódź	290.94	393.64
Lesser Poland	364.09	514.05
Masovia	509.63	684.41

Opole	265.87	376.79
Subcarpathia	201.25	296.32
Podlaskie	162.79	239.64
Pomerania	399.89	594.46
Silesia	559.03	743.12
Holy Cross	201.10	258.51
Warmia-Masuria	203.39	281.61
Greater Poland	360.56	553.17
West Pomerania	309,83	559.78
Class 2 – Industrial sites		
Voivodeship	First planning cycle	Second planning cycle
	Value in PLN/m² in 2008	Value in PLN/m² in 2016
Lower Silesia	473.44	822.13
Kuyavia-Pomerania	461.52	750.65
Lublin	508.97	916.26
Lubusz	639.37	1201.97
Łódź	829.20	1256.78
Lesser Poland	606.64	1028.11
Masovia	943.83	1429.69
Opole	474.32	691.71
Subcarpathia	641.34	980.58
Podlaskie	509.85	803.29
Pomerania	595.82	1053.13
Silesia	549.65	928.73
Holy Cross	537.68	819.90
Warmia-Masuria	504.73	832.46
Greater Poland	702.50	1198.75
West Pomerania	326.21	457.21
Classes of use 3-5		
All voivodeships	First planning cycle	Second planning cycle
	Value in PLN/m² in 2008	Value in PLN/m² in 2016.
Class 3 – Transport areas	436.00	717.00
Class 4 – Forests	0.008	0.04
Class 5 – Recreational and leisure areas	5.10	8.00
Class 6 – Arable land and permanent crops		
The voivodeship	First planning cycle	Second planning cycle
	Potential unit flood loss (PLN/m²) 2008	Potential unit flood loss (PLN/m²) 2016
Lower Silesia	0.14	0.31
Kuyavia-Pomerania	0.14	0.30
Lublin	0.14	0.33
Lubusz	0.14	0.31
Łódź	0.14	0.32
Lesser Poland	0.14	0.40
Masovia	0.14	0.37
Opole	0.14	0.34
Subcarpathia	0.14	0.26
Podlaskie	0.14	0.18
Pomerania	0.14	0.26
Silesia	0.14	0.33
Holy Cross	0.14	0.37
Warmia-Masuria	0.14	0.24
Greater Poland	0.14	0.30
West Pomerania	0.14	0.27
Class 7 – Grassland		
Voivodeship	First planning cycle	Second planning cycle
	Potential unit flood loss (PLN/m²) 2008	Potential unit flood loss (PLN/m²) 2016
Lower Silesia	0.07	0.08
Kuyavia-Pomerania	0.07	0.09
Lublin	0.07	0.09
Lubusz	0.07	0.08

Łódź	0.07	0.10
Lesser Poland	0.07	0.08
Masovia	0.07	0.08
Opole	0.07	0.10
Subcarpathia	0.07	0.06
Podlaskie	0.07	0.10
Pomerania	0.07	0.08
Silesia	0.07	0.10
Holy Cross	0.07	0.07
Warmia-Masuria	0.07	0.10
Greater Poland	0.07	0.09
West Pomerania	0.07	0.08

10.8. UPDATE OF THE ATTRIBUTE STRUCTURE OF FRM DIGITAL LAYERS

As in the case of flood hazard maps, the changes between the development of the first and second planning cycles also occurred in the attribute structure of flood risk maps. These changes are summarised in Table 39.

Table 39 Changes in the attribute structure between first and second planning cycles.

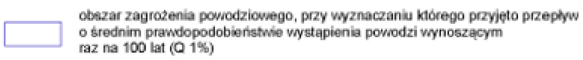
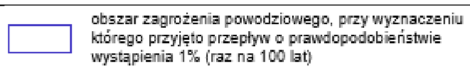
Layer	First planning cycle	Second planning cycle
Cities		• BDOT10k identifiers
use_10, use_1, use_02, use_WZ,	• attribute L_OS_ZAM – number of persons registered	• CHAR_ZAB attribute – character of housing development
use_loss_10, use_loss _1, use_loss _02, use_loss _WZ,	• POWIERZ attribute – area in m^2	
Buildings	• L_MIESZ attribute – number of residents registered in the building • link to BDOT/BDOT10k database (BDOT/BDOT10k ID)	• FUNCTION attribute – other object classification • L_MIESZ attribute – estimated number of inhabitants in the building • link to the BDOT10k database (BDOT10k identifiers)
Plants		• no link to the BDOT10k database (no identifiers)
bathing waters	• no link to the MPHP database (no reservoir identifier and name)	• no link to the PRNG database (no reservoir identifier and name)
forms_of_nature_protection		• extended attribute TYP_OCHR with Natura 2000 sites
culturally_valuable_areas		• the extended OBJECT attribute with a fixed asset
culturally_valuable_objects		• the extended OBJECT attribute with a fixed asset

For layers: zoo_gardens, cemeteries, landfills, pumping_stations, water_abstractions, abstraction_zones – no changes.

10.9. DIFFERENCES IN THE DEVELOPMENT OF THE FRM CARTOGRAPHIC VERSION

Differences in the development of the cartographic version between the first and second planning cycles concern the elements that make up the content of the map, explanations of signs and extra-lock elements. The differences are presented in Table 40.

Table 40 Changes between first and second planning cycles concerning the elements making up the content of the map, sign explanations and non-blocking elements for all types of FRM.

First planning cycle	Second planning cycle
Differences in the elements that make up the map content	
• *rem*. – fire brigade	• *rem*. – fire protection units
• *d. op.* – home, social care centre, hospice	• *d. op.* – social welfare home, nursing home, hospice
• *d. wych*. – nursing home, correctional home	• *d. wych*. – nursing home
• the number of ranges and values for potential flood damages amounted to 8 • the value of potential flood loss ranges [PLN/m²]: areas for which no damages are calculated <1 1,01-25 25,01-50 50,01-100 100,01-150 150,01 – 300 >300	• the number of ranges and values for potential flood damages were reduced to 7 • the values of the potential flood loss ranges [PLN/m²] have changed: areas for which no damages are calculated <1 2-50 51-150 151-300 301-600 >600
• for parts of cities and villages exposed to flooding the population is given in brackets	• resignation from the number of inhabitants exposed to flooding for parts of cities and village
• the side dam included with embankments	• the side dam was specified from the embankments
• total destruction of the flood embankment or side dam	• place of destruction of the flood embankment or side dam
• forms of nature conservation: Natura 2000 area without division	• forms of nature protection: from the Natura 2000 area special bird protection area and special habitat protection area have been specified
Differences in sign explanations	
DIFFERENCES IN EXPLANATIONS OF SIGNS FOR THE FLOOD RISK MAP – POTENTIAL ADVERSE EFFECTS ON HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES	
	
	

First planning cycle	Second planning cycle
sieć rzeczna	cieki naturalne i kanały
The sign was not present	zapora boczna
KALISZ 135 (1380) nazwa miasta i szacunkowa liczba mieszkańców zagrożonych powodzią w przypadku wydzielonych części miasta sumę zagrożonych mieszkańców dla całej miejscowości podano w nawiasie Chotów 21 (52) nazwa wsi i szacunkowa liczba mieszkańców zagrożonych powodzią w przypadku wydzielonych części wsi sumę zagrożonych mieszkańców dla całej miejscowości podano w nawiasie Rypinek 15 nazwa części miasta, wsi lub innej miejscowości i szacunkowa liczba mieszl zagrożonych powodzią	KALISZ 1380 nazwa miasta i szacunkowa liczba mieszkańców zagrożonych powodzią Chotów 52 nazwa wsi i szacunkowa liczba mieszkańców zagrożonych powodzią Rypinek 15 nazwa części miasta, wsi lub innej miejscowości i szacunkowa liczba mieszkańców zagrożonych powodzią
DIFFERENCES IN THE EXPLANATION OF SIGNS FOR THE FLOOD RISK MAP – POTENTIAL NEGATIVE EFFECTS ON THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY	
	In sign descriptions the subject groups have been removed obszary i obiekty dziedzictwa kulturowego formy ochrony przyrody potencjalne ogniska zanieczyszczeń składowisko odpadów
obszar Natura 2000	The Natura 2000 logo has been replaced by two others, denoting a special bird protection area and a special habitat protection area: obszar Natura 2000 - obszar specjalnej ochrony ptaków obszar Natura 2000 - specjalny obszar ochrony siedlisk
zakłady przemysłowe: z rejestru zakładów o dużym i zwiększonym ryzyku wystąpienia poważnej awarii z listy zarejestrowanych w Ministerstwie Środowiska (MŚ) wniosków i pozwoleń zintegrowanych z rejestru zakładów o dużym i zwiększonym ryzyku wystąpienia poważnej awarii oraz z listy zarejestrowanych w MŚ wniosków i pozwoleń zintegrowanych	Change in the description of industrial plants – the signature for plants with two properties at the same time was removed: zakłady przemysłowe: instalacje mogące powodować znaczne zanieczyszczenie poszczególnych elementów przyrodniczych albo środowiska jako całości zakłady stwarzające zagrożenie wystąpienia poważnej awarii przemysłowej
całkowite zniszczenie wału przeciwpowodziowego	miejsce zniszczenia wału przeciwpowodzioweg lub zapory bocznej
The sign was not present	zapora boczna
obszar zagrożenia powodziowego, przy wyznaczaniu którego przyjęto przepływ o średnim prawdopodobieństwie wystąpienia powodzi wynoszącym raz na 100 lat (Q 1%)	obszar zagrożenia powodziowego, przy wyznaczeniu którego przyjęto przepływ o prawdopodobieństwie wystąpienia 1% (raz na 100 lat)
sieć rzeczna	cieki naturalne i kanały
Differences in non-blocking elements	

First planning cycle	Second planning cycle
Map title: FLOOD RISK MAP – NEGATIVE CONSEQUENCES FOR THE POPULATION AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS WHERE THE PROBABILITY OF FLOODING IS MEDIUM – 1% (ONCE EVERY 100 YEARS) FLOOD RISK MAP – NEGATIVE CONSEQUENCES FOR THE POPULATION AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS WHERE THE PROBABILITY OF FLOODING IS HIGH – 10% (ONCE EVERY 10 YEARS) FLOOD RISK MAP – NEGATIVE CONSEQUENCES FOR THE POPULATION AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS EXPOSED TO FLOODING IN CASE OF DAMAGE OR EMBANKMENT DAMAGE FLOOD RISK MAP – NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WITH A LOW PROBABILITY OF FLOODING – 0.2% (ONCE EVERY 500 YEARS) FLOOD RISK MAP – NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WHERE THE PROBABILITY OF FLOODING IS MEDIUM – 0.1% (ONCE EVERY 100 YEARS) FLOOD RISK MAP – NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WITH A HIGH PROBABILITY OF FLOODING – 10% (ONCE EVERY 10 YEARS) FLOOD RISK MAP – NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS EXPOSED TO FLOODING IN CASE OF EMBANKMENT DAMAGE	Map title: 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 – 1% (ONCE EVERY 100 YEARS) FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS WITH A HIGH PROBABILITY OF FLOODING – 10% (ONCE EVERY 10 YEARS) FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR HUMAN LIFE AND HEALTH AND THE VALUE OF POTENTIAL FLOOD DAMAGES AREAS EXPOSED TO FLOODING IN THE EVENT OF TOTAL DESTRUCTION OF THE EMBANKMENT FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WITH A LOW PROBABILITY OF FLOODING – 0.2% (ONCE EVERY 500 YEARS) FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WHERE THE PROBABILITY OF FLOODING IS MEDIUM – 0.1% (ONCE EVERY 100 YEARS) FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS WITH A HIGH PROBABILITY OF FLOODING – 1% (ONCE EVERY 10 YEARS) FLOOD RISK MAP – POTENTIAL NEGATIVE CONSEQUENCES FOR THE ENVIRONMENT, CULTURAL HERITAGE AND ECONOMIC ACTIVITY AREAS EXPOSED TO FLOODING IN THE EVENT OF TOTAL DESTRUCTION OF THE EMBANKMENT
• data frame defined as a “sheet layout” with the range of the main data frame marked, – 1:10 000 scale sheet division of topographic maps, in rectangular flat-plate coordinate system EN-1992, – the main three-tier territorial division of the country.	• data frame defined as a “sheet layout” with the range of the main data frame marked – 1:10,000 scale sheet division of topographic maps, in rectangular flat-plate coordinate system PL-1992, – the main three-tier territorial division of the country, • area of activity of organisational units of the State Water Holding Polish Waters: regional water management boards and catchment area boards.

First planning cycle	Second planning cycle
• logotypes: Innovative Economy sign (National Cohesion Strategy), National Water Management Board, European Union sign (European Regional Development Fund, National Fund for Environmental Protection and Water Management sign, Institute of Meteorology and Water Management – National Research Institute sign	• Logotypes: sign of the European Fund (Infrastructure and Environment), sign of the State Water Holding Polish Waters sign of the European Union (Cohesion Fund),
• no information	• information on the authorities competent to draw up and approve the map
• information on the map contractor directly next to the logotype	• information on the map contractor under the logotype
• reservation on the reproduction and use of the map	• no information
Differences in file formats	
• tiff (version with extra description)	• pdf (version with extra description)

11. DATA SUBJECT TO SUBMISSION OF ADMINISTRATION BODIES INDICATED IN THE WATER LAW ACT

Pursuant to article 171, paragraph 3 of the Water Law Act, State Water Holding Polish Waters submit draft flood hazard maps and flood risk maps to the minister responsible for water management for approval. The next paragraph (article 171, paragraph 4) stipulates that the minister in charge of water management approves the flood hazard maps and flood risk maps and submits them in electronic form to:

1) Surveyor General of Poland;
2) competent environmental inspection authority;
3) Director of the Government Security Centre;
4) State Water Holding Polish Waters;
5) Chief Commander of the State Fire Service;
6) competent voivodes;
7) competent voivodeship marshals;
8) competent starosts;
9) competent vogts, mayors or city presidents;
10) competent provincial and poviat (city) commanders of the State Fire Service;
11) competent directors of inland waterway authorities and competent directors of maritime authorities;
12) competent railway infrastructure authorities and competent public road authorities.

In accordance with the above, data sets of the FHM and the FRM are prepared in appropriate data carriers, in order to be transmitted in electronic form to the abovementioned institutions. The content and scope of the sets of FHM and FRM shall be prepared depending on the competence of a particular administrative authority. Files prepared for transmission are not compressed. Storage media with the data are sent with a return receipt.

The scope of the data recorded to the data storage devices transferred to the directors of regional water management boards, maritime authorities and inland waterway directors shall include at least:

1) databases of spatial flood hazard maps and flood risk maps for all types of floods;
2) cartographic versions of flood hazard maps and flood risk maps;
3) models made for delineating flood hazard areas;
4) riverbed cross-sections and parameters of bridge, hydrotechnical and embankment structures;
5) valley cross-sections used in hydraulic models, generated from digital terrain model together with information on terrain cover and roughness coefficients adopted;
6) hydrological data used in model development;
7) metadata of flood hazard maps and flood risk maps for all types of floods;
8) library of styles and signs together with files (lyr) specifying the symbolism of individual layers of flood hazard maps and flood risk maps;
9) reports and descriptive documents, including attachments.

The scope of the data recorded to the data storage devices provided to the other authorities indicated in the Water Law Act will include at least:

1) databases of spatial flood hazard maps and flood risk maps for all types of floods, spatially limited to the area of administration of individual authorities;
2) cartographic versions of flood hazard maps and flood risk maps, including sheet frames covering the area of administration of individual authorities;
3) metadata of flood hazard maps and flood risk maps;
4) library of styles and conventional signs together with files (*.lyr) specifying the symbolism of individual layers of flood hazard maps and flood risk maps;
5) reports and descriptive documents, including attachments.

12. COORDINATION WITH DIRECTIVE 2000/60/EC

The Floods Directive in article 9, point 1 provides that the preparation of the first flood hazard maps and flood risk maps, as well as their subsequent reviews, as referred to in articles 6 and 14 of this Directive shall be carried out in such way that the information contained in the maps is consistent with relevant information provided under Directive 2000/60/EC. These shall be coordinated with and may be integrated into the reviews provided for in article 5, paragraph 2 of Directive 2000/60/EC.

The first paragraph of article 5 of the Framework Water Directive provides for an analysis of the characteristics of each river basin area a review of the impact of human activities on the status of surface water and groundwater, as well as an economic analysis of water use.

In accordance with article 5, paragraph2, the analyses and reviews mentioned under paragraph 1 shall be reviewed and, where necessary, updated in the course of maximum 13 years after this Directive enters into force, and every six years thereafter.

In accordance with article 326, paragraph 2 of the Water Law Act, the information presented on flood hazard maps and flood risk maps should be consistent with the information contained in the planning documents referred to in article 315, paragraphs 1 and 3, i.e.:

– point 1 – plans of river basins management;
– point 3 – drought prevention plan, taking into account the division of the country into river basin areas

Pursuant to Article 326, paragraph 3 of the Water Law Act, the preparation of flood hazard maps and flood risk maps, as well as their reviews is carried out in a manner coordinated with the analysis of planning documentation, referred to in Article 317, paragraph 1, points 2, 3 and 6, i.e. elements of water management plans:

– point 2 – characterisation of water reservoirs, indicating artificial and heavily modified bodies of water, as well as reservoirs threatened with failure to meet environmental objectives;
– point 3 – identification of significant anthropogenic impacts and assessments of their impact on the status of surface water and groundwater;
– point 6 – economic analyses related to water use.

The FRMs contain data resulting from Annex VI (i), (iii) and (v) RDW:

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

In order to ensure that this data is as up-to-date as possible, in accordance with the list contained in Chapter 5.4, data shall be retrieved directly from the institutions operating individual registers.

The coordination of FHM and FRM updates with the second update of the Water Management Plans (planned until 2021) and the development of drought plans consists of the use (exchange) of input data and products generated by the work on the aPGW and PPSS, as well as the transfer of intermediate and final products of FHM and FRM updates for use in the work on the PGW and PPSS update. This ensures consistency of the data on which all these studies are based. The scope of data exchange is presented in Table 41. The table presents information that is common to the documents, as well as data that can be used in the works on aPGW and PPSS after FHM and FRM are developed.

Table 41 Scope of coordination with the PGW and PPSS updates

Information	PGW	PPSS
COMMON INPUT		
List of bathing waters	+	
Boundaries of Natura 2000 areas, including boundaries of special bird protection areas and special areas of habitat protection	+	+
National park borders	+	+
Borders of nature reserves	+	+
List of IPPC installations held in the register of applications and integrated permits	+	
List of establishments with high and increased risk of a major industrial accident	+	
Industrial plants (spatial location)	+	+

Information	PGW	PPSS
Groundwater abstractions	+	+
Surface water abstractions	+	+
Zones of abstraction protection	+	
Land-use classes	+	+
Buildings of social importance (hospitals, schools, kindergartens, nurseries, hotels, shopping and service centres, social welfare homes, nursing homes, hospices, penitentiaries, correctional facilities, custodial facilities, police units, fire brigade units)	+	+
Orthophotomaps (field pixel size: 1.0 m; 0.5 m; 0.25 m, 0.1 m)	+	+
State Border Register (PRG)	+	+
National Register of Geographical Names (PRNG)	+	+
Topographical Object Database BDOT10k	+	+
Execution/pre-implementation projects, data on investments having a significant impact on the extent of floods	+	
Current reservoir water management instructions /reservoir project or post-project documentation	+	+
Data on embankments and water facilities	+	+
Results of surveys of RZGW, ZMiUW, GDDKiA, railway authorities, Maritime Offices	+	+
Map of Hydrographic Division of Poland MPHP10k	+	+
INTERMEDIATE AND FINAL RESULTS OF FHM AND FRM		
Hydrological-meteorological data	+	+
Modified DTM	+	+
Inventory of investments affecting the extent of flood hazard areas	+	
Hydraulic models	+	
Estimated number of inhabitants likely to be affected by flooding	+	+
Values of potential flood damages	+	+
Flood hazard areas	+	+
Water depth	+	+
Water flow velocity	+	+
Flow directions	+	+
Maximum water level ordinates	+	+
Places of water overflow through embankments	+	
Embankment damage or destruction site	+	
Flood embankments	+	+
Modified river axes with updated chainage	+	+
Maximum flow value	+	+

13. EXCHANGE INFORMATION WITH NEIGHBOURING COUNTRIES IN THE PREPARATION OF FHM AND FRM

The issues concerning the exchange of information with the countries neighbouring Poland on the preparation of the MHP and FRM are specified in the Water Law Act:

Article 171.6 The preparation of flood hazard maps and flood risk maps for areas referred to in article 169, paragraph 2[4]*, situated in river basin areas, parts of which lie within the territory of other Member States of the European Union, shall be preceded by measures for the exchange of information in this regard with their competent authorities.*

7. Preparation of flood hazard maps and flood risk maps for areas, referred to in article 169, paragraph 2, that fall within river basin areas whose parts fall within the territory of states outside the European Union shall be preceded by measures to establish cooperation with the competent authorities of those States in this regard.

The requirement to exchange information on the preparation of the FRM and the FRM is also indicated in Directive 2007/60/EC on the assessment and management of flood risks:

Article 6.2 The preparation of flood hazard maps and flood risk maps for areas identified under Article 5[5]*, shared with other Member States, requires a prior exchange of information between the Member States concerned.*

Information exchange should take place within each river basin area. Table 42 shows the location of Poland’s neighbouring countries in individual river basin area, with an indication of the form of cooperation.

Table 42. Location of Poland's neighbouring countries in river basin areas

River basin area	Neighbouring country	Form of cooperation
Oder	Germany (EU)	International Commission on the Protection of the Oder against Pollution German-Polish Border Water Commission
	Czech Republic (EU)	International Commission for the Protection of the Oder River against Pollution Czech-Polish Border Waters Commission
Vistula	Russia (non-EU)	-
	Belarus (non-EU)	Polish-Belarusian working meetings, aimed at signing an agreement on cooperation in the field of protection and rational use of transboundary waters
	Ukraine (non-EU)	Polish-Ukrainian Commission for Border Waters
	Slovakia (EU)	Polish-Slovakian Commission for Border Waters
Pregola	Russia (non-EU)	-
Neman	Lithuania (EU)	Polish-Lithuanian Commission for Border Waters

[4] Applies to areas presented on the FHM, i.e. areas where the probability of flood occurrence is low and amounts to 0.2%, or where there is a likelihood of an extreme event; special flood hazard areas; areas including areas exposed to flooding in the event of damage or destruction of the embankment or damming structure.
[5] Subject: Areas where Member States conclude that a high flood risk exists or is likely to occur, i.e. areas exposed to flooding identified in the preliminary flood risk assessment.

River basin area	Neighbouring country	Form of cooperation
Dniester	Ukraine (Extra-EU)	Polish-Ukrainian Commission for Border Waters No areas exposed to flooding
Danube	Slovakia (EU)	Polish-Slovakian Commission for Border Waters
Elbe	Czech Republic (EU)	Czech-Polish Border Water Commission International Commission for the Protection of the Elbe
Banówka	Russia (non-EU)	No areas exposed to flooding
Świeża	Russia (non-EU)	No areas exposed to flooding

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

The Oder river basin area

International Commission on the Protection of the Oder against Pollution

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

The primary objectives of the ICPO are

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

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

Czech-Polish Border Waters Commission

The formal basis for bilateral cooperation is the 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. (ratified by Poland on 17 December, 2015).

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

- ensuring the protection, mutual coordination and rational use of border waters and improving their quality, as well as preserving and restoring ecosystems dependent on waters, including their biodiversity;

- coordinating efforts to mitigate the adverse effects of floods and drought.

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

German-Polish Border Waters Commission
The formal basis for bilateral cooperation is the 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.(ratified by Poland on 26 September, 1996).

The agreement represents a mutual commitment to cooperation on water management in border waters. Its objectives are:
- ensuring rational management and protection of border waters and improve their quality;
- ensuring that ecosystems are preserved and, if necessary, restoring them.

In order to coordinate and implement the tasks of the agreement, a German-Polish Border Waters Commission has been established – W4 Working Group on the Maintenance of Border Waters deals with cooperation and data exchange in the field of floods.

Vistula river basin area

Polish-Ukrainian Commission for Border Waters
The formal basis for bilateral cooperation is the Agreement between the Government of the Republic of Poland and the Government of Ukraine on cooperation in the field of water management in border waters of 10 October, 1996.

The agreement represents a mutual commitment to cooperation on water management in border waters. Its objectives are:
- protecting and using border waters, protecting against damage caused by border waters;
- ensuring rational management of border waters and improving their quality, as well as preserving ecosystems.

In order to coordinate and implement the tasks of the agreement, a Polish-Ukrainian Commission for Border Waters was established – cooperation and data exchange in the field of floods is handled by the OP Working Group on Flood Protection, Regulation and Remediation.

Polish-Slovakian Commission for Border Waters
The formal basis for bilateral cooperation is the 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.

The Agreement represents a mutual commitment to cooperation on water management in border waters. Its objectives are:
- use and protect border waters against pollution;
- maintain and improve the ecological status of border waters and establish rules for their shared use.

In order to coordinate and implement the tasks of the Agreement, the Polish-Slovakian Commission for Border Waters was established – cooperation and data exchange in the field of floods is handled by the HyP Working Group on Hydrology and Flood Protection.

Cooperation with Belarus

The cooperation agreement on protection and rational use of transboundary waters was signed on 7 February, 2020 As a result, the Polish-Belarusian Commission for Cooperation on Transboundary Waters was established.

As a part of the negotiations of the above agreement, the parties expressed their willingness to cooperate in the field of flood risk management for the Bug river basin. The Belarusian side proposed a Polish-Belarusian-Ukrainian project for the joint development of planning documents, resulting from the Floods Directive, including FHM and FRM. KZGW presented the Belarusian side with the scope, method and legal conditions for the preparation of the above documents in Poland. It also pointed out the need to make arrangements for the availability of data and the possibility of its exchange between countries, in order to develop a hydraulic model that would allow the identification of flood hazard areas. The Belarusian side agreed with the solutions proposed by Poland, taking into account some specificity of the legislation of the Republic of Belarus.

Cooperation with Russia

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 on water economy in border waters of 17 July, 1964. This agreement is valid on the basis of succession and is subject to automatic extension for subsequent five-year periods, while the Russian side shows no practical interest in its implementation.

Pregola river basin area

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

Neman river basin area

Polish-Lithuanian Commission for Border Waters

The formal basis for bilateral cooperation is the 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 agreement represents a mutual commitment to cooperation on water management in border waters. Its objectives are:

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

In order to coordinate and carry out the tasks of the agreement, the Polish-Lithuanian Border Water Commission has been established – the cooperation and data exchange in the field of floods is handled by Working Group No. 1 on the development of water management plans and flood risk management.

Dniester river basin area

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

Elbe catchment area

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

The primary objectives of the ICPER are:

- sustainable water use, in particular promoting the abstraction of drinking water as a result of river water infiltration and enabling agriculture to use water and sediment;
- striving to achieve natural ecosystems;
- defining a continuous strategy to reduce the cargoes entering the North Sea from the Elbe basin.

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

In addition, cooperation and information exchange for the Elbe catchment area takes place within the framework of the Czech-Polish Boundary Waters Commission (detailed description for the Oder river basin).

Measures to exchange information with neighbouring countries (EU and non-EU) on the preparation of the FRM and the FRM in the second planning cycle of flood risk management should be carried out using the following objectives:

1) The scope of activities in international river basins should build on existing international agreements on water cooperation (bilateral agreements on border waters and agreements on international river commissions).
2) The activities should make use of developed and functioning forms of cooperation, especially the working groups dealing with the subject of floods.
3) In the case of countries that are not members of the European Union (Russia, Belarus, Ukraine) cooperation should be sought. In the case of Russia cooperation should take place within the framework of cooperation with the Kaliningrad Oblast.

4) The exchange of information on FRM and FRM should take into account their subsequent use for flood risk management plans.

Three models of cooperation are introduced for the exchange of information with neighbouring countries on the preparation of the FHM and the FRM. The assumptions of cooperation according to the above models are presented below.

Model 1

Providing an information note on the work conducted in Poland on FHM and FRM. The memo should contain information on the following subjects:

1) FHM and FRM developed so far (in short):
   - the area coverage of the FHM and FRM in the first planning cycle for the river basin area (common to Poland and the neighbouring country);
   - information on the absence of an MSP and an FRM when no flood hazard areas have been identified for the river basin district (common to Poland and a neighbouring country);
2) the work being carried out:
   - the beginning of work in Poland under the *Review and update of FHM and FRM* project;
   - the purpose and scope of the project;
   - the area scope of the FHM and FRM in the second planning cycle for the river basin area (common to Poland and the neighbouring country);
   - general methodological assumptions for the development of the FHM and FRM in the second planning cycle;
   - the project timetable (in relation to the timing of obtaining products);
   - the outputs of the project, including the integration of the results of the review and update of the sea-water maps and the development of the FHM and FRM for other types of floods (other than river and sea-water).

The cooperation according to model 1 takes place by correspondence.

Model 2

Model 2 involves a two-stage cooperation:

Stage 1:
Cooperation according to model 1.

Stage 2:
Detailed exchange of information to ensure coordination for border rivers – this concerns in particular the exchange of information and data necessary for the identification of flood hazard areas, especially with regard to obtaining possibly uniform ordinates of water level as possible for the same flood probability scenario. The exchange of information should focus on the data to be included in hydraulic modelling, i.e.:

- hydrological data;
- topographical data;
- altitude data;
- riverbed and valley cross-sections;
- engineering structures;

- embankments;
- investments affecting the extent of flood hazard areas.

The cooperation in stage 2 according to model 2 requires a meeting within the functioning forms of cooperation. For each meeting the goal, scope of issues to be discussed, materials in the form of documents and presentations should be prepared.

Model 3

Model 3 involves a two-stage cooperation:

Stage 1:
Cooperation according to model 1.

Stage 2:
Detailed exchange of information on the possibility of exchanging data necessary to identify flood hazard areas. The exchange of information should focus on the data to be included in hydraulic modelling, i.e.:

- hydrological data;
- topographical data;
- altitude data;
- riverbed and valley cross-sections;
- engineering structures;
- embankments;
- investments affecting the extent of flood hazard areas.

As far as possible, consistent results (water level ordinates) should be sought for the same flood probability scenario.
The cooperation in stage 2 according to model 3 requires a meeting within the functioning forms of cooperation. For each meeting the goal, scope of issues to be discussed, materials in the form of documents and presentations should be prepared.

In Table 43 individual cooperation models are assigned to every neighbouring country.

Table 43: Cooperation models for the exchange of information on the preparation of FHM and FRM with neighbouring countries

Neighbouring country	**Form of cooperation**	**Model of cooperation**
Countries of the European Union		
Czech Republic	International Commission on the Protection of the Oder against Pollution	model 2
	Czech-Polish Border Waters Commission	model 1
	International Commission for the Protection of the Elbe	model 1
Lithuania	Polish-Lithuanian Commission for Border Waters	model 1
Germany	International Commission on the Protection of the Oder against Pollution	model 2
	German-Polish Border Waters Commission	model 1
Slovakia	Polish-Slovakian Commission for Border Waters	model 2
Countries outside the European Union		
Belarus	Polish-Belarusian working meetings	model 3
Russia	--	--
Ukraine	Polish-Ukrainian Commission for Border Waters	model 3

Comments:

1. Lithuania: possibility to move to model 2 if, as a result of the review and update of the PFRA in 2018, it is considered necessary to designate flood hazard areas in the Neman river basin area in border waters

LIST OF ANNEXES

Annex 1 – Update of the methodology for the calculation of flows and maximum precipitation with a defined probability of exceedance for controlled and uncontrolled catchments and identification of precipitation to outflow models.

Annex 2 – Attribute structure of the digital version of flood hazard maps and flood risk maps.

Annex 3 – Description of the cartographic version of flood hazard maps and flood risk maps.

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