Interreg CENTRAL EUROPE
European Union
European Regional Development Fund

RAINMAN

D T3.6.4

ACTION PLAN FOR NON-TECHNICAL MEASURES AND RECOMMENDATIONS FOR SPATIAL PLANNING

PILOT ACTION 6 - LOWER SILESIA

Mariusz Adynkiewicz-Piragas[1)], Iwona Lejcuś[1)], Irena Otop[1)], Iwona Zdralewicz[1)], Marzenna Strońska[1)], Bartłomiej Miszuk[1)], Joanna Kryza[1)], Agnieszka Kolanek[1)]

[1)] Institute of Meteorology and Water Management - National Research Institute (PP9)

Our Project is funded by the Interreg CENTRAL EUROPE Programme that encourages cooperation on shared challenges in central Europe and is supported under the European Regional Development Fund

Action plan for non-technical measures and recommendations for spatial planning (Pilot Action 6 - Lower Silesia)

Version 3	25.06.2020
Authors	Mariusz Adynkiewicz-Piragas[1)], Iwona Lejcuś[1)], Irena Otop[1)], Iwona Zdralewicz[1)], Marzenna Strońska[1)], Bartłomiej Miszuk[1)], Joanna Kryza[1)], Agnieszka Kolanek[1)]
	[1)] INSTITUTE OF METEOROLOGY AND WATER MANAGEMENT - NATIONAL RESEARCH INSTITUTE (PP9)

Acknowledgements

We would like to thank the Institute of Regional Development for helping us understand the complexities of the process of creating spatial development plans

Contents

1. Context and goals of this study

1.1. Project context

One of the most important issues in terms of regional protection against natural phenomena are non-technical measures that are significant support for technical solutions. Appropriate management related to information flux, standards and procedures during emergency situations and structure of services activities are crucial for maintaining proper functionality of the region. In terms of natural disasters, like i.e. heavy rain events, they are important especially in the regions with high morphological and hypsometric variability as extreme precipitations events occur very often there. Heavy rains can cause abrupt flash floods that can affect human health, transport, dwellings, agriculture and other sectors. Additionally, vulnerability of such areas is increased when they are also affected by potential river floods.

In the region of Lower Silesia (Poland) a good example of such area is Lusatian Neisse river basin. It forms a border between Poland and Germany and is characterized by high morphological and hypsometric variability. In the past, the region was affected by both flash and river floods. The region is mainly located within Zgorzelec district. In the following part of the Action Plan, this district is described in details in terms of its geographical conditions, structure of emergency management, strategies, etc. The district of Zgorzelec was considered in the analysis because of heavy precipitations events in this region, confirmed by historical data analysis carried out for the needs of RAINMAN project and the results of KLIMAT project.

1.2. Goals

In the Action Plan, various aspects have been considered when it comes to characteristics of the region, its potential resources, information flux during extreme situations and strategic documents. The goal of the Action Plan is to indicate solutions related to non-technical measures in the context of flash flood occurrence and methods for their mitigation. They are aimed to increase public awareness in terms of dealing with extreme events and help for better understanding decision making process on a district level.

1.3. Approach and structure

Action plan is aimed for implementation of non-technical measures (like land use, retention). Recommendations for spatial planners and end users are related to prioritisation of actions as a basis for land use optimisation and strategies for flood protection. The Action Plan

should be a document containing procedure connecting all single tasks into a complex system that guarantees safety of inhabitants and properties as well as mitigation of losses caused by floods. Current legal regulations do not precise the content of operational plans, however the communes are obliged to include the aspects of flood protection in these plans. In the district of Zgorzelec, flood events were noticed already in the past. Thus, one of the most important issues is to deal with crisis management system that enables undertaking appropriate measures in the context of flood occurrence. So far, pluvial floods were the only that were considered in the regulations or legal acts. A very important issue is spatial planning as land use is a crucial factor in flash floods effects. In these terms, recommendations were given. RAINMAN project provides additional aspect to the problem of floods that concerns flash floods which result from sudden, intensive precipitations. It concerns especially TOOLBOX that will be a very useful mean in the context of public awareness and undertaking proper measures in terms of flash floods.

Considering the mentioned above problems, the Action Plan contains the following aspects:

- Description of the pilot area, including flood events in the past,
- Crisis management in Poland, including district level and the role of IMGW-PIB,
- Legal acts and regulations related to floods and spatial planning
- Contribution of RAINMAN project results to non-technical measures on the district level.
- Recommendations for spatial planning

The results of this elaboration can be useful for local authorities, stakeholders, public services and inhabitants and will contribute to rising awareness among the inhabitants of the region. It will also enable cooperation between particular bodies dealing with flood issues, civil protection and crisis management in the district area.

2. Action plan for non-technical measures and recommendations for spatial planning

2.1. Description of the region

The district of Zgorzelec, which was selected as a pilot region for the purposes of RAINMAN project, is locates in the Lower Silesian Voivodeship in the south-west Poland. **Lower Silesia** is the northwestern part of the historical and geographical region of Silesia located generally in the basin of the middle River Odra basin (fig. 1) with its historic capital in Wrocław. The region area is 19 946 km^2, population reaches 2 908 457 inhabitants.

Altitude of Lower Silesia varies from 69 to 1 603 m above sea level. The northern part of the area are lowlands that cover about 75 % or region. In the south, the lowlands change into the highlands (Sudety Foreland) and the Sudetes Mountains with the highest peak of Śnieżka. Natural hazards affecting Lower Silesia region are typical for moderate latitudes regions, like: heat waves, cold waves, thunderstorm, drought, flood, strong wind and heavy rain.

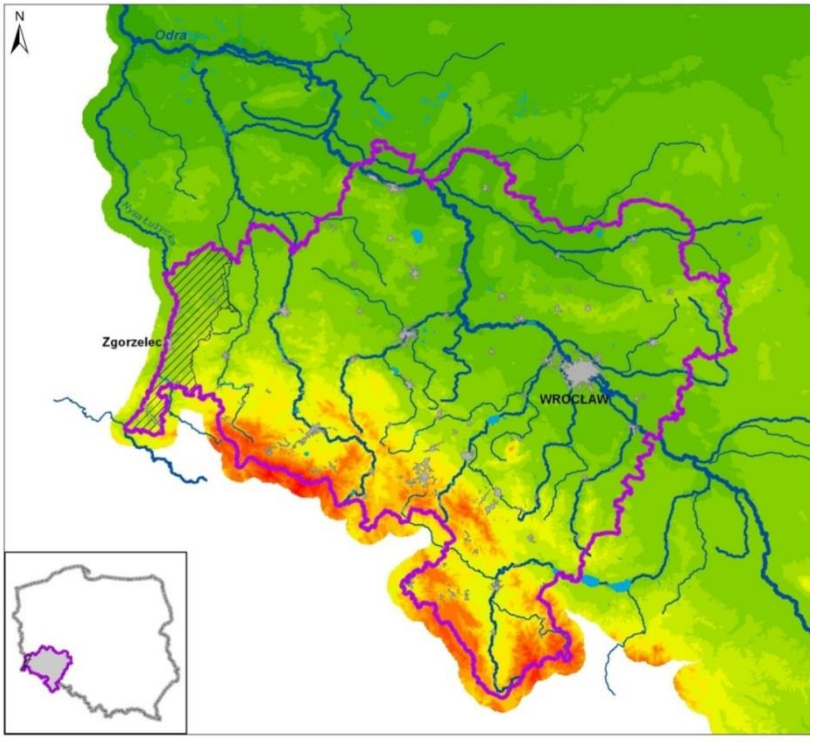

Fig. 1. The Lower Silesia region

The western part of the Lower Silesia is Zgorzelec district (county) that was considered as a pilot region. As mentioned in the Introduction section, the district is characterized by high hypsometric and morphologic variability. Similarly to Lower Silesia, the south part is covered with mountains while lowlands dominate in the north. The region is very important because of its transborder character. Its south border is the border state with Czech Republik while in the west Lusatian Neisse river forms a border with Germany (fig. 2). In terms of geographical classification, it is located in the area of the Śląsko-Łużycka Lowland and the Western Sudetes Foothills. The altitude varies from 30 to 620 m a.s.l. Three mesoregions can be distinguished in the area: Bory Dolnośląskie (covering the north lowlands), Isera Foothills (hilly terrains in the central part, located at 300-500 m a.s.l.) and Żytawsko-zgorzelecka depression located in the south.

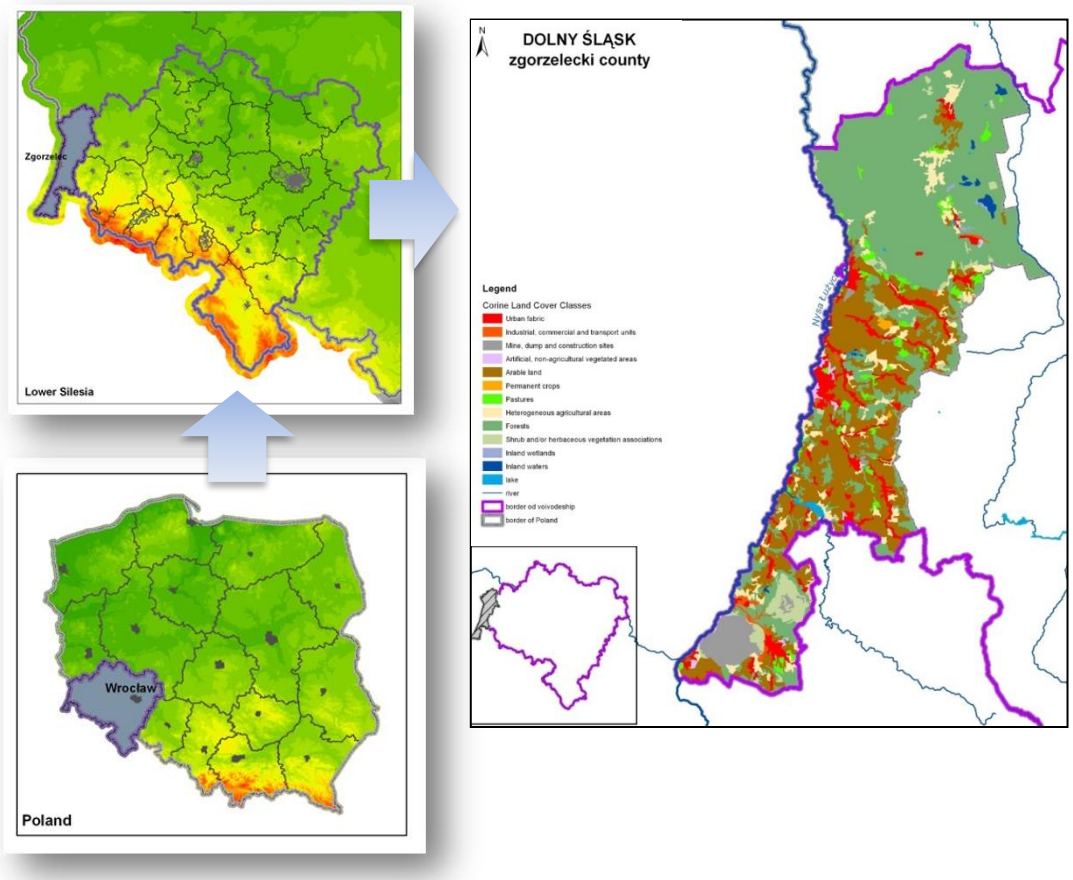

Fig 2. Location of Zgorzelec district in Poland and Lower Silesia

Climate conditions of the district are typical for its latitude and comparable to other areas of Lower Silesia, located in the lowlands or mountain foreland. According to Koppen's climate classification, the region belongs to Cfb zone, characterized by mean air temperature of the coolest

month higher than -3°C and balanced annual course of precipitation totals. Circulation conditions are usually related to western advection of marine polar air masses that are predominant in the district. Mean annual air temperature varies from about 8°C to 9°C. In Zgorzelec, it is equal to 8,4°C. July is the warmest month while the lowest air temperature is observed in January. Because of significant hypsometric and morphologic variability, air temperature can be modified due to altitude and terrain relief.

Precipitation is an element of climate that is characterized by very high temporal and spatial variability. The amount of precipitation depends mainly on altitude, terrain and exposure to the dominant wind from the west direction. The highest annual precipitation totals, approx. 750-800 mm, occurs in the highest part of the Zgorzelec district, i.e. the southern and south-eastern part of the Western Sudetes Foothills (Bogatynia, Bierna), and the lowest precipitation totals occur in the central part of the Śląsko-Łużycka Lowland (approx. 570 mm). The precipitation totals are characterized by a high range of changes in individual years. In the years of 1971-2015, the highest annual totals occurred in 2010, reaching over 150% of the climatic norm. The most dry ones were: 1982 (60-52% of norm) and 2003 (60% of norm). In the pilot area, days with heavy precipitation (≥ 10 mm per day) occur on average 14-18 days annually. Days with very heavy precipitation (≥ 20 mm per day) are less frequent, on average 3-4 days. Heavy and very heavy precipitation occur mainly in the summer months. In the years of 1971-2015, the highest daily precipitation totals exceeded 100 mm and were recorded in the summer months (July-August). The highest rainfall in the Zgorzelec district was recorded in August 2010. On 7th August 2010, daily precipitation total at Bogatynia station reached 160,2 mm (14,7% of the annual precipitation norm). At Sieniawka station, it reached 110,8 mm (13,3% of the annual norm). The maximum totals of 5-day precipitation can reach 200 mm, e.g. at Bierna station in July 1981, the 5-day precipitation was equal to 199,7 mm.

In the past, occurrence of long-lasting and/or heavy precipitations often resulted in floods. Most of historical floods in the Zgorzelec district was related to pluvial floods, especially precipitation-type floods. Some of the floods were caused by heavy precipitations when surface runoff was observed. Unfavorable influence of intensive precipitations was shown in historical sources. These are selected hydrological phenomena connected with intensive precipitations in the Lusatian Neisse catchment (Migoń 2010):

- IV 1604 - flood caused by Miedzianka river due to storm precipitations;
- 13 VII 1622 – strong flood from Witka River due to heavy precipitations caused numerous losses and damages in housing and agriculture;
- 23 VI 1759 – flood from Miedzianka river due to storm precipitations;

- VII 1769 – flood from Miedzianka river due to intensive precipitations caused numerous damages;
- 16 VII 1803 – heavy precipitations during nighttime that caused flood from Miedzianka river; such an event occurred several times more in the summer;
- 2 V 1804 – huge flash flood in Bogatynia due to storm precipitations in Detřichov and northern Heřmanice. Numerous damages, e.g. destroyed bridge
- 27 VI 1808 – flood from Miedzianka river due to storm precipitations;
- 8 VIII 1888 – flood from Lusatian Neisse due to intensive precipitations.

One of the most disastrous floods occurred in August 2010. It was a multi-genesis-type as dams at Niedów reservoir were additionally broken. Constant rainfall was observed from the morning of 6th August till the evening of 7th August. The most intensive heavy rain occurred at night on 6/7 August and in the morning on 7th August. Intensity of rainfall at some meteorological stations reached almost 60 mm/hour and daily precipitation totals reached up to 180 mm. Water gauges in upper Nysa Łużycka river recorded almost 3 m higher levels than the previously noticed maximal level. As a result, 4 people lost their lives while material losses in Bogatynia commune exceeded 225 mln PLN (ca. 55 mln €).

2.2. Structure of crisis management

Natural disasters, including floods, require appropriate actions in order to maintain public order and provide safety for the inhabitants and properties. In this case, a very important role is played by crisis management which structure is based on cooperation between particular bodies dealing with selected stages of the crisis management.

There are four levels of crisis management in Poland: national, voivodeship, district and commune (fig. 3). All the levels are operated by crisis management centres that are main bodies in the system. The most important is Government Centre of Security (RCB) which is managed by a director called up by the Prime Minster. The RCB cooperates with i.e. IMGW-PIB in terms of meteorological and hydrological warnings that are a basis to inform inhabitants of endangered region about potential natural disaster risk. Crisis management centres are created at each level. There are constant voivodeship and districts crisis management centres while in case of commune level, such a centre can be created optionally.

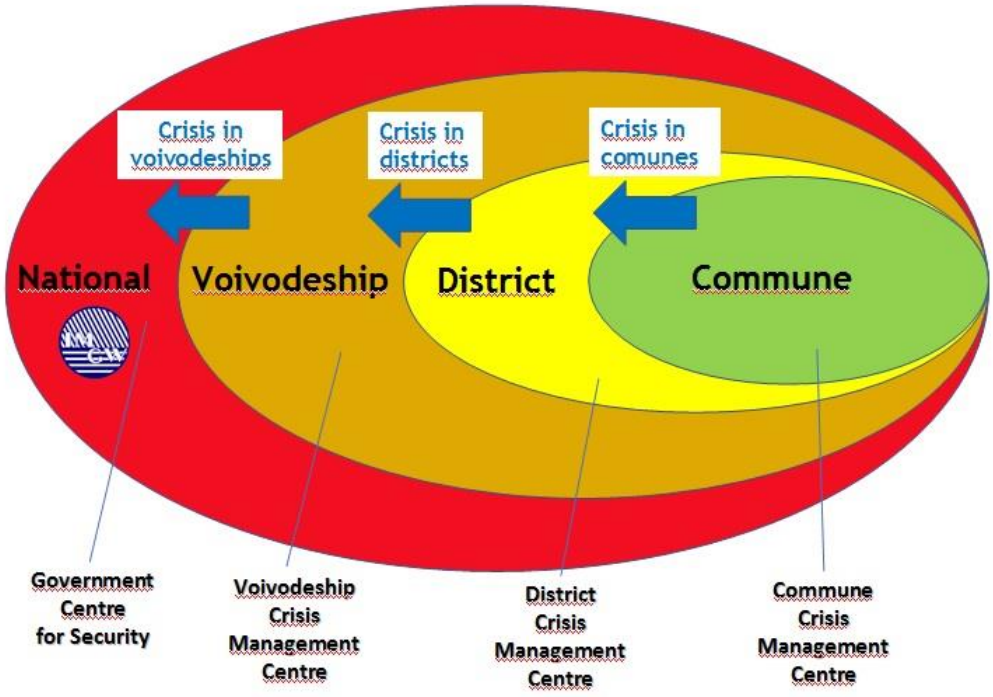

Fig. 3. Structure of crisis management in Poland (source: https://rcb.gov.pl/zarzadzanie-kryzysowe)

A very important role in terms of crisis management in Poland is played by IMGW-PIB. It is especially significant when it comes to regional and local level. On a district scale (i.e. district of Zgorzelec), the first step is collecting data from the region as a basis for issuing warnings and meteorological/hydrological information. In case of extreme phenomenon occurrence (i.e. heavy precipitations or flood), meteorological warnings and forecasts are issued and transferred to the Government Security Centre (RCP) and the Voivodeship Crisis Management Centre. Next, the Government Security Centre sends information to inhabitants with the use of mass media and mobile connections. Simultaneously, the Voivodeship Crisis Management Centre provides the warnings concerning the phenomenon to the District Crisis Management Centre (fig. 4). Subsequent steps on a district level are undertaken by the District Crisis Management Centre that manages the problem on a regional level.

After receiving information on weather conditions, the District Crisis Management Centre communicates with public services, like fire brigades or local police and send them information and warnings concerning weather events. The information and warnings are received by the District State Fire Brigades and the District Police Station (fig. 5).

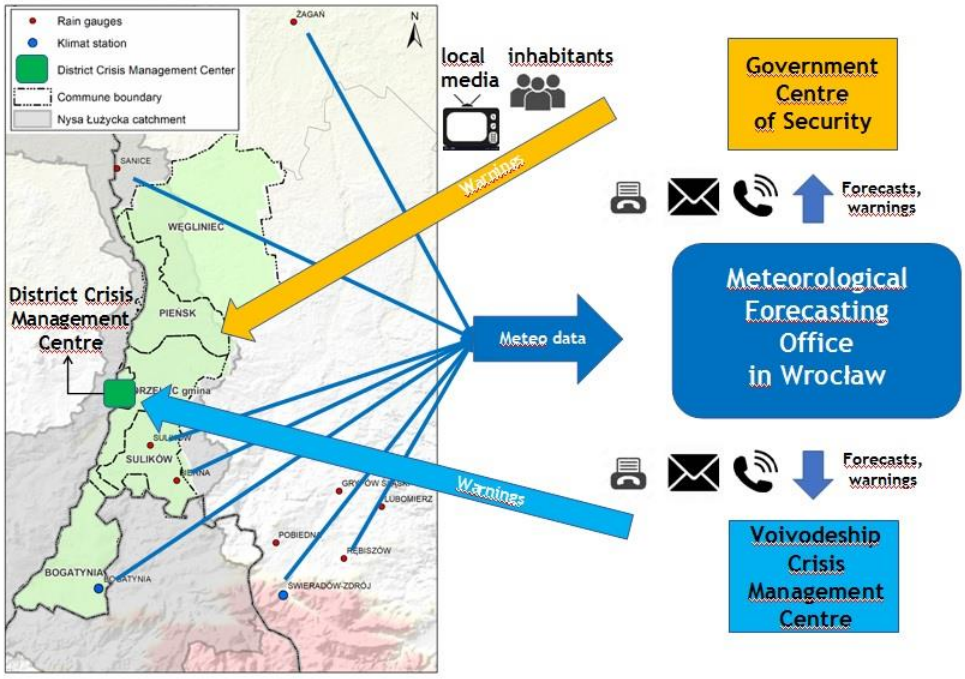

Fig. 4. Crisis management system in the Lower Silesia and district of Zgorzelec

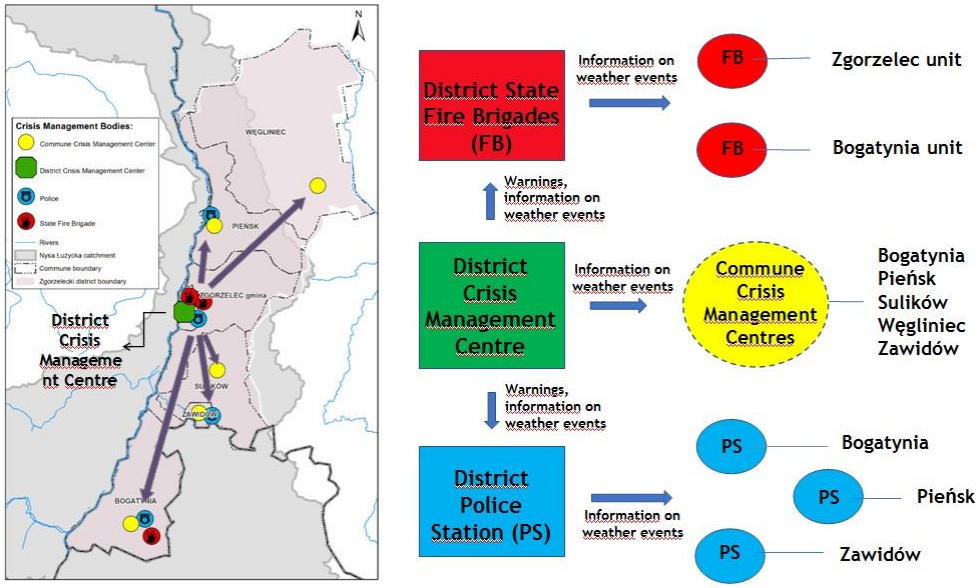

Fig. 5. Crisis management on a district level (district of Zgorzelec)

They transfer the information and warnings further, to their units located in the district. There are two units of fire brigades (Zgorzelec and Bogatynia) and three police stations (Bogatynia, Pieńsk, Zawidów). Additionally to fire brigades and police stations, the District Crisis Management Centre can also send information and warnings to Commune Crisis Management Centres. Such centres can be optionally created in particular communes during emergency situations. In the district of Zgorzelec, five communes are located: Bogatynia, Pieńk, Sulików, Węgliniec and

Zawidów. The role of the Commune Crisis Management Centres includes cooperation with other crisis management centres, support of services dealing with crisis situations, etc.

The role of IMGW-PIB is also related to the recovery stage of crisis management. After extreme weather event occurrence, inhabitants of the region submit a request for refunding to the local authorities. Next, the information is forwarded to the Voivodeship Governor who submits the request to IMGW-PIB. On the basis of measurement data, information on meteorological conditions is prepared by IMGW-PIB. It can contain meteorological data, expertise, etc. Subsequently, the governor provides the information to the local authority who transfers it to the interested inhabitants (fig. 6).

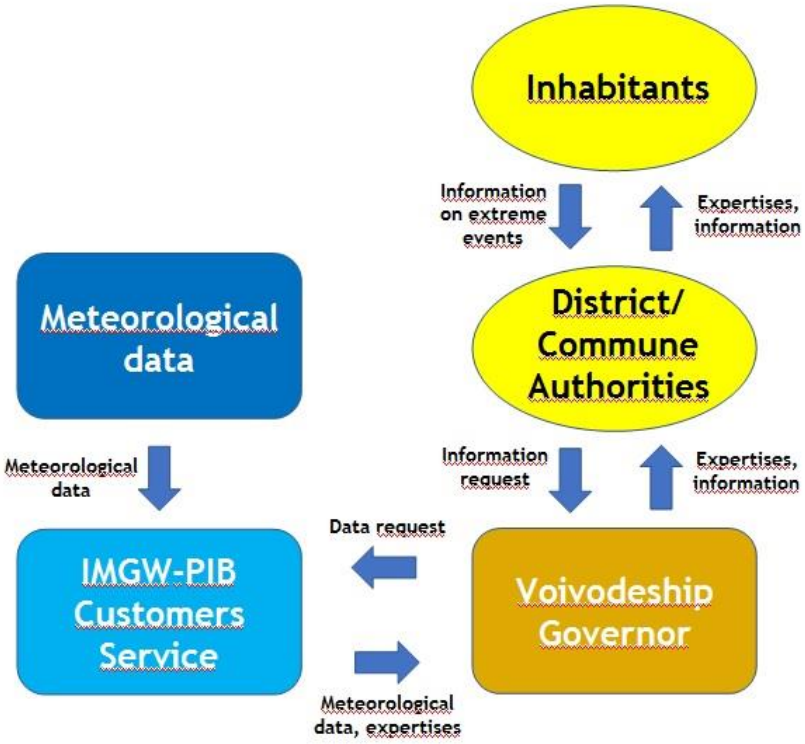

Fig. 6. The role of IMGW-PIB in recovery stage of crisis management

2.3. Legal regulations related to floods and spatial planning

Floods events, including both pluvial and flash floods, require special legal regulation in order to prevent and mitigate the effects of floods occurrence. The most important legal acts concerning the problems of natural disasters, including flood, are Act on Natural Disasters, Water Law and Act on Crisis Management. They define duties and schemes of operational actions during emergency situations. It also concerns floods, however the aspect of flash floods and their consequences has not been included in these legal acts. Water Law, which was implemented on 1 January 2018, considers organization of units responsible for water management on

both national and regional level. It also defines aspects of financial issues related to water use, including economic significance of rainwater management, preservation of green areas, and development of green and blue infrastructure. In terms of floods, the Water Law presents definition of flood, however does not regulate the issue of floods caused by rainwater and sustainable management of rainwater comprehensively. Current approach to rainwater usually refers to sewer system and its technical parameters. Some regional legal acts define use of water in municipalities. In terms of Flood Directive in Poland, analysis on floods caused by heavy rains are not treated separately. There are no flood risk and flood hazard maps dedicated to rainfall floods. These maps cover the area outside the immediate vicinity of the watercourse and do not indicate danger zones in terms of heavy rains. Currently, the Water Act contains information that flood protection should be run with the consideration of flood risk maps, flood hazards maps and flood risk management plans. In order to ensure the inhabitants and facilities protection against flood, the vulnerable areas are considered in the concept of the national spatial management, voivodeship spatial management plan, strategy of development of the voivodeship, frame study of the conditions and directions of the spatial management of the metropolitan area, study of the conditions and directions of the spatial management of the metropolitan area of the community, local spatial management plan, community revitalization plan, decision on location of public goal investment and decision on development conditions. The projects of documents like i.e. study of the conditions or local spatial management plan still require agreement with the Polish Waters association in terms of development and management in the area vulnerable to floods. The Polish Waters formulate these agreements in a way of decisions that include requirements and conditions of planned development or spatial management plan.

On a local scale, a very important legal regulation is Act on a Local Government that contains recommendations for local authorities to provide safety for the inhabitants and flood protection, including equipment maintenance.

One of the most significant documents is National Strategy for Regional Development 2030. It includes improvement in management and implementation of policies focused on regional scale. In the Strategy, the aspects of strengthening cooperation and integrated approach to development on local, regional and national level is included. It is also focused on increase administrative potential in the context of development management. Therefore, it has indirect impact on flood management issues on a regional scale. In the context of spatial planning, the crucial legal regulation is Act on Spatial Planning and Development. It defines vast range of problems related to spatial planning. In terms of local scale, it regulates aspects of local spatial development plan, including development conditions.

Act on spatial planning and development is related to two documents that are a basis for spatial development and policies conducted by a commune:

1. Study of conditions and directions of spatial development of the commune,

2. Local Spatial Development Plan.

The first of the mentioned documents obliges a commune to conduct spatial policy. Study of conditions and directions of spatial development of the commune is a document indicating frame of spatial development and policies in the commune, considering conditions (factors and limits) of spatial development. The Study is not a legal act, so it cannot be a basis for issuing administrative decisions concerning spatial development. It contains information that enables conducting spatial policy. Elaboration and implementation of the Study is obligatory and its development should be preceded by elaboration of a local spatial development plan. The functions of the Study conditions and directions of spatial development of the commune concern spatial policy of the commune, coordination of regulations of local development plans, promotional actions. Whereas a local spatial development plan is a local law and defines spatial development policy of the commune.

Furthermore, each commune elaborates Strategy on commune development that is a perspective plan which defines strategic development goals, directions and measures through goals and operational tasks and indicates financial sources for their realization. Therefore, the Strategy contains recommendations and measures focused on the commune development management in long-term period (10-15 years), defining measures that should be undertaken so the commune can operate and develop. The final date for most of implemented Strategies is 2020. The strategies of development are carried out by the bodies dealing with development policy, including:

- National Government
- Voivodechip Government
- District and commune governments.

The principles of the strategy include the following aspects:

- diagnose situation from the perspective of strategic planning, considering state of environment and spatial variability,
- projections of development trends in the period considered in the Strategy,
- evaluations of development trends in terms of the aspects included in the Strategy,
- indices of implementations,
- evaluation of intervention directions on a regional or local scale,
- systems of realization and financial frames,

On a district level, one of the current problems connected with intensive precipitations are floods that are caused i.e. by irrational activities undertaken by local authorities and real estate

owners. Unfavorable actions are related to removal or channeling surface watercourses, no drainage conservations, building up flood areas and decrease in biological surface. Legal regulations on spatial planning inform only about consultation of the local plans and stadium projects with the directors of the local Regional Board of Water Management in terms of building and land use in the areas threatened by floods (only river floods, without consideration of precipitation-type floods). In case when there is no local plan, the regulations defining the conditions of development as an administrative decision allow to build up the area in almost every case. The only condition to receive the permission is existence of planned similar-type development in the direct surroundings. The solution to limit such inconvenient situation is to develop spatial management plan, however it is connected with large costs for local authorities. Therefore, recommendations carried out within RAINMAN project would be a great advantage to the currently developed plans and strategies.

2.4. Contribution of RAINMAN project

The problem of floods caused by heavy rains was considered within RAINMAN project. Basing on experience of particular partners, methods for mitigation of heavy rain floods were carried out, including non-technical measures and recommendations for local authorities, inhabitants, stakeholders, etc. All the actions undertaken within the project were run according to scheme presented in fig. 7. The basis for analysis was the partners' experience, documents and historical database that consequently were used in further stage connected with risk assessment. In this case, maps related to heavy rain risk were concerned as well as risk classification. The first step was to develop methods for risk assessment related to heavy rains in different regions of the central Europe. These methods were adjusted to rural and urban areas located in the lowlands or in mountain area and help identifying areas characterized by increased risk. The results of risk analysis will be a basis for local authorities to adopt planning documents to identify risk and consequently to improve management. The results of these analysis were subsequently considered in the development of TOOLBOX that is one of the most important results of the project. It contains a set of five tools focused on mitigation of risk related to heavy rains. It is also aimed to support local and regional administration units in the context of risk management. The TOOLBOX contains:

- a tool used for risk evaluation and mapping related to intensive precipitations,
- a manual of measures to mitigate risk and the aspects concerned with warning systems and crisis management,
- recommendations for flood risk management plans,

- tools for increasing public awareness and involvement of stakeholders,
- catalogue of good practices limiting risk of floods caused by heavy rains.

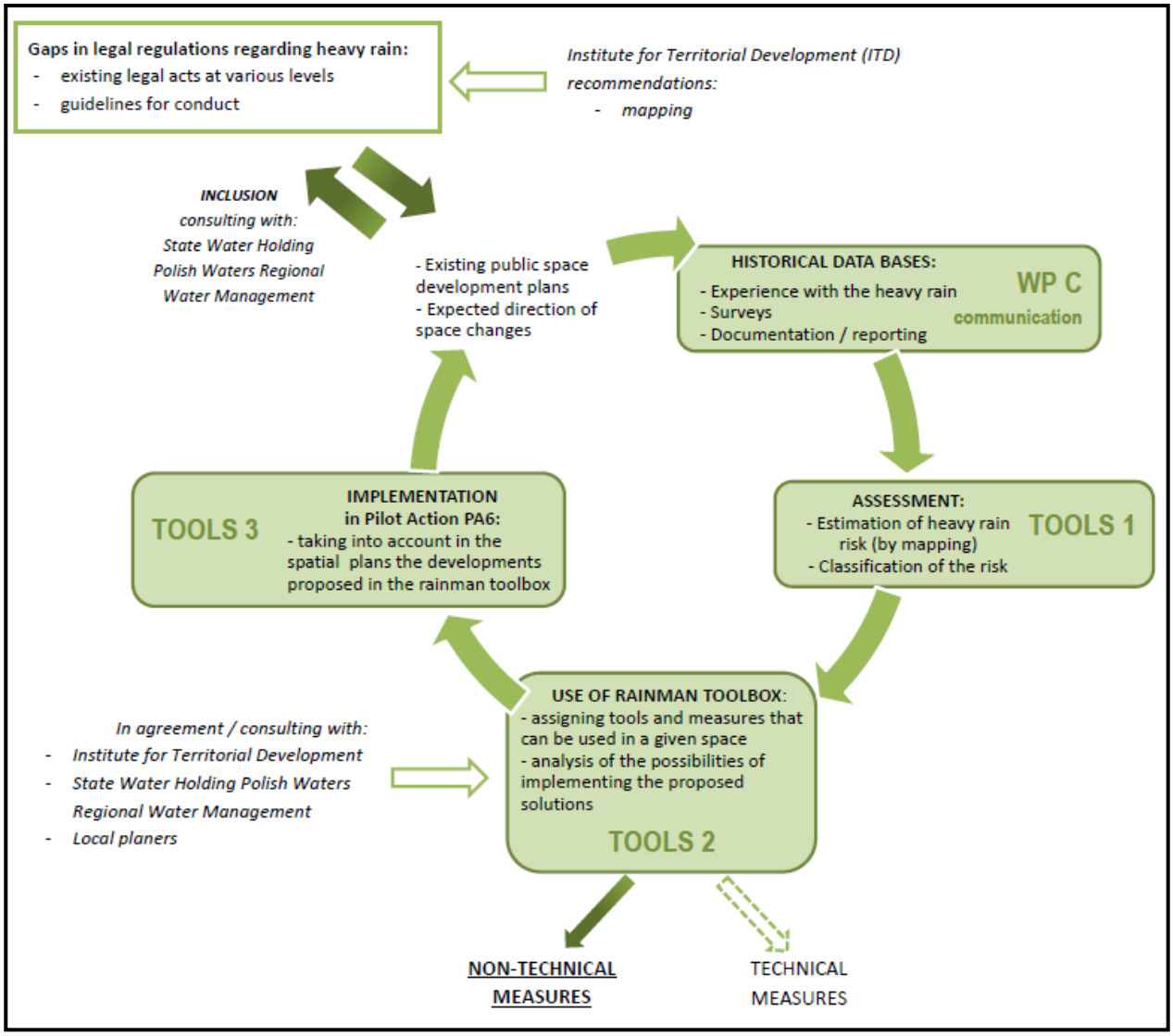

Fig. 7. Scheme of measures undertaken in RAINMAN project

Another step was to implement developed products with a consideration of numerous bodies whose activity is related to water and flood issues. The results were consulted with Institute for Territorial Development (IRT), State Water Holding Polish Waters (PGWWP) and local planners. Taking into consideration suggestions and remarks concerning legal gaps and regulations, list of recommendations was developed in order to submit support for local authorities, stakeholders and spatial planners in terms of flood protection measures. In case of Poland, the district of Zgorzelec was taken into consideration as a pilot area because of frequent flood occurrence and heavy precipitation events.

2.5. Recommendations and non-technical measures

Considering the results of RAINMAN project as well as legal gaps and the needs submitted by interested bodies, list of recommendations contains measures that should be considered in the local and national legal regulations, spatial planning in the region or in the structure of crisis management in terms of flood protection.

As a part of the activities implemented in the RAINMAN project, a set of actions has been carried out that can be helpful in supporting and reducing heavy rain effects. Table of *Catalogue of 100 risk reduction measures_EN_DE_200224.xlsx*, contains 100 examples of measures divided into various impact areas, i.e. farmlands, forest, watercourses, settlement areas, buildings, early warnings and risk awareness / communication. Furthermore, the measures that can contribute to the modification of spatial development in terms of mitigation of heavy rain effects were identified. Non-technical spatial planning measures are summarized in the diagram below (fig. 8).

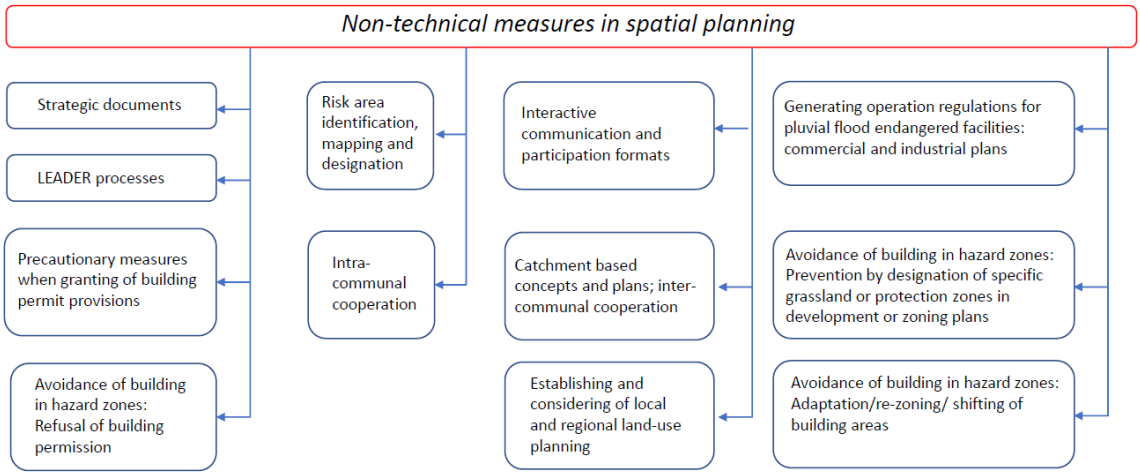

Fig. 8. Scheme of non-technical measures for spatial planning

One of the measures is activity ‘Strategic document’, which can be a crucial document in spatial planning in term of mitigation of heavy rain effects. Therefore, recommendations to changes in official document are necessary to present the significance of heavy rain problem and e.g. pluvial floods.

Below are presented selected recommendations which resulted from RAINMAN project.

1. Implementation of procedures and recommendations related to flood risk to local spatial development plans.

Spatial planning structure is a hierarchic system, carried out at three levels of government administration (fig. 9). It is an important tool that defines land use, including areas vulnerable to floods. Therefore, spatial planning should be a general instrument used for risk prevention. On a local level, one of the most important regulations is a local spatial development plan. Existence of such a plan creates high opportunity for implementation of various measures and solutions, as current content of this plan is not defined in details. In terms of flood issues, the plan should be supplemented with information about data concerning location of terrains vulnerable to flood phenomena. It also should include historical data on floods that occurred in the past and damaged infrastructure, in order to have approximate knowledge what magnitude of floods and material losses can occur in the future. Furthermore, area of the terrains vulnerable to flood should be also considered. The mentioned above features, data and characteristics could be a basis for further stages of development of the plan. One of the most important issues concerning the content of the plan is the aspect of measures mitigating potential losses in the flood areas. It concerns especially methods for development of such areas. Recommendations given in a spatial development plan should consider potential risk and losses in case of flood occurrence. Such recommendation should refer to already existing facilities, buildings as well as to newly designed development concepts. The development of flood areas should be limited and adopted to existing geographical conditions. Therefore, spatial development plan should consider factors that contribute to minimization of surface runoff and increase in retention (fig. 10). Thus, in the elaboration of the plan, aspects of proper vegetation should be also included. Such solutions should be preceded by analysis on costs and benefits.

Numerous consultations run with various bodies and institutes that deal with water problems indicated that local spatial development plan should be strengthened as a legal document. A very important task is also related to study of conditions and directions of spatial development of the commune as these two documents are going to be linked in the future in order to strengthen spatial planning. Therefore, the recommendations will be useful for planners who prepare spatial local development plan.

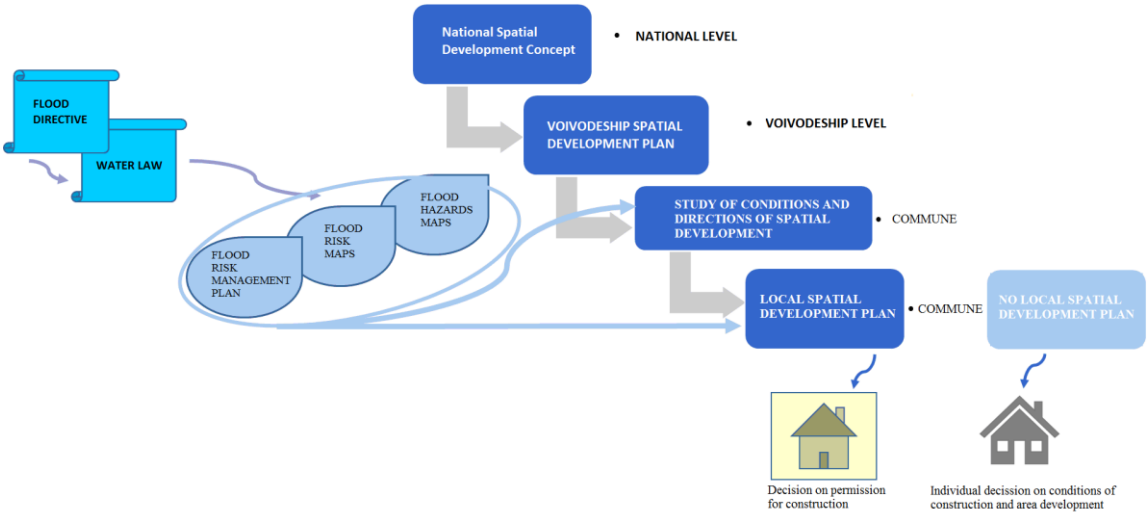

Fig. 9. Scheme of hierarchy of spatial development system

Fig. 10. Infiltration ditch as an example of retention areas which should be considered in local spatial development plans (phot. I. Lejcuś)

2. Risk analysis as a basis for spatial planning and legal regulations in the areas vulnerable to flood occurrence.

One of the most important tasks within RAINMAN project was to evaluate risk concerned with flood occurrence. So far, such features, especially in the context of local flash and urban floods as well as morphological factors, have been taken into consideration in minor degree in strategic, legal and planning documents. Risk identification started with analysis focused on data related to interventions of fire brigades. Simultaneously, flash flood events that had occurred in the past, were selected in order to conduct further analysis. The pilot region of Zgorzelec district is morphologically differentiated. Thus, inclination and type of minor basins are a crucial factor in this case. Maps of flood hazard and flood risk do not cover entire spectrum of flood danger, as they do

not include the problem of flash floods. According to Water Law, flood hazard maps should include area with existing probability of extreme event. Such a zone should be marked especially in minor basins. Selection of the basins bases on shape and size of a given basin, geographical conditions (altitude, inclination, etc.), hydrological conditions (i.e. slope length, density of watercourses), soils and land use.

In the district of Zgorzelec, three types of minor basins were selected in terms of vulnerability to sudden water level increase. In this case, Bryndal's method (Bryndal 2015, Bryndal et al. 2017) was used. This had been previously developed for mountains basins in other Polish regions. It classifies basins into three classes (A, B, C) according to their vulnerability (fig. 11). The analysis with the use of this method for river basins in the district of Zgorzelec showed that southern regions are the most vulnerable to sudden flash flood occurrence. It results from morphological conditions as the southern part of the district is covered by mountain and hill areas. This is a very important aspect, as the problem of flash floods has not been considered in legal and planning documents so far. Such information about flash floods should be considered in national regulations, like i.e. water law or national strategies. Nevertheless, from the perspective of local authorities and planners, changes at national levels are impossible to implement. Therefore, the actions focused on implementation of the flash flood aspects and methods of their evaluation should be focused on two documents that operate on a local scale: study of conditions and directions of spatial development of the commune and local spatial development plan. The first of the mentioned documents contains directions related to evaluation of areas vulnerable to floods. It concerns marking terrains of flood hazard of Q1% and Q10%, however these regulations are related to pluvial floods. The aspect of flash floods and urban floods that may occur suddenly even in the areas located far from river zones, has not been considered so far. The area of possible flash flood occurrence should be also included in the local plans of spatial development. In case of the plans, the analysis on possible flash flood should be added to the existing areas of flood vulnerability zones (marked as ZZ). In the RAINMAN project, the aspects of flash flood mapping and risk analysis was considered in the deliverables of D.T1.1.1. ('Existing approaches and methods for heavy rain modelling, mapping and risk assessment') and D.T3.6.3. ('Hazard/risk maps for small cities and rural areas').

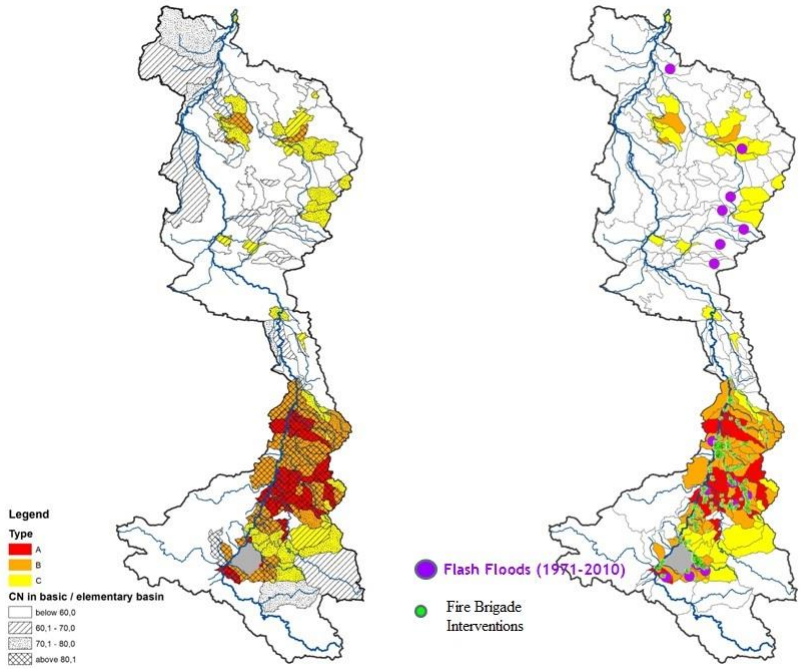

Fig. 11. Risk analysis according to Bryndal's method, flash flood occurrence and locations of fire brigade interventions in the district of Zgorzelec

3. Development of green and blue infrastructure as a measure reducing risk of floods caused by heavy rains.

The idea of green and blue infrastructure is relatively new, therefore, it has not been included in legal acts, regulations and local recommendations for a very long time. The updated Water Law, which was implemented in 2018, informs about new aspects related to introduction of green and blue infrastructure and proper development of urban areas with a consideration of minimization of rainwater discharges (fig. 12). It is proved that decrease in artificial surface with simultaneous increase in green and water areas is favorable in the context of mitigation of flash floods effects. Therefore, another step to increase significance of that kind of infrastructure is to introduce its regulations to a local level. First of all, this aspect should be considered in the studies of conditions and directions of spatial development of the commune and local spatial development plans.

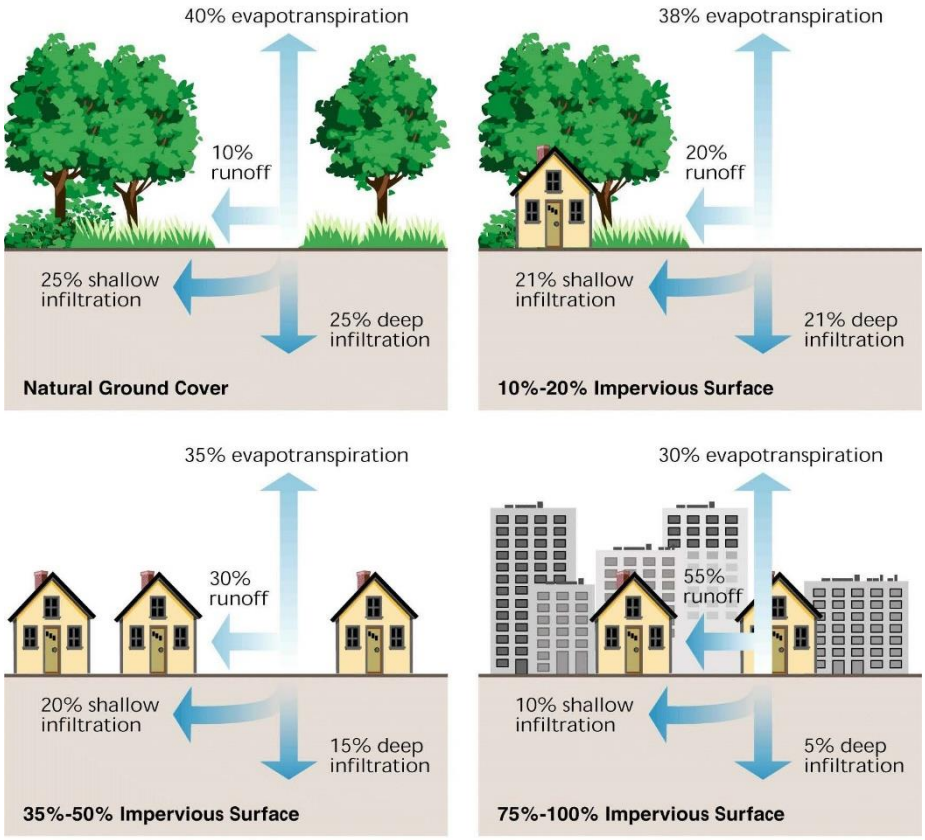

Fig. 12. Impact of green infrastructure on rainwater drainage (source: WMO 2008)

In case of the studies, they are a basis for administrative decisions on spatial development and should consider various factors and limits. Thus, the aspect of blue and green infrastructure should be considered in the studies and in local spatial development plans. While developing these two documents, planners should take into account possibilities of introduction of new blue and green area as well as preservation of already existing terrains. In the planning process, the aspects of local conditions should be taken into consideration, i.e. morphology, vegetation, distribution of urban areas, artificial surface, etc. Maps presenting the most vulnerable areas in terms of heavy rain effects would contribute to appropriate spatial planning and distribution of green and blue infrastructure. In the planning, geographical features should be also considered, informing about inclination, soils and their permeability. Therefore, appropriate blue infrastructure can be designed, like surface infiltration reservoirs (fig. 13). Advantages of green and blue infrastructure were presented in deliverable DT2.2.5 of the RAINMAN project (‘Retention concepts and optimization for storage management’).

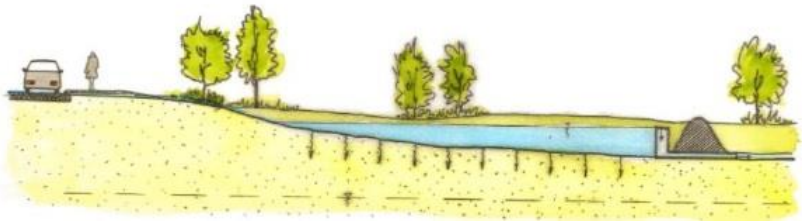

Fig. 13. Surface infiltration reservoir (source: Lejcuś et al. 2017)

4. Support of additional remote rainfall and water gauges for the needs of early warning systems.

Analysis on flash flood and heavy precipitation occurrence in the pilot region, which based on material losses as well as on national and volunteer fire brigade interventions records, showed that heavy precipitations can occur in single locations, even though surrounding areas are not affected by rainfall. In the district of Zgorzelec, monitoring of weather and hydrologic situation is carried out with the use of several stations of IMGW-PIB. As it was mentioned in the chapter concerning description of the region, the area is differentiated in terms of altitude and morphology. Therefore, it is highly probable that extreme rainfall situations can occur not even being noticed. A map presenting fire brigade interventions in 2013, during extreme precipitation events, show that effects of such phenomenon are spread throughout the region but with various intensity (fig. 14). Most of interventions concern urban areas (like municipalities of Zgorzelec and Bogatynia) or mountain region (mainly Isera Mts) where due to terrain inclination and higher precipitation totals, the effects are more noticeable. It indicates that problem of data flux is very important because of the need for urgent information of the inhabitants about the threat. Protection of the inhabitants is included in the commune strategies and other legal and planning documents. In case of the mountains, the problem is related to flood character in this area. Floods in mountains occur suddenly and are characterized by high intensity which requires quick reaction from public services and bodies dealing with crisis management. In terms of hydrological conditions, there are uncontrolled watercourses that can be a potential source of pluvial and flash floods as well. In this case, early warning systems existing in the region should be supported with current information from additional rainfall and water gauges. The information could be sent immediately to the District Crisis Management Centre and would be a support for meteorological warnings issued by IMGW-

PIB. The supporting role of water and rain gauges may be implemented to the crisis management system on a district level which was already discussed in the chapter devoted to crisis management issues. Special regulations indicating the use of current data from such stations would significantly improve efficiency of the system and would enable quick reaction of public services to extreme meteorological and hydrological phenomena. The information obtained from the gauges could be an addon to the Domestic Map of Security (fig. 14). It would be very important to include the additional measurements to the local early warning systems in the district of Zgorzelec that has been operating for almost ten years. Such a structure could contribute to shorten information flux and consequently to provide precious meteorological and hydrological data sooner than nowadays.

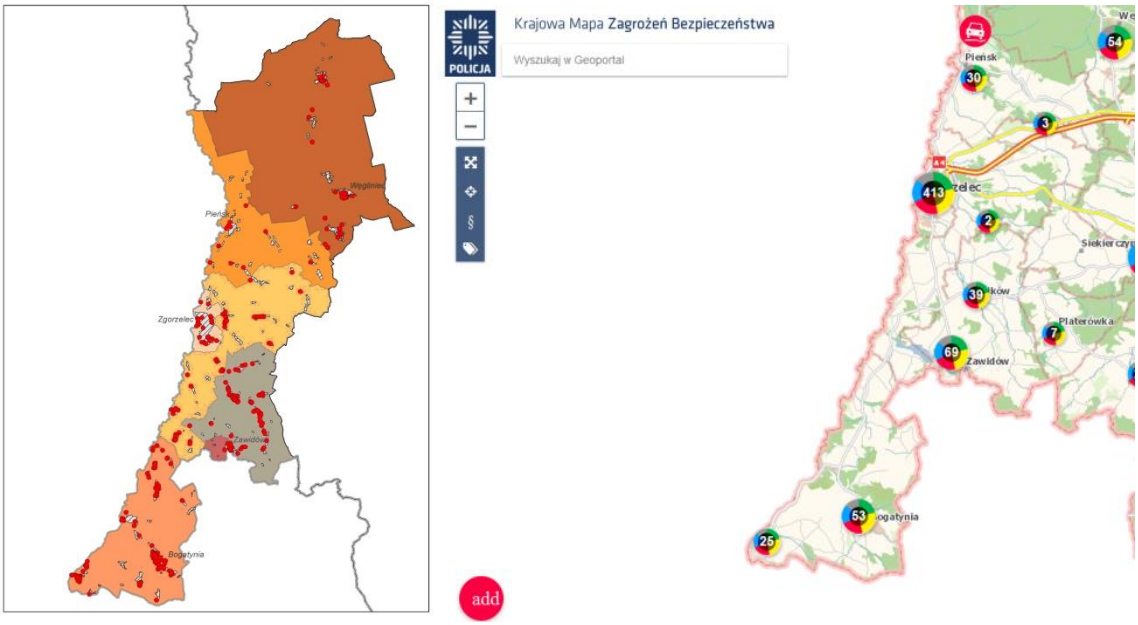

Fig. 14. Fire brigade interventions in 2013 (left) and domestic map of security (right) for the district of Zgorzelec (source: https://mapy.geoportal.gov.pl/iMapLite/KMZBPublic.html)

3. Summary and Conclusions

3.1. Discussion of approach

The information presented in the study concerns the aspects of legal regulations, spatial planning, strategic documents and structure of crisis management that have not been considered in today system or have been taken into account in minor spectrum. The information needed for the Action Plan was gathered from various sources, however it usually was taken from existing legal acts, strategies and regulations. Additional source were institutes and bodies dealing with water management that provided a lot of precious hints on current requirements related to flood and water management issues. In the study, the authors tried to include vast range of problems that could be improved in further regulations in the considered region. Therefore, the recommendations included problems of legal acts (including local documents) on flood risk and hazard, aspects of water retention in the flood vulnerable areas, risk analysis (especially for flash flood phenomenon) and even crisis management structure.

3.2. Summary

The issues and problems considered in this document contain general information about the pilot region with a consideration of currently valid legal regulations. As significant area of the region is covered with mountains and hills, the problem of flood is crucial here. It concerns not only pluvial but also flash floods. Risk analysis with a consideration of mapping particular river basins showed that there is a lot of areas vulnerable to flash flood occurrence. Such additional information should be included in the local documents, like study of conditions and directions of spatial development of the commune and local spatial development plan. These documents should also include additional information on appropriate spatial planning in the context of green and blue infrastructure and sustainable policy related to water retention in the flood-prone area. In case of crisis management and early warning system, additional direct data flux would be a helpful tool. It is worth emphasizing that according to the analysis carried out in the project, most of fire brigades interventions (and usually the highest material losses) were noticed in densely urbanized areas. Therefore, the hints developed in the project should especially concern municipal terrains. All the recommendations, resulted from the RAINMAN project, could be useful in planning process that requires detailed information for particular areas, especially in terms of vulnerability to floods.

3.3. Conclusion

Developed recommendations carried out in the project can be a basis for further regulations and spatial planning. Considering flash flood aspect, besides pluvial flood, can be a milestone in risk evaluation in case of the regions often affected by floods. Appropriate regulations included in various acts and documents can considerably increase significance of spatial planning and its principles in flood vulnerable areas. Furthermore, results carried out in the project and implemented to the regulations will be a basis for future measures related to increase public safe in such regions.

4. References

Bryndal T., 2015, *Local flash floods in Central Europe: A case study of Poland*, Norsk Geografisk Tidsskrift, 69 (5), 288-298,

Bryndal T., Franczak P., Kroczak R., Cabaj W., Kołodziej A. 2017, *The impact of extreme rainfall and flash floods on the flood risk management process and geomorphological changes in small Carpathian catchments: a case study of the Kasiniczanka river (Outer Carpathians, Poland)*, Natural Hazard, 88, 95-120,

Lejcuś K., Burszta-Adamiak E., Dąbrowska J., Wróblewska K., Orzeszyna H., Śpitalniak M., Misiewicz J., 2017, K*atalog dobrych praktyk. Zasady zrównoważonego gospodarowania wodami opadowymi pochodzącymi z nawierzchni pasów drogowych*, Wrocław University of Environmental and Life Sciences, Opracowanie na zamówienie Gminy Wrocław, Wrocław, Available from: https://www.wroclaw.pl/srodowisko/files/dokumenty/8811/Katalog%20Dobrych%20Praktyk%20-%20drogi.pdf,

Migoń P. (ed.), 2010, *Wyjątkowe zdarzenia przyrodnicze na Dolnym Śląsku i ich skutki*, Institute of Geography and Regional Development, University of Wrocław,

WMO, 2008, *Urban Flood Risk Management. A Tool for Integrated Flood Management*, Flood Management Tool Series, Technical Document, No. 6, World Meteorological Organization.

RAINMAN Key Facts

Project duration:	07.2017 – 06.2020
Project budget:	3,045,287 €
ERDF funding:	2,488,510 €
RAINMAN website & newsletter registration:	**www.interreg-central.eu/rainman**

Interreg CENTRAL EUROPE
RAINMAN
European Union
European Regional Development Fund

Lead Partner

LANDESAMT FÜR UMWELT, LANDWIRTSCHAFT UND GEOLOGIE | Freistaat SACHSEN

Saxon State Office for Environment, Agriculture and Geology
rainman.lfulg@smul.sachsen.de

Project Partner

Saxon State Ministry of the Interior
STAATSMINISTERIUM DES INNERN | Freistaat SACHSEN

Environment Agency Austria
umweltbundesamt

Office of the Styrian Government
Das Land Steiermark
Wasserwirtschaft

T. G. Masaryk Water Research Institute, p.r.i
VÚV TGM

Region of South Bohemia
The Region of South Bohemia

Croatian Waters
HRVATSKE VODE

Middle Tisza District Water Directorate

IMGW
Institute of Meteorology and Water Management
National Research Institute

Leibniz Institute of Ecological Urban and Regional Development
Leibniz Institute of Ecological Urban and Regional Development

Project support

INFRASTRUKTUR & UMWELT
Professor Böhm und Partner

INFRASTRUKTUR & UMWELT
Professor Böhm und Partner
RAINMAN@iu-info.de