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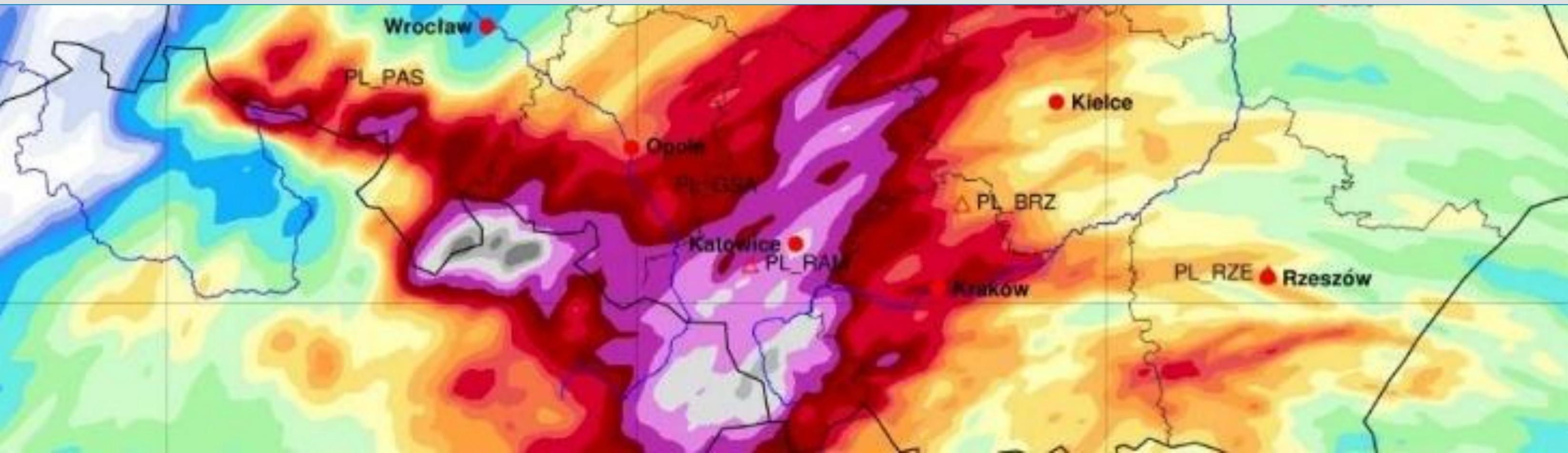
XLII  
International School  
of Hydraulics

# FLOOD IN SEPTEMBER 2024 – Hydrological Analysis, Infrastructure Functionality and Consequences

**Marta Barszczewska**



# HYDROLOGICAL ANALYSIS OF THE FLOOD



# TIME AND PLACE OF THE FLOOD

## Heavy rainfall

Due to prolonged rainfall in southwestern Poland, flooding occurred in many provinces, with the peak intensity from September 15 to 20, 2024, which caused significant damage.

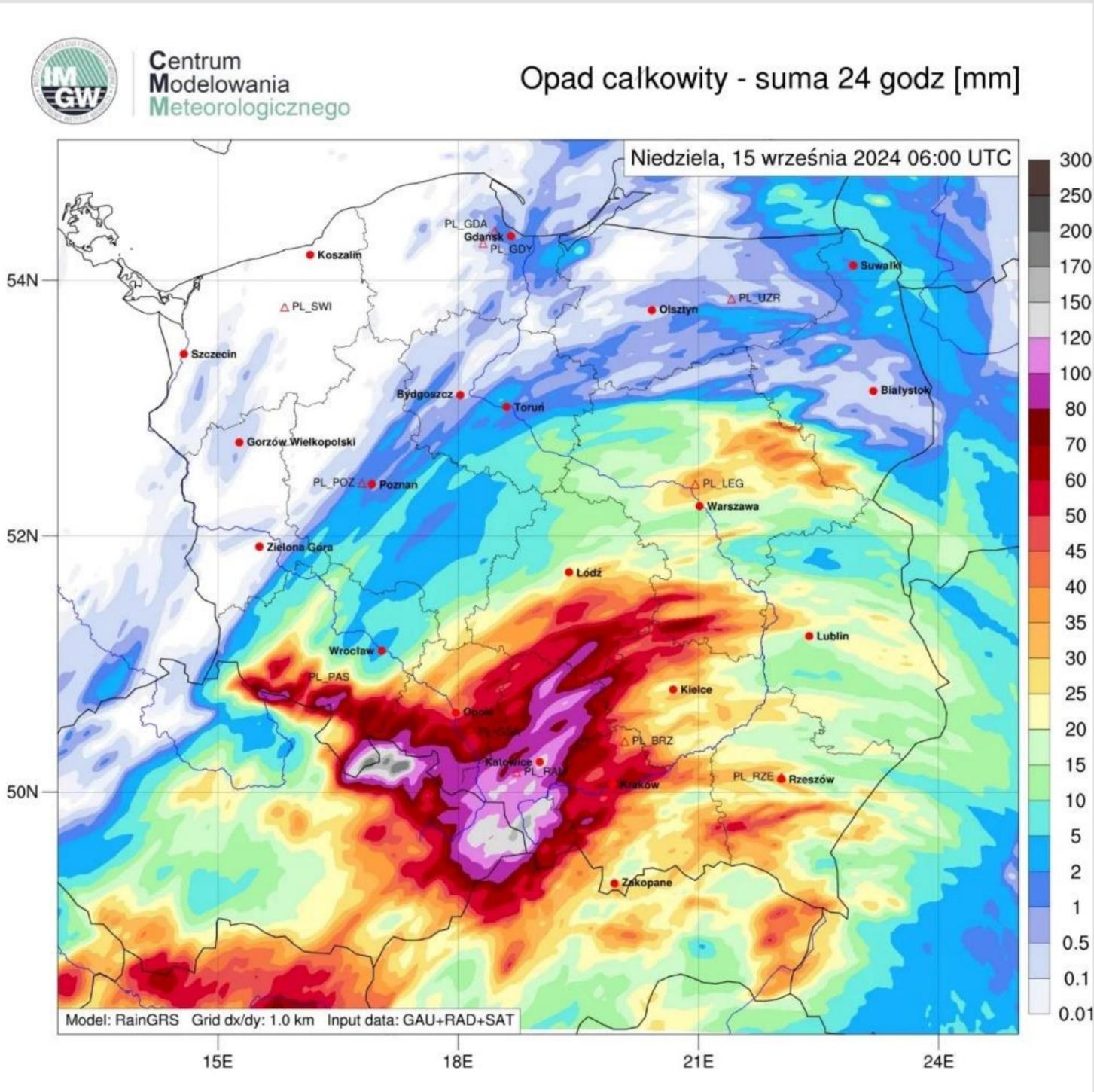
**The flood began: 2024-09-13.**

**The flood ended: 2024-10-04.**

**Last: 22 days.**



# TIME AND PLACE OF THE FLOOD



## The flood affected in particular the following rivers:

in the Odra river basin area: Odra and its tributaries:

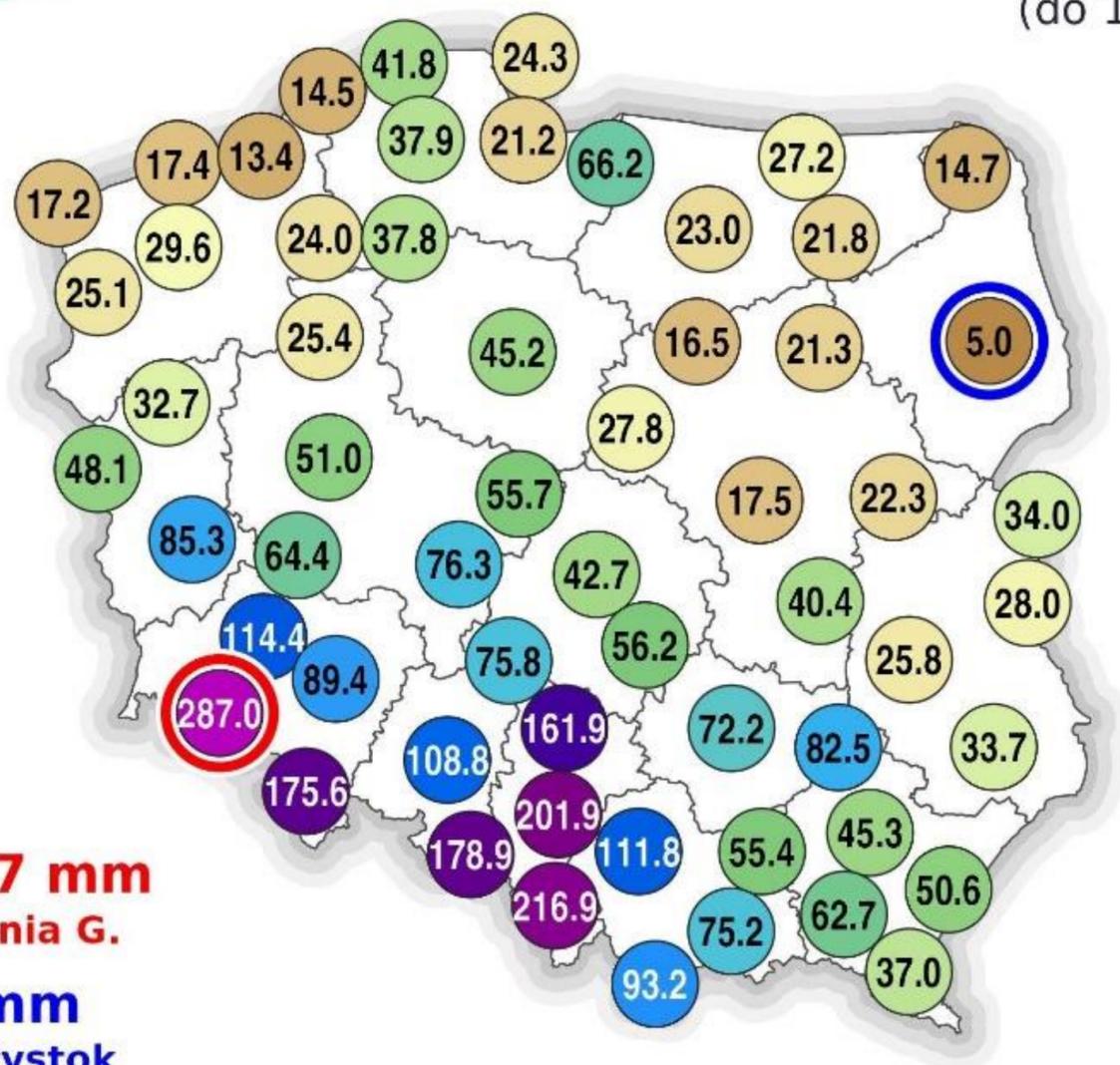
- in the Upper Odra region: Opawa, Opawica, Olza, Piotrówka, Szotkówka, Psina, Troja, Sumina, Stradunia, Osobłoga, Prudnik, Złoty Potok, Biała,
- In the Middle Odra region: Nysa Kłodzka, Budzówka, Biała Głuchołaska, Ścinawa Niemodlińska, Oława, Krynka, Ślęza, Mała Ślęza, Bystrzyca, Piława, Czarna Woda, Strzegomka, Pełcznica, Średzka Woda, Nysa Szalona, Wierzbiak, Barycz, Orla, Polski Rów, Bóbr, Bystra, Zadrna, Jedlica, Radomierka, Kamienna, Wrzosówka, Podgórna, Kwisa, Długi Potok, Oldza, Cielnica, Rudna, Jodłownik, Świdna, Widna;

In the Vistula river basin:

- in the Small Vistula region: Knajka, Łownica, Jasienica, Wapienica.

# TIME AND PLACE OF THE FLOOD

 **Suma opadu** **WRZESIEŃ 2024**  
(do 15.09)



**287 mm**  
Jelenia G.

**5 mm**  
Białystok

Opracowano na podstawie danych operacyjnych ze stacji synoptycznych.  
Prezentowane wartości w procesie kontroli i weryfikacji mogą ulec zmianie  
Wizualizacja danych: dr Alan Mandal

## Hydrological and meteorological causes

### Rainfall intensity

Long-term rainfall in southwestern Poland, especially on September 15-20, 2024, caused a significant increase in river levels.

### Soli saturation

High soil moisture resulting from earlier rainfall reduced the ability to absorb water, which contributed to the rapid rise of rivers and floods.

### Terrain factors

The terrain and soil type in the region were crucial to the spread of floods, especially in areas with low water retention.

# TIME AND PLACE OF THE FLOOD

## Flood course and its characteristics

### AREA AFFECTED BY FLOOD

The flood affected the Lower Silesia, Opole, Silesia, Lubuskie, Małopolskie, West Pomerania and Wielkopolskie voivodeships, causing significant destruction.

### DURATION OF PRECIPITATION

Heavy rainfall continued for several days, causing water levels in rivers to rise rapidly.

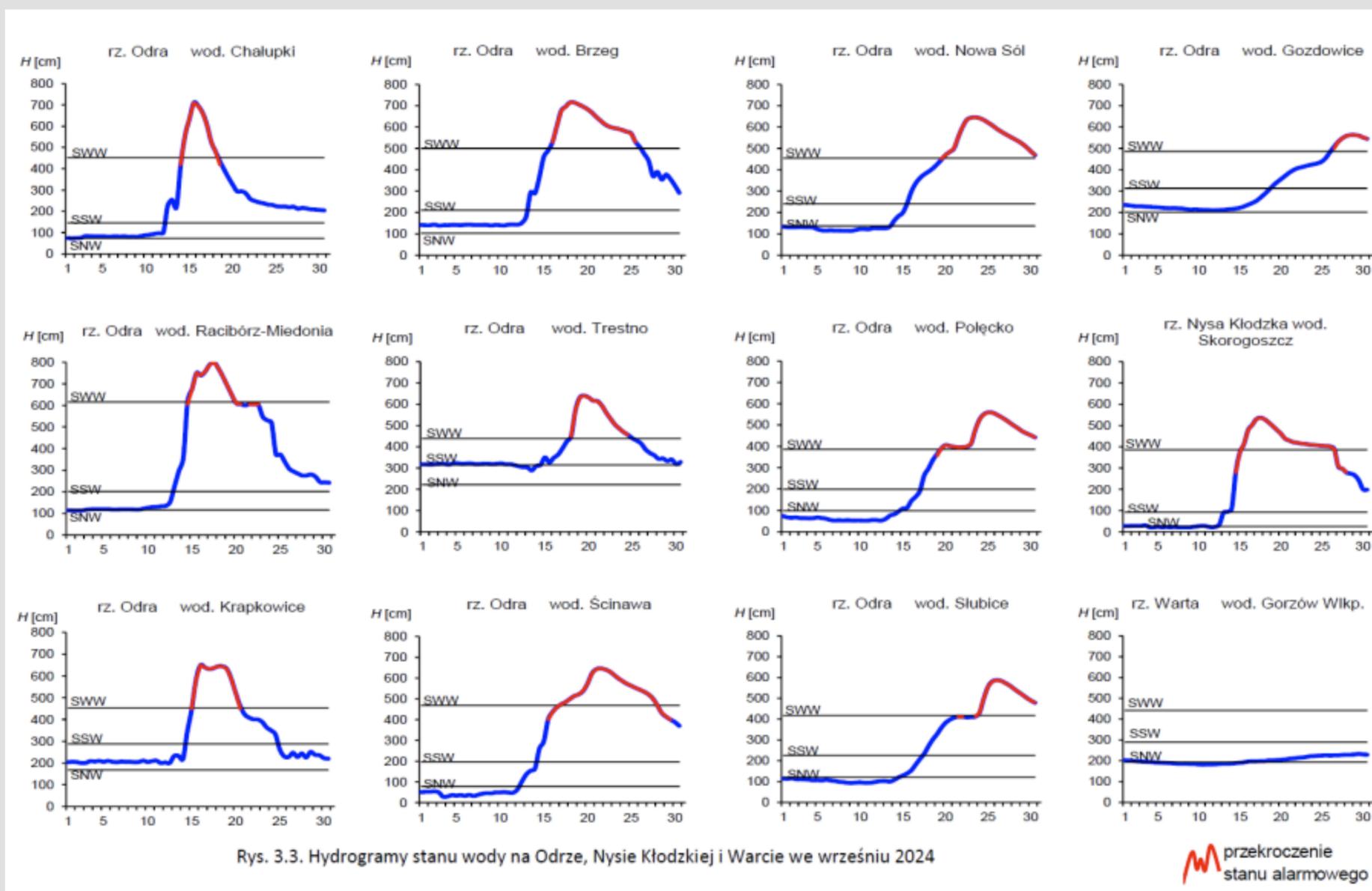
### CLIMATE CHANGE

The increase in the frequency of heavy rainfall indicates the impact of climate change on the occurrence of floods in the region.

# TIME AND PLACE OF THE FLOOD

## Hydrological and meteorological causes

- After extremely high rainfall on 13-15 September, flood waves formed rapidly on the rivers of the upper and middle Oder basins, which exceeded the alarm level extremely quickly. The highest number of exceedances of the alarm level: **81 was recorded on 16 September**. After 16 September, the number of exceedances of the alarm level in the Oder basin systematically decreased, while on the Oder itself it increased, as a result of the movement of the flood wave. At the end of the second decade, almost the entire Oder (with the exception of the estuary zone) was recorded with high water levels, generally with exceedances of the alarm level, much less often the warning level.
- The highest number of exceedances of the alarm level in the Vistula basin: **21 was recorded on 15 September**. After 16 September, high rainfall was no longer recorded in the whole of Poland and in both basins drops in water level prevailed. On the last day of the month, the water level in the Vistula basin and on the Vistula was generally in the low water zone.



## Types and frequency of floods

### TYPES OF FLOODS

Floods can be classified according to their source, including rainfall, river, urban and storm floods, with different mechanisms and environmental effects.

### FACTORS AFFECTING FREQUENCY

Climate change, urbanisation and changes in catchment use can lead to increased flood frequency, requiring adapted risk management strategies.

# FUNCTIONING OF INFRASTRUCTURE





## Impact of floods on infrastructure

### Road and track damage

The flood caused damage to many roads, which limited the mobility of residents and the transport of goods.

The suspension of timetables and track damage affected communication between cities.

### Connectivity issues

Power and telecommunications network failure.

### Failures of hydrotechnical infrastructure

Damage and loss of controllability of infrastructure.

# FUNCTIONING OF INFRASTRUCTURE

## Dry flood reservoirs and retention reservoirs

Dry flood reservoirs:

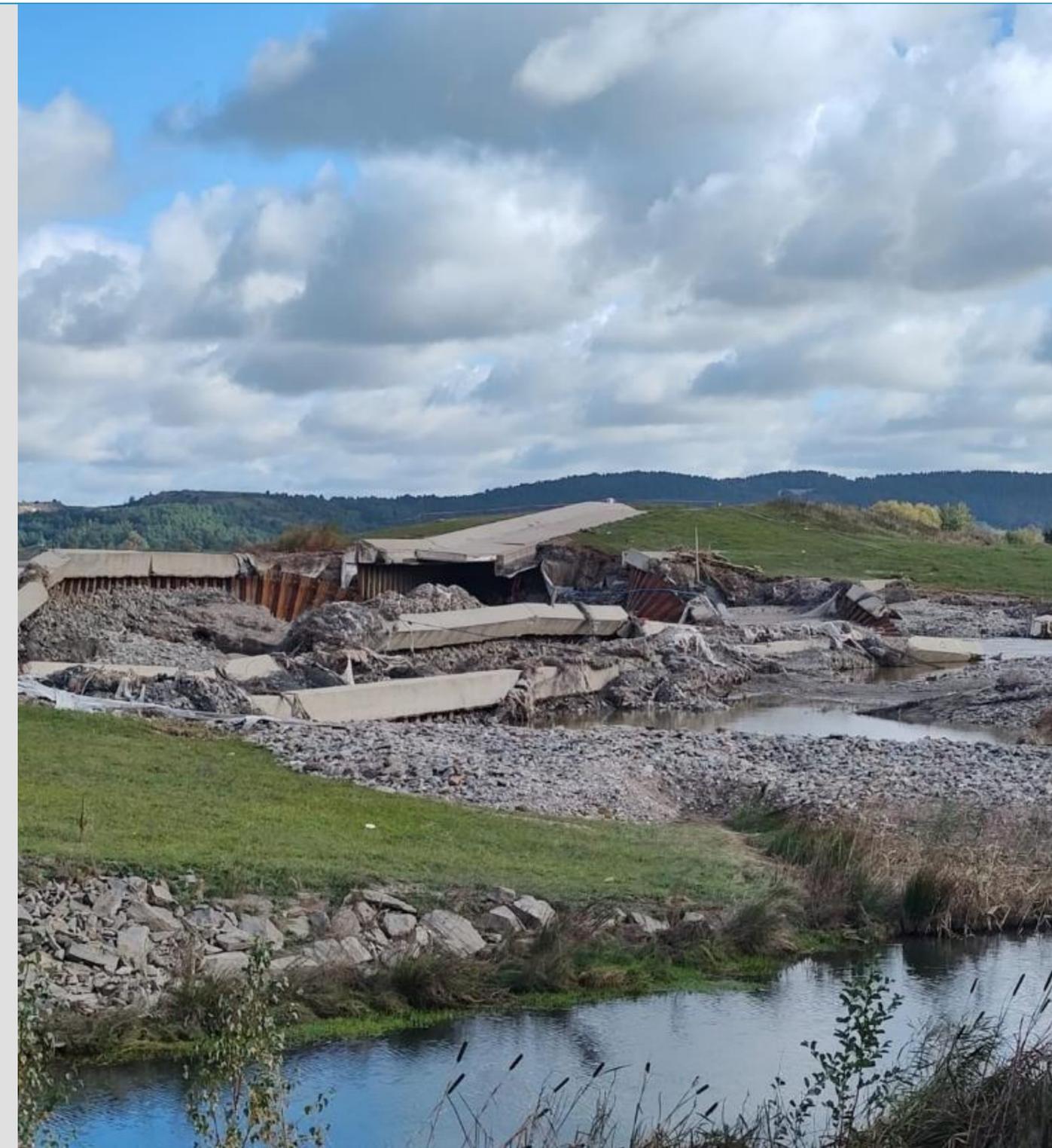
- in the Odra catchment area: Racibórz Dolny, Buków;
- in the Nysa Kłodzka catchment area: Szalejów Górny, Krosnowice, Roztoki, Międzygórze, Stronie Śląskie, Boboszów, Roztoki Bystrzyckie;
- in the Kaczawa catchment area: Kaczorów, Świerzawa, Bolków;
- in the Bóbr catchment area: Mysłakowice, Cieplice, Sobieszów, Mirsk, Krzeszów I i II.

Dry flood reservoirs in the area of the Regional Water Management Authority in Wrocław accumulated water from 12.09 to a maximum of 24.09 and collected a total of over 32.9 million m<sup>3</sup> of water.

Retention reservoirs:

- in the Nysa Kłodzka catchment area: Topola, Kozielno, Otmuchów, Nysa;
- in the Bystrzyca catchment area: Mietków, Lubachów, Dobromierz (Strzegomka);
- in the Kaczawa catchment area: Słup (Nysa Szalona),
- in the Bóbr Catchment area: Bukówka, Pilchowice, Sosnówka (Czerwonka), Złotniki i Leśna (Kwisa).

There were also **six flood polders** operating in the Wrocław Regional Water Management Authority, which collected flood waters from the Odra River (from 16.09 to a maximum of 23.09): Rybna-Stobrawa, Zwanowice, Brzezina-Lipki, Lipki-Oława, Oławka, Blizanowice-Trestno.



# FUNCTIONING OF INFRASTRUCTURE



## Racibórz Dolny Reservoir

- The flood capacity of the Racibórz Dolny reservoir on the Oder is 185 million m<sup>3</sup>. It is currently the largest hydrotechnical facility of this type in Poland.
- On September 14, 2024, after exceeding the alarm level at the Krzyżanowice water gauge, the facility was prepared to begin damming and taking over the peak of the flood wave passing through the Oder River. Over the course of two days: September 15 and 16, the reservoir used 80% of its capacity, accumulating approx. 147 million m<sup>3</sup> of water.
- The Buków polder located above cooperated with the Racibórz reservoir, which began operating on September 14 and at the same time used its full capacity, accumulating approx. 57 million m<sup>3</sup> of water.

## Reservoirs of the Nysa Kłodzka cascade



- Before the flood, the Nysa Kłodzka cascade reservoirs had a total free capacity of 177 million  $\text{m}^3$ , which is comparable to the capacity of the Racibórz Dolny flood protection reservoir on the Oder.
- On Saturday, September 14, as a result of heavy rainfall and rising water levels, work on the Nysa Kłodzka cascade reservoirs entered flood mode.
- The inflow to the reservoirs of 2,030  $\text{m}^3/\text{s}$  was reduced to an outflow from the Nysa reservoir of 1,000  $\text{m}^3/\text{s}$ .
- The Nysa Kłodzka cascade reservoirs captured approximately 155 million  $\text{m}^3$  of water, reducing the flood wave below the reservoir.
- The flood in the city of Nysa did not occur from the Nysa Kłodzka river and the Nysa reservoir. The outflow from the Nysa reservoir did not exceed 1000  $\text{m}^3/\text{s}$ . The water flow of the Biała Głuchołaska River took place from the towns of Przełęk and Biała Nyska through the fields along the right side of the side dam of the Nysa reservoir towards the city of Nysa.

# FUNCTIONING OF INFRASTRUCTURE

## Failures of hydrotechnical structures

### Stronie Śląskie Reservoir

The Stronie Śląskie dry flood control reservoir located on the Morawka stream, a left-bank tributary of the Biała Łądecka, was built in 1907. The Stronie Śląskie reservoir began to accumulate water on Friday, September 13. On Sunday, September 15, the reservoir's earth dam was destroyed as a result of water overflowing through its left section. The reservoir was designed for a flow of 70-80 m<sup>3</sup>/s, and it is estimated that it received a flood wave of 320 m<sup>3</sup>/s, which is four times greater.



# FUNCTIONING OF INFRASTRUCTURE

## Failures of hydrotechnical structures

### Topola Reservoir

On September 16, the side surface spillway of the reservoir was damaged. This failure did not pose a threat to the towns below. The entire flood wave was absorbed by the Otmuchów and Nysa reservoirs.

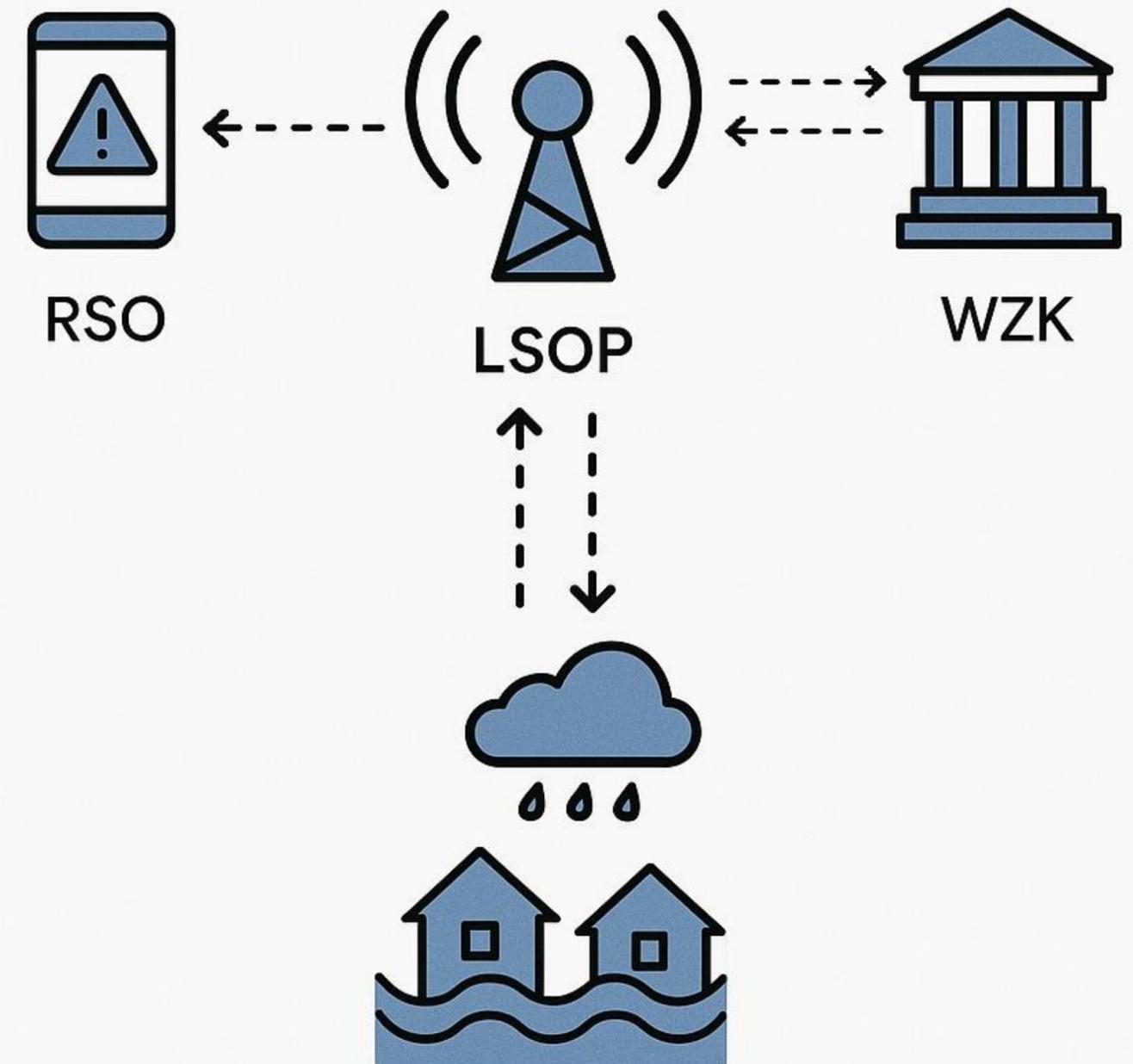


# FUNCTIONING OF INFRASTRUCTURE

## Response of crisis management systems

### Coordination of rescue operations

Cooperation between public institutions and non-governmental organizations was crucial to the effectiveness of rescue operations, enabling the rapid mobilization of resources and support for affected communities.



## Evaluation of the effectiveness of preventive measures

### SYSTEM GAP ANALYSIS

The preventive mechanisms introduced have not managed to fully reduce the risk of flooding, which indicates the need for a more detailed analysis of their effectiveness and identification of existing gaps.

### THE IMPORTANCE OF SOCIAL EDUCATION

Raising public awareness through educational programmes is key to improving residents' response to flood threats and the effectiveness of preventive measures.

# FUNCTIONING OF INFRASTRUCTURE

## Conclusions from the analysis of infrastructure functioning

- ▶ **Infrastructure investment**  
Increased funding needed to build resilient infrastructure systems.
- ▶ **Integrated monitoring systems**  
Implementation of modern technologies for forecasting and monitoring flood hazards.
- ▶ **Institutional cooperation**  
Strengthening coordination between institutions for effective crisis management.



# FLOOD CONSEQUENCES



## Negative effects on human health and life



- Number of fatalities: 9
- Number of injured: 238,045
- Number of people evacuated: approximately 4,493
- Number of flooded residential buildings: 10,522
- Number of buildings destroyed or excluded from use: 421, including 273 residential buildings, 148 farm buildings
- Number of flooded buildings of special social importance: 814, including: schools, kindergartens, nurseries, offices, social welfare centers, social welfare homes, museums, community centers, libraries, OSP buildings, police stations, health centers.

# FLOOD CONSEQUENCES

## Negative effects on business activity



Losses in the infrastructure of local government units

Opolskie voivodeship:  
508 954 273 zł

Dolnośląskie voivodeship :  
5 703 140 745,33 zł



Losses of entrepreneurs in the Lower Silesian Voivodeship

Number of affected companies:  
11 996

Total value of aid provided to entrepreneurs:  
84 573 909,46 zł



Losses in flood protection infrastructure

The total value of the inventoried works to be carried out, necessary to remove the effects of the flood in September 2024 amounted to about 1 379 mln zł

## Negative effects on business activity



### Road infrastructure losses

The total length of damaged roads is approximately **3 633 km**. Approximately **127 km of bicycle paths**, **229 bridges** and **1,823 culverts** were also destroyed. The largest losses were recorded in the Lower Silesian Voivodeship. The amount of losses caused by flooding in this area in terms of road infrastructure was estimated at **7 639 297 072,60 zł**.



### Rail infrastructure losses

As of 30/10/2024, the estimated cost of repairing rail infrastructure damage was estimated at **892.4 million zł**.



### Losses in agriculture

Losses were recorded in 4 provinces: Lubuskie, Dolnośląskie, Śląskie and Opolskie. A total of **3,144 farms** were flooded. The area of crops affected by the flood amounted to over **29 thousand ha**. The total value of losses for agriculture was estimated at around **118 million zł**.

# FLOOD CONSEQUENCES

## Negative effects on the environment and objects that pose a threat to the environment

The protected areas affected by the flood include:

- Gęsi Bastion nature reserve near Stara Rudnica,
- areas of the NATURA 2000 Lower Oder Valley PLB320003 and Lower Oder Valley PLH320037 areas,
- areas adjacent to Lake Dąbie,
- areas adjacent to the Szczecin Lagoon,
- Olszanka nature reserve,
- Święta nature reserve,
- Białodzrew Kopicki nature reserve,
- areas of the NATURA 2000 PLH240013 Border Meander of the Oder areas,
- Cicha Dolina nature reserve in the Głuchołazy commune,
- Kokorycz and Dębina nature reserves in the Grodków commune..

As a result of the flood in September 2024, numerous facilities were damaged that may negatively affect human health. These included:

- cemeteries: 22 facilities,
- landfills and waste incinerators: 9 facilities,
- treatment plants: 155 facilities,
- water treatment plants and drinking water intakes: 165 facilities.

Losses were also recorded in the linear water and sewage infrastructure. The length of the sewage network affected by the flood is approximately 265 km and the water supply network approximately 173 km.



## Negative effects on cultural heritage

The total value of losses in the scope of cultural heritage located in the areas of the Lower Silesia, Silesia and Opole voivodeships amounted to **4 976 229,36 zł**.

In the area affected by the state of natural disaster, the flood affected a total of 475 historic buildings listed in the register of monuments, including:

- Silesian Voivodship: 18,
- Opole Voivodship: 183,
- Lower Silesia Voivodship: 240,
- Lubuskie Voivodship: 34.

The flood also affected 3,850 historic buildings listed in the Municipal Registers of Monuments, including:

- Silesian Voivodeship: 309,
- Opole Voivodeship: 1,358,
- Lower Silesian Voivodeship: 2,120,
- Lubuskie Voivodeship: 63.

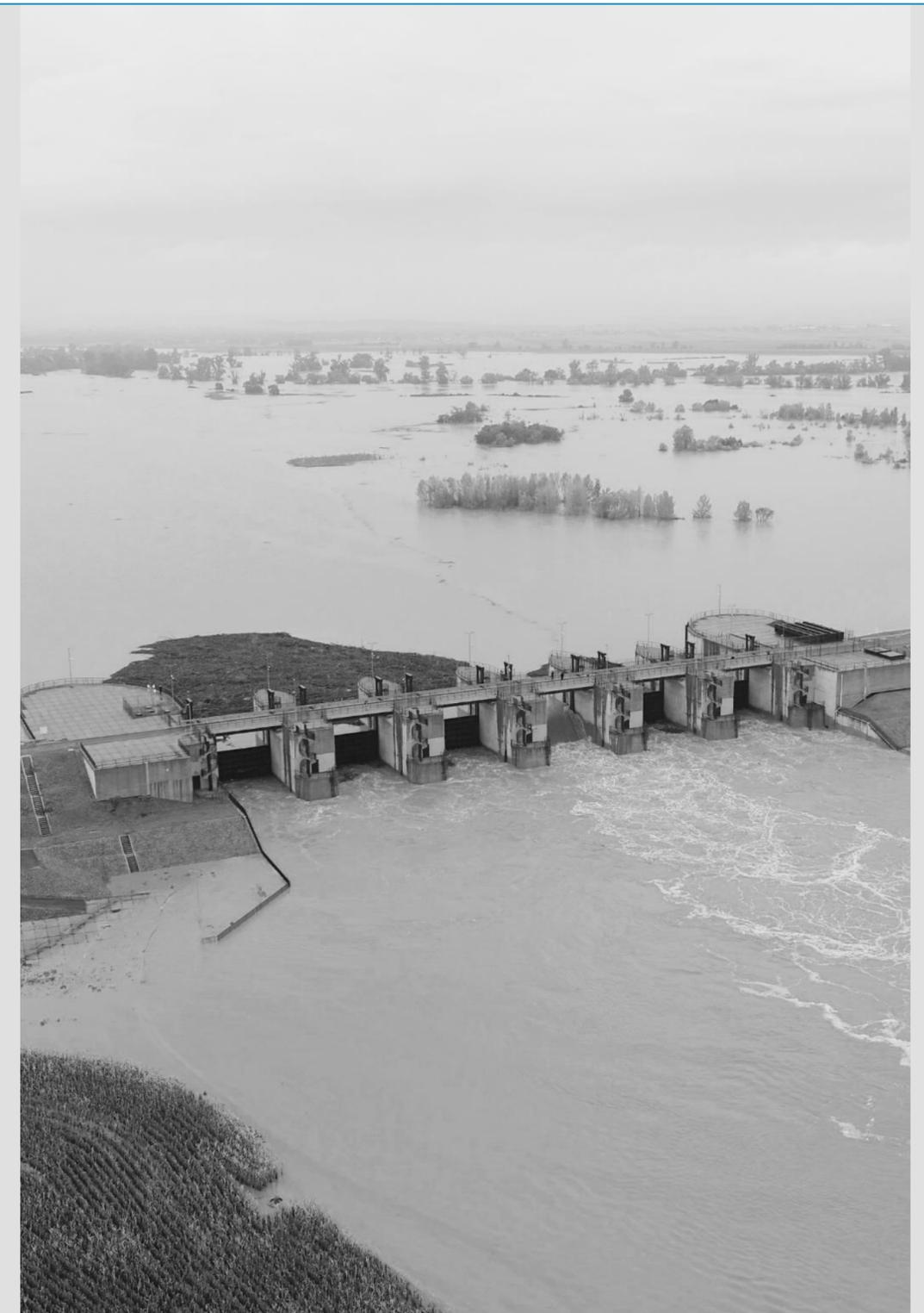


# FLOOD IN SEPTEMBER 2024

– hydrological analysis, infrastructure functioning and effects

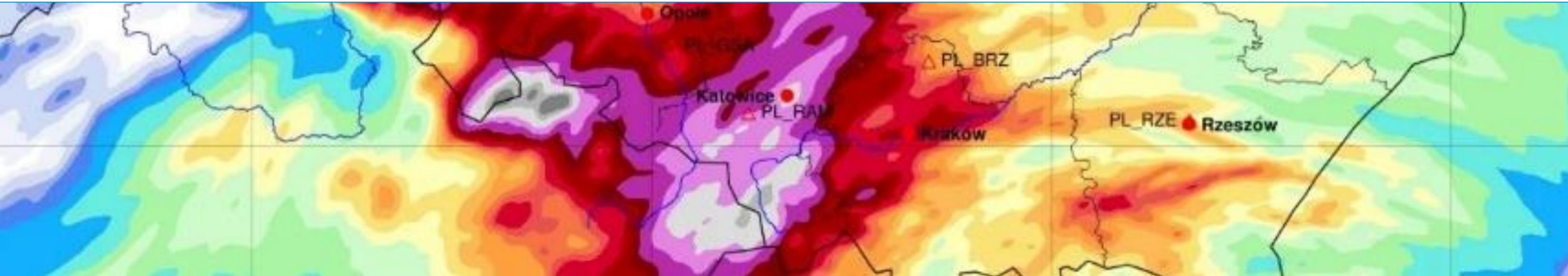
## DATA SOURCES

1. Bulletin of the State Hydrological and Meteorological Service No. 9 (276), September 2024, Institute of Meteorology and Water Management - National Research Institute.
2. Daily IMWM-PIB announcements from 12 September to 04 October.
3. Characteristics of selected climate elements in Poland in September 2024, Institute of Meteorology and Water Management - National Research Institute.
4. Data from PGW WP RZGW in Wrocław
5. <https://www.gov.pl/web/mswia/polska-zlozyla-wniosek-o-pomoc-finansowa-z-funduszu-solidarnosci-ue-w-zwiazku-z-powodzia>
6. Data from the Ministry of the Interior and Administration, as of 10.12.2024.
7. Data from the Opole Voivode, as of 11.12.2024.
8. Data from the Opole Voivode, as of 13.12.2024.
9. Data from the Lower Silesian Voivode, as of 17.12.2024.
10. Data from the Lower Silesian Voivode, as of 19.12.2024.
11. Data from the General Directorate for National Roads and Motorways, December 2024.
12. Data from PKP Polskie Linie Kolejowe S.A. , December 2024
13. Data from the Ministry of Agriculture and Rural Development, December 2024
14. Data from the Ministry of Culture and National Heritage, December 2024



# FLOOD IN SEPTEMBER 2024

– hydrological analysis, infrastructure functioning and effects



## Thank You

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Director of Investments and Renaturalization Department