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METEOROLOGICAL CAUSES OF FLOODS IN THE ODRA BASIN

Discussion paper transmitted by the Government of Poland [1]

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The aim of the study is to analyze the biggest floods, which occurred in the second half of the 20th century and in the beginning of the 21st century in the Odra Basin. High water stages in flowing waters are connected with the nature of the physico-geographical environment, especially with the surface features and the climate of a given area. The main causes of floods in Western Poland are adverse atmospheric conditions and a small water-retaining capacity of the basins.

In Poland – as results from records in chronicles and historical observations – natural disasters have most frequently been associated with floods. The oldest information from the Odra Basin was reported by the Czech chronicler Dolimil, who described the catastrophic summer flood of 1310, when high waters of the Nysa Klodzka River flooded a part of the town of Klodzko and the neighboring towns, leading to the death of approx. 1500 people and significant losses in agriculture.

The flood of 1997 in the Odra Basin proved that the descriptions in chronicles and historical observations should be treated seriously, even though they are not supported by concrete results of observations and measurements. Data of this type date back only to the beginning of the 19th century, when systematic meteorological observations were initiated, along with observations of water stages in rivers.

Large floods on the Odra and its tributaries have occurred relatively frequently, e.g. in the year 1813, 1829, 1854, 1880, 1902, 1903, as well as the second half of the 20th century, i.e. in 1958, 1965, 1970, 1972, 1975, 1977, 1978, 1981,1985, 1997 and 2001.

Floods of the second half of the 19th century and the beginning of the 20th century forced man to realize a series of hydraulic engineering investments. The system of flood control in the upper and lower Odra (up to the river mouth of the Nysa Luzycka) consists of 19 storage reservoirs with the joint capacity of 740.58 mln m^3, including 150 mln m^3 of flood ullage, of 12 dry flood-control reservoirs with the total capacity of 28.57 m^3, 13 polders with the capacity of 178.4 mln m^3 and 799.1 km of flood embankments. Moreover, three cities, i.e. Racibórz, Opole and Wroclaw have relief channels.

High water stages resulting in material losses, threat to human lives and social losses are called floods. Not every high water stage is actually a flood, whereas each flood is caused by a high water stage. According to J. Lambor (4), in terms of their origin floods may be divided into:

a) Floods of the summer half-year:
- torrential floods – i.e. local floods caused by torrential rains,
- rainfall overbank floods – i.e. floods lasting longer in mountainous areas,

b) floods of the winter half-year:
- meltwater floods – caused by rapid snow melting observed primarily in lowland areas,
- ice-jam floods – caused by the water lifting by wind in the period of ice floating, usually accompanying the spring thaw,
- slush ice-jam floods – caused by the water damming resulting from the jamming of the river cross-section with slush ice (observed locally in Poland in some lowland rivers),
- storm floods – observed on the coast during strong onshore winds (water lifting in river mouths, coastal areas are flooded).

Floods of the winter half-year are local in character and their intensity in the Odra Basin has considerably decreased since the second half of the 20th century.
Depending on the intensity of the phenomenon, high water stages and floods are distinguished, occurring on average every 3 to 3.5 years, and catastrophic ones occurring every dozen years or so up to several decades.

Winter meltwater flush stages, beginning in small lowland watercourses, are determined by:
- an extensive low pressure area moving over Poland, in which an intensive slide of warm polar-maritime air-masses is found, due to which the daily precipitation reaches values rarely observed in Poland in the winter season.
- almost complete water-vapour saturation up to the height of several kilometers, shortening the evaporation process to the minimum at the simultaneous conditions highly conducive to the melting of the snow cover, caused by intensive thawing weather, and rainfall at the temperature exceeding 0^{o}C,
- a high value of the flow coefficient, caused by the formation of the ice cover in the near-ground layer of the snow cover, formed as a result of thawing weather combined with rainfall, alternating with periods of frosty weather and possibly with glazed frost.

Torrential rains, causing the occurrence in small watercourses of flush torrential floods in the warm season, are characterized by the following major properties:
- they occur practically only in three pressure systems: low-pressure furrows (70%), saddle points (16%) and shallow barometric depressions (12%),
- in approx. 90% cases they are found in the zone of slowly moving fronts,
- they take place in case of the simultaneous occurrence in the front zone of both thermal and dynamic conditions conducive to the intensive development of vertical air currents, at the same time with the occurrence of a sufficient water vapour content in the lower half of the troposphere,
- they are formed from the Cb clouds, the tops of which in the Polish climatic conditions are at least approx. 6 km high.

In the Odra Basin floods occur most frequently in February and March in the Nysa Luzycka catchment and in the catchments of the Przymorze rivers, whereas they are observed a little later (in March - April) in the river basins of Central Poland, i.e. the lower Warta, Notec, and Odra. Summer floods (July - August) are observed most frequently in the catchments of mountain rivers. In October and November they are rare. In winter (December - January) primarily storm floods are observed, which is connected with the hydrological and meteorological situation of the Baltic Sea, and they cover mainly river mouths (including the Odra river mouth).

In the climatic conditions of Poland spring floods may be predicted with relatively high accuracy in terms of their date and the amounts of flowing water. Summer floods are sudden, violent and protection measures have to be taken within a matter of hours.

General characteristic of selected large floods in the Odra Basin

Flood of June – July 1958.

The genesis of this flood is to be found in the atmospheric situation conducive to intensive rainfall, and created by the extensive barometric depression lying over Western and Southern Europe. As a result of this situation in the night from the 27th to 28th June heavy

rainfall was observed in the Sudety mountains, the highest intensity of which moved on the 28th and 29th June over the Karpaty mountains.

In the night from the 3rd to the 4th of July very heavy downpours occurred in the Lower Silesia, causing new floods - even more dangerous as they took place in the river valleys already filled with water. The daily rainfall values were close to the average totals for the month of July in this region (the town of Szklarska Poreba 98 mm). Downpours occurred also on the 4th and 5th July.

Flood of 1970

On the 15th of July atmospheric fronts moved over Poland causing the first precipitation period. The second of these fronts brought rainfall which was slightly heavier and at the same time it was moving faster, as a result of which in the night from the 15th to 16th July these fronts combined into one frontal zone, which ran through Europe from the North – East to the South – West. As a result of the blocking of the high pressure system expanding heavily vertically, the center of which was lying at that time over the middle Volga, this front took the quasi-stationary character.

Rains, which caused a flood in Poland in the second half of July 1970, occurred in three precipitation periods.

The first period started in the morning hours of the 15th of July and lasted 24 hours throughout the country. The main flood rainfall occurred in the second period, beginning on the 17th of July in late morning. Heavy rains lasted in the south of the country until the morning hours of the 19th of July, whereas in Central and Northern Poland they lasted until the evening of the 19th July.

After a five-day break, during which slight rains were observed in places, on the 25th July at noon the third precipitation period started, lasting approx. 24 hours. In comparison to the precipitation occurring on the 17th –19th July, these rainfalls were considerably smaller.
The meteorological analysis of the flood of July 1970 showed that when Poland is covered by the circulation of the South-European depression, extremely heavy rainfall is to be expected if:

- in the cool air mass there is a strong flow from the north with wind velocity at the near-ground level of 10-12m/s, whereas at the 850 mbar level – a low-tropospheric jet-stream with the velocity of approx. 25m/s,
- in the warm air mass the totals of mixing ratios at the 850, 700 and 500 mbar levels reach values higher than or equal 17g/kg,
- air masses on both sides of the front show at least humid-unstable stratification, which leads to the development of thermal vertical currents, and subsequently – convective clouds, from which occasional precipitation falls with high intensity.

The flood in July 1970 was the result of heavy rainfall, which occurred mainly in the right-bank part of the upper Odra catchment.

Flood in the Odra Basin – August 1977

The hydrological situation in the whole country, particularly in the Odra Basin, was directly affected by the meteorological conditions observed from the 31st July till the end of August. Initially the weather in Poland was influenced by the depression from the Hungarian Plain moving northwards. Heavy rainfall occurred, particularly in the region of the Sudety mountains, with the daily totals between 50 and 100mm.
In the first days of August weather in Poland was shaped by the cyclone systems with air masses with varying physical parameters. It resulted in rainstorms. In the South-East and locally in Central Poland heavy rains fell, the total precipitation of which frequently exceeded 50 mm. The heaviest rainfall occurred on the 10th, 13th – 15th, 19th, 21st, 22nd and 27th August.

Heavy precipitation and its flow resulted in a rapid increase in water stages starting as early as the 1st August in the rivers of the mountainous part of the Odra Basin. A particularly severe flood situation occurred in the middle of August.
Intensive long-term and torrential precipitation, occurring at the end of July and repeated many times during August 1977 caused, especially in the Odra Basin, dangerous flood high water stages.

Flood – 1997

The flood in July 1997 was of the rainfall overbank type, but due to the high storm clouds embedded in the system of stratus clouds, and extremely heavy precipitation, it may be classified – especially in the region of the upper Odra and Nysa Klodzka – as a torrential flood. Rainfall, which caused high water stages of unprecedented intensity, size and territorial range, covered all the upper and middle Odra Basin with the area of approx. 11 thousand km^2.

Due to the fact that it was hundred-year flood observed in the Odra Basin, the synoptic and precipitation situation in 1997 is characterized below in more detail.

On the 3rd of July almost the whole Europe was found within the range of shallow depressions with centers over Great Britain, the Norwegian Sea, Finland and southern Germany. The Azores anticyclone dominated over the Atlantic. Poland was initially found on the verge of the high-pressure area with its center over Rumania, but during the day the field of the pressure system was rapidly reshaped.

From the South-West, from over Germany, a shallow low-pressure area was approaching with atmospheric fronts, which at the end of the day covered most of Poland. Along with the fronts from the South- West the zone of heavy cloud cover was moving with occasional rain precipitation and local storms. On the 4th of July the low pressure area became a quasi-stationary system, and the system of fronts running meridionally through the center of Poland divided air masses differing drastically thermally and in terms of humidity. Over the eastern half of Poland hot tropical air stayed, over the western part – considerably cooler humid polar-maritime air. It caused a further intensive development of the cloud cover and precipitation along the front line. On the 5th July Poland remained under the influence of the quasi-stationary cyclone, which was moving very slowly towards the south-east, being blocked there by the stagnant anticyclone system. In the night of the 5th / 6th July the shallow low pressure area moving from the south-west caused a strong regeneration of the cyclone with its center over the Lubelska Upland. On the 6th July the regenerated cyclone – while deepening – at the ground level (at 1000 hPa) moved from above the Lubelszczyzna region to the northwest and then southerly.

On the 7th of July the low pressure center in the near-ground layer of the troposphere moved to the Malopolska region, and then to Slovakia and Ukraine, towards the Black Sea. On the 8th July at 00:00 GMT a shallow low pressure center was formed at the level of 500 hPa, which subsequently filled within the next 12 hours. The cyclone vortex reached the stage of a mature system. The location of the low pressure center over the Malopolska region resulted in such a system of air mass influx that still an extensive thick system of clouds was developing and a zone of the most intensive rainfall remained over southwestern Poland. Along with the movement of the cyclone towards the north and the weakening of the Azores anticyclone the pressure gradient was decreasing. Precipitation was getting smaller and gradually disappeared and the weather was improving.

From the 9th to the 17th July 1997 Poland was on the verge of the Scandinavian anticyclone. From the middle of July from the Atlantic through Central Europe a weakly expressed system of atmospheric fronts was slowly moving to the east. The other front system was moving from the Mediterranean to north-east. Both systems were not very active.

On the 17th of July at noon the frontal cloud cover of both systems was still not very well developed and was broken. The situation changed when the systems began to approach each

other. In its frontal part cool air was coming over Europe through Great Britain and the North Sea.

In the night of the 17th / 18th July a depression was formed at the near-ground level over the southern Czech Republic, covering in its range Slovakia, Austria and southern Poland. An independent closed low pressure center was formed in the middle troposphere, which on the 18th July moved over Germany, on the 19th July over the Czech Republic and on the 20th and 21st July remained over Slovakia and Poland, functioning as the steering system. The heaviest rainfall was observed in the Karkonosze mountains, where it was intensified by the windward effect, caused by the air mass influx in the back part of the cyclone. In the morning of the 19th July the low pressure center moved from Bohemia to Poland.

The high water content and a large vertical range of clouds over south-western Poland resulted in the whole area of the upper and middle Odra Basin experiencing intensive rainfall. Under these conditions uniform precipitation, formed as a result of entering masses of humid and warm tropical air, was intensified by rainfall from convective clouds, which were embedded into the system of frontal stratus clouds, whereas in the Sudety mountains the precipitation total was increased as a result of the orographic processes. In the Lower Silesia storms occurred and the most intensive rainfall was observed in the basins of the Bóbr, Bystrzyca, Nysa Klodzka and Barycza.

On the 20th of July the cyclone was moving slowly towards the north-east, blocked – as in case of the previous precipitation wave – by the high pressure system in the east and here it became stationary. The cyclone reached the stage of maximum development and covered the whole of Poland, the Czech Republic, Slovakia, western Byelorussia, southern Ukraine and Hungary. In the zone of central and southern Poland quite an intensive rainfall was observed. From the 21st of July the depression was filling, precipitation was decreasing and changing into occasional rain.

The size, intensity and spatial arrangement of atmospheric precipitation in July 1997.

Precipitation, which was the direct cause of the flood, started on the 5th July 1997 between 4 and 7 p.m. in the area of the upper Odra and between 8 and 10 p.m. in the Nysa Klodzka basin. It lasted incessantly for 60 to 70 hours, whereas in the upper Odra and Olza basin – by approx. 24 hours longer – until the 9th July 1997. Thus, the precipitation zone in the middle Odra basin remained until the afternoon hours of the 8th July, whereas in the upper Odra basin – until the evening hours of the 9th July.

Intensive rainfall covered the whole of the upper and middle Odra basin, the upper Warta and the Vistula basins. Precipitation concentrated in the area of the upper Odra and the eastern part of the Nysa Klodzka basin. The area experiencing very heavy precipitation covered approx. 12 thousand km^2. The heavy precipitation zone reached also to the east – the upper Vistula basin, and the north-east, including the upper Warta basin.

Especially intensive precipitation was observed on the right-side Odra in the Beskid Slasko-Morawski region and in the region of the Beskid Slaski, covering the basins of the Ostravica and Olza. Precipitation in that area ranged from 415 to 617 mm.

The highest precipitation in the basin of the upper Odra was observed in the Ostravica catchment in the Sance and Lysa Hora stations. Within the 5 days from the 5th to the 9th July 1997 in these stations the precipitation amounted to 616.9 and 585.7 mm, respectively. Its extreme intensity needs to be stressed here, as during the 24 hours from the 6th to the 7th July the Lysa Hora station reported 233.8 mm, whereas in the Sance station it was 230.2 mm, which corresponds to the average intensity of almost 10 mm/h.

The other precipitation center was located on the left side of the Odra in the mountains. The precipitation observed in this area ranged from 316 to 513 mm. The remaining part of the Odra basin was covered by rainfall that was two-three times lower.

The second wave of precipitation started on the 17th July 1997 and lasted for the next 5 days, i.e. until the 22nd July 1997. Its center was located in the Bystrzyca, Kaczawa and Bóbr and Kwisa basins. In the basin of the upper Odra and Nysa Klodzka it was by approx. 40% lower. The precipitation total for the period of the 18th – 22nd July 1997 in the basin of the upper Odra only locally exceeded 100 mm. Again high precipitation amounts were observed in the Kotlina Klodzka. Its 5-day total was within the 100 – 200 mm range. More than 120 mm water fell in the lowland areas of the middle Odra basin. Exceptionally high precipitation was found in the Bystrzyca and Kaczawa, and Bóbr and Kwisa basins. Its total fell within the 120 – 300 mm and 150 – 220 mm ranges. Thus, the high precipitation center was located over the water-head areas of the mountain tributaries of the middle Odra.

The rapidity of the formation of flood high water stages in the Odra basin and the diversity of their origin result in their being very difficult to forecast in terms of the time and place of their generation. Usually they are unexpected and thus even more tragic in their consequences. Various types, kinds and varieties of floods found in Poland exhibit – depending on their genetic factors – differing genesis, courses, ranges and seasons. The systematics of the types, kinds or varieties of floods as random natural phenomena, is helpful in the preparation of short-, medium- and long-term meteorological and hydrological forecasts. The accuracy of prediction in case of flood high water stages and their course is essential in flood control actions conducted on the basis of implementation plans.

The analysis of meteorological conditions, which caused in Poland extremely heavy precipitation in the days of the 17th – 19th July 1970, as well as a comparison of synoptic situations, in which the heaviest rainfall was generated in the last 40 years (in July 1960 and 1934), indicate that the highest flood hazard in the summer season is caused by the southern-European depressions and orographic precipitation connected with the influx of air from the north. Thus, if within three days in the catchments of the Odra basin precipitation reaches the amount of 150 – 300 mm, then irrespective of the hydrological and meteorological conditions

preceding the flood period the probability of the occurrence of a catastrophic flood must be considered.

In terms of their genesis, according to the classification by Lambor, the biggest floods in the Odra basin may be classified as follows:
1958 — flood of the summer half-year - torrential and rainfall overbank flood,
1965 - flood of the summer half-year – torrential and rainfall overbank flood,
1970 - flood of the summer half-year - torrential and rainfall overbank flood,
1972 - flood of the summer half-year – torrential flood,
1975 - flood of the summer half-year – torrential flood,
1977 - flood of the summer half-year – torrential and rainfall overbank flood,
1978 - flood of the summer half-year – torrential flood,
1981 - flood of the summer half-year – torrential flood,
1985 - flood of the summer half-year – torrential flood,
1997 - flood of the summer half-year - torrential and rainfall overbank flood,
2001 - flood of the summer half-year – torrential flood.

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