SUMMER 1997 FLOOD IN POLAND IN PERSPECTIVE

ZBIGNIEW W. KUNDZEWICZ
Research Centre for Agricultural and Forest Environment, Polish Academy of Sciences, Bukowska 19, 60-809 Poznań, Poland
zkundze@man.poznan.pl
Potsdam Institute for Climate Impact Research, Telegrafenberg, D-14412 Potsdam, Germany
zbyszek@pik-potsdam.de

Abstract- A considerable increase in flood damage has been observed worldwide, with mean annual values reaching tens of billions of US$ and still considerable number of fatalities. Most dramatic floods occur overseas (in particular in Asia - China, India, and Bangladesh), but in the last decade, floods have severely hit large parts of the European continent. For example, Poland was visited by dramatic summer floods in 1997, 1998, and 2001. The flood hitting the drainage basins of the rivers Odra and the Vistula in summer 1997 has been labeled by the media (in a somewhat exaggerated way, as far as the number of fatalities are concerned) as the greatest natural disaster in the 1000-year history of Poland, being definitely costliest ever. The Odra (Oder) flood in the summer of 1997 had an international dimension. It hit three countries in Central Europe – Czech Republic, Poland, and Germany, causing 110 fatalities in the first two countries and large material losses in all three. The present contribution puts the destructive 1997 Odra flood in perspective. Information on this dramatic flood event of unprecedented severity is provided, including meteorological, hydrological, socio-economic and disaster management aspects. From the hydrological point of view, this flood was a very rare event; with return period in some river cross-sections of the order of several hundred years and more. It was associated with the Vb type of weather system. The context of the flood is discussed, in the sense of both past-to-present records and projections for the future. Flood management options are reviewed. In Poland, as well as in much of Central Europe, river flooding has been recently recognized as a major hazard. Having observed that flood risk and vulnerability are likely to have grown in many areas, one is curious to understand the reasons for growth. These can be sought in the

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domains of socio-economic systems (humans encroaching into floodplain areas and accumulating increasing wealth there), terrestrial systems (land-cover changes – urbanization, deforestation, reduction of wetlands, river regulation), and climate system.

Keywords: floods, damage, climate change, river Odra

1. Introduction

The issue of the Russian weekly magazine *Itogi* of 5 April 2005 contains a citation from Mr Rustem Khamitov, Chairman of the Federal Water Resources Agency of the Russian Federation: „Unconditionally, every spring a considerable part of the country's territory is inundated by water. This is unavoidable, because there are many rivers." The intention of the journal's editor might have been to raise controversy (citizens may trust that they should be adequately protected against floods). However, it is indeed a fair statement in the largest country on Earth, where the number of rivers and streams is of the order of 3 million (hence one river per 50 citizens), as estimated by Mr Khamitov in his lecture at the present NATO Workshop in Novosibirsk. Floods occur in Russia every spring; with possibly different times and places of occurrence, magnitude and duration.

The present contribution reviews the great Polish flood of summer 1997. Polish rivers are much smaller than the rivers of Siberia and floods are by no means commonplace occurrences. However, the 1997 flood, baptized in the Polish media as „the Millennium flood", was more destructive, in terms of absolute material losses, than any other flood event ever occurred in Poland. Even if the 1997 flood event occurred a long time (eight years) ago, it still lives in the national memory as the most dramatic disaster.

The flood of July 1997 occurred in the drainage basins of two large Polish rivers - the Vistula and the Odra and their tributaries. As the losses recorded in the drainage basin of the Vistula were significantly lower than those in the Odra basin, this paper will largely concentrate on the latter. The Odra is the second largest river in Poland with the total length of 854 km and the area of its drainage basin, 118 861 km^2 (of which, respectively, 742 km and 106 056 km^2 are in Poland). The source of the river Odra is located in the Sudety mountains in the Czech Republic. The Odra forms (at a distance of approximately 162 km) state boundary between Poland and Germany. In its upstream course, the Odra has features of a highland river,

while in the middle and downstream course, the Odra flows through lowlands and has its mouth in the Baltic Sea.

The water resources of Poland are rather scarce, with the average annual precipitation of the order of 600 mm. It is estimated that annually about 55 km^3 of water runs off the land area of Poland (312 thousand km^2). Dividing the total annual river runoff by the number of inhabitants one gets an aggregated average water availability of the order of 1400 m^3 per capita, being one of lowest values in Europe. Typical water-related problems are three-fold: having too dirty water (nearly always, in most rivers), too little water (often), and too much water (sometimes). The hydrological variability is high and at times there is a destructive abundance of water.

Throughout the history of the Polish state, lasting over a thousand years, there have been many occurrences of floods (cf. Girgus & Strupczewski, 1965). Historical extremes on the Odra have been either summer rain-caused or winter (snowmelt or ice-jam) floods. However, for a long time before 1997, only minor floods had occurred and this considerably weakened the awareness and preparedness.

2. Diary of the Great Flood

In the second half of June of 1997, the weather in Poland was shaped by intense cyclonic precipitation over much of the country. This precipitation filled the natural water retention, saturating available soil storage.

In the beginning of July, quasi-stationary atmospheric conditions developed, with a front dividing humid air masses that significantly differed in temperature: hot and very water-rich air to the east, and humid and cooler polar sea air to the west. Such weather system stayed over the catchment area of the upper Odra and its tributaries for a longer time, releasing large volumes of intensive precipitation, culminating between 6 and 8 July. The highest precipitation between 5 and 9 July was recorded in Lysa Hora, Czech Republic (586 mm), while in the Polish drainage basin of the Odra, the highest three-day precipitation amounts were recorded in Kamienica (484 mm) and Międzygórze (455 mm), cf. IMGW (1997).

One could distinguish three stages of the flood in Poland, each characterized by distinctive features. During the first stage, a fast runoff increase (flash flood) occurred, following the intensive, and long-lasting, rainfall in the Upper Odra and its highland tributaries. This flood was very dynamic (water level rose by four meters in 12 hours) and destructive. The flood devastated the town of Kłodzko (31 000 inhabitants) located on the river Nysa Kłodzka, left-hand tributary to the Odra. There were 11 dead, 503 families lost virtually everything they owned. The total losses reached

300 million USD, being 50 times higher than the annual municipal budget of Kłodzko.

In the second stage, a huge flood wave was already in the river channel of the Odra and it propagated downstream to inundate several towns located on the river. In Racibórz-Miedonia, the water level exceeded the maximum recorded stage by over 2 m. Having inundated the town of Racibórz (65 000 inhabitants) on 9 July, the Odra flooded further large towns located downstream, such as Opole (131 000) on 11 July and Wrocław (700 000) on 13 July. Due to the size of the wave it was not possible to avoid inundation of towns, yet, thanks to the time lag, some preparation could be made. While about one third of Wrocław was inundated, still much of the town was saved by massive flood defence, with street barricades, ad hoc levees and sandbags. The peak of the flood wave flattened while travelling downstream along the river Odra, so the return period of the maximum flows decreased with distance from the river source.

Finally, in the third stage, high water reached the boundary stretch and the Lower Odra. From the Czech boundary to Gozdowice the average speed of propagation of the flood peak was 1.6 km h^{-1}; thus the propagation time was 16 days. There was more time for preparation - heightening and strengthening of embankments. The action was largely successful on the Polish side, e. g. the town of Słubice was saved by intensive defence. Dikes were heightened by 1.2 to 1.5 m. Comprehensive preparations included e.g. emptying fuel from petrol stations. The population was evacuated. The alarm water level of the Odra near Słubice was exceeded over 34 days but the town was not inundated. Upstreams, on the German side several breaches of embankments and significant material losses occurred.

The precipitation in the whole month of July 1997 was much higher than the long-term average (cf. Fig. 1). Only a few days after the heavy and long-lasting rains in the period 4–10 July, another series of intensive rains occurred. The highest precipitation from 17 to 22 July was recorded in the drainage basins of the rivers Bystrzyca and Kaczawa (tributaries to the Odra; up to 120–300 mm), in the drainage basins of the rivers Bóbr and Kwisa (up to 150–200 mm), while in the Kłodzko valley the precipitation totals reached 100–200 mm, contributing to another peak of the flood wave. A third wet spell in July 1997 occurred basically in the drainage basin of the River Vistula.

The nation-wide toll for both Odra and Vistula floods of summer 1997 was an all-time high as far as economic damage is concerned. There is no official figure for total material losses and the estimates range from 2 to 4 billion US$, indicating that the costs were of much significance to the national economy. The number of fatalities reached 54. The number of flooded towns and villages was 2592. The flood caused damage to 46 000

houses and apartments. The number of evacuees was 162 000. Around 665 000 ha of land were flooded, therein over 450 000 ha of agricultural fields. Some 480 bridges were destroyed and 245 damaged. The flood resulted in serious damage to roads and railways. Loss of 1900 cattle, 5900 pigs, 360 sheep and around 1 million poultry was recorded. Embankments were damaged or seriously weakened at a length of about 1100 km. Due to destruction of numerous sewage treatment plants, at the end of July, some 300 000 m^3 of untreated sewage entered the river per day. More detailed information on the flood and its impacts can be found in Kundzewicz et al. (1999).

The flood in the summer of 1997 had an international dimension. It hit all three riparian countries of the Odra basin – Czech Republic, Poland, and Germany, causing altogether 110 fatalities in the first two countries and large material losses in all three.

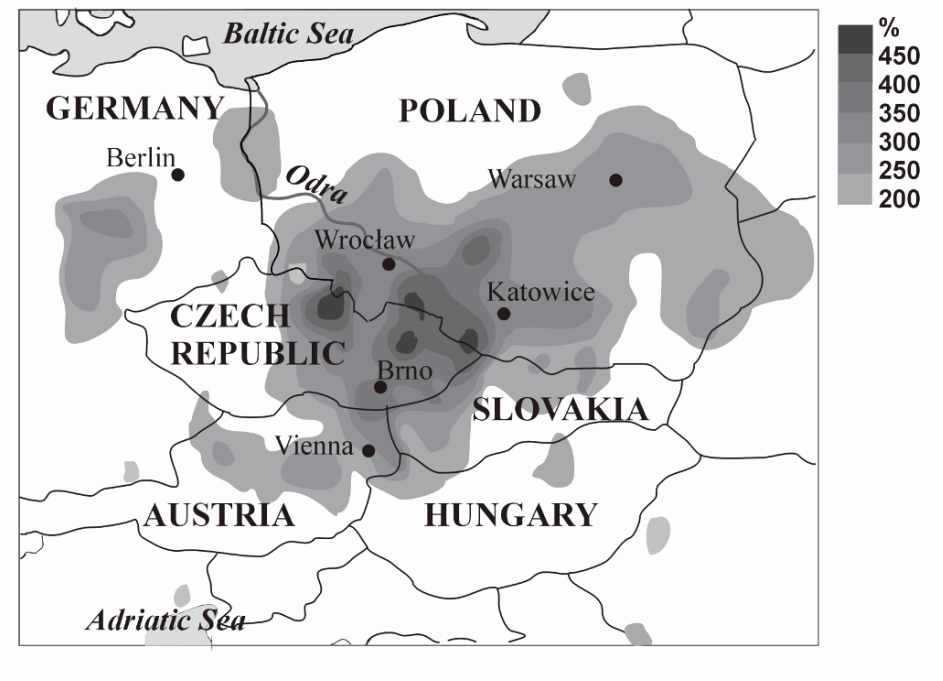

Figure 1. Precipitation in July 1997, compared to a mean monthly value (courtesy of Dr Bruno Rudollf, Global Precipitation Climatology Centre (GPCC), German WeatherService, Offenbach)

3. The 1997 Flood in Context

Floods in Poland, both in the Vistula and the Odra river basins, have not been uncommon. However, floods covering the whole length of the river Odra have been rare and usually very dramatic. The Odra flood in the summer of 1997 was an extreme one in this category.

During the 1997 flood, several all-time maximum stages and discharges were recorded along the river. For example, in Racibórz-Miedonia, the record stage and the record discharge observed during the 1997 flood were 1045 cm and 3260 m^3 s^{-1} (the latter being twice higher than the second highest value on record), respectively. The flow rate of the exceedance probability of 1% (100-year-flood), based on seven decades of records, reads 1680 m^3 s^{-1}. In Opole, on the Odra, water level outstripped the absolute historic maximum by 173 cm, while at the Nysa Kłodzka in Kłodzko, the historic stage record was exceeded by 70 cm.

Since historical flow data are typically only available for an observation period of several decades to a century, assessing the exceedence probability for such a rare event as the Great Flood of 1997 can only be based on an extensive, thus not very credible extrapolation. Making inferences on the tails of probability distributions strongly depends on the subjective choice of the distribution. Without getting involved in the dispute on the return periods of very rare events, one could compare, for perspective, the observed values with those calculated as rough characteristics of 1000-year floods (Grünewald, 1998) and see that at some gauges, the peak flow in July 1997 was of this range.

The Great Flood of 1997 on the Odra was long-lasting as the wave travelled slowly downstream. The alarm water levels were uninterruptly exceeded for several weeks along the Odra: for 16 days in Miedonia, 17 days in Opole, 32 days in Ścinawa, 36 days in Głogów, 35 days in Połęcko, and 34 days in Słubice. The exceedence of historic absolute maximum water level lasted from 4–7 days on the upper Odra to about 16 days in Połęcko (cf. IMGW, 1997).

The flood wave on the Odra in the summer of 1997 had two crests corresponding to two periods of abundant precipitation. During the first peak of the flood wave, the all-time highest stage and flow between the Czech–Polish border and Nowa Sól were broken, while during the second peak, the maxima were reached from Cigacice to Gozdowice.

Before 1997, the most dramatic flood event of the century in Poland was the deluge of the Vistula and its upstream south bank tributaries in summer 1934. The inundated area of 1260 km^2 in 1934 was nearly twice that in 1997, while the number of fatalities was comparable (55 vs 54).

In the light of objective hydrological data, it is clear that the summer 1997 disaster could not have been avoided. The flood magnitude was

exceptionally high. Indeed, if a flood record is doubled, as it was in Raciborz-Miedonia, and if the flood recurrence interval enters the range of thousands of years, there is no way to avoid high material losses.

A question was frequently asked: Has the flood risk grown? And, if so, why? Even if there has been no general and ubiquitous response to this question, changes in climate and hydrological systems (land-use change, urbanization, deforestation, river regulation – channel straightening, embankments) and changes in socio-economic systems: (increasing exposure – flood plain development, growing wealth in flood-prone areas) are likely to have influenced flood risk and vulnerability. It is important to note that three recent summer flood events in Central and Eastern Europe, i. e. 1997 (on the Odra and Vistula), 2001 (on the Vistula), and 2002 (on the Elbe), were all caused by similar atmospheric drivers – so called summer Vb events. Yet, there has not been convincing evidence of increase in occurrence of the Vb-type events (cf., Kundzewicz et al., 2005).

The catastrophic 1997 and 2002 floods had similar features; flash floods in the headwaters, propagation of huge water masses in large rivers, leading to dike breaks and inundation of large areas (disaster for local population but reduction of danger to downstream). High return periods of maximum flow/stage observed upstream were decreasing downstreams.

The 1997 flood in Poland fits a global image of increasing flood vulnerability. There have been many destructive floods in various parts of the world in the last decade, with numerous events in each of which material losses exceeded 1 billion US$ and number of fatalities exceeded 1000. Most river flood losses, in terms of fatalities and material damages, have occurred in Asia, with 30 billion US$ damage in China in 1998. Hence, the recent floods in Eastern Europe, including those most dramatic ones, in 1997 and 2002, reviewed at the present Workshop, can be seen in a more general context.

However, Mudelsee et al. (2003), who searched for long-term trends in the occurrence of extreme floods in central Europe, therein on the Odra, did not find any upward tendency. Instrumental database used in their study was extended by concatenation of the historical database, of a largely different (lower) accuracy. For 1920–2002, in the instrumental dataset, decrease in winter flood occurrence on the Odra was observed, with fewer events of strong freezing. Indeed, winter floods, which were so frequent in the past, have become quite rare now. For instance, the last ice flood on the Odra took place in 1947. Mudelsee et al. (2003) did not find trends for major summer flood events at significance level of 10% on the Odra, except for an upward trend for all flood events (including minor ones) and with correction for reservoirs.

4. Management Context

Flood protection along Polish rivers is based on structural means, such as dikes (at 9 thousand km length in the nation-wide scale). However, the available storage volume in the country is not high – only about 6% of the annual total river flow in Poland can be stored in reservoirs.

In the nineteenth century, the River Odra as measured from Ratibor (Racibórz) to Schwedt, was shortened by 26.4% by digging channels. Regulation has continued since then and floodplain areas (and their vast water storage capacities) have been considerably reduced. The present flood protection system in the basin of the Odra and its tributaries consists of embankments, weirs, reservoirs (including dry flood protection reservoirs), relief channels, and a system of polders.

The existing flood defenses protect several larger towns upon the Odra and its tributaries, and vast areas of agricultural land, proved to be dramatically inadequate in the context of a rare flood. Flood defenses were designed for much smaller, more common floods. The flood protection system of Wrocław was designed for a flow rate of 2400 m^3 s^{-1}, yet the peak flow rate in July 1997 was greater by nearly 50%. Hence, the system had to fail when exposed to a much higher pressure. There is insufficient storage volume; the 23 weirs on the Odra itself (19 built before the end of the World War II), principally serve navigation and hydropower purposes. There are also several reservoirs on tributaries to the Odra. Some of the reservoirs contributed to mitigating the flooding downstream, but, in general, the existing flood reserve in reservoirs was far too low in the context of the Great Flood of 1997.

The rescue operation during and after the flood was the greatest civil and military operation in Poland since the World War II. The numbers of firemen, soldiers and policemen involved were 25 000, 45 000 and 10 000, respectively, while more than 100 000 civilians and volunteers were also directly involved in flood mitigation.

The flood relief programme in 1997 has been labelled as the largest humanitarian action in the history of Poland. Considerable assistance came from abroad, from individual countries as well as from the European Union.

The flood unveiled numerous weak points in the existing operational flood management system (observation–forecast–response–relief), where improvements were badly needed. Organization was also a weak point, especially at the beginning of the flood. Legislation was inadequate; for example, there was a lack of consistent regulations concerning the financial aspects of flood action. Division of responsibilities and competence was ambiguous. As a result, regional and local authorities were uncertain as to their share in decision making (with financial implications).

The Anti-Flood Committees, whose statutory responsibility was to undertake and manage flood actions, have never been actually involved in such a large-scale action before 1987. Units involved in action had instructions and directives that were partially out of date (e.g. delegating military units that had ceased to exist, to combat flood). Even the maps in use for flood mitigation were dated. The dissemination of information related to floods was poor to non-existent in provinces, towns and villages in the period before the 1997 flood. No real civil defense was available; the existing civil service was oriented towards war rather than natural disaster.

The information gap was clearly felt, especially in the first phase of the flood. This resulted from the lack of an automatic observation system, destruction of gauges by the flood, communication breakdown (including failure of cellular telephony) and the evacuation of observers.

The upsides were: accelerated awareness raising and generation of national, and international, solidarity. People fighting the flood at every level (army, fire brigades, local authorities, and numerous volunteer civilians) worked hard and persistently, taking rational risks. The saving of towns and land during the third phase of the flood, i.e. the protection of the lower Odra, was a real success story. For further information on the flood action, see Kundzewicz et al. (1997).

The event made the broad public aware of how dangerous and destructive a flood can be. It also demonstrated the weaker and stronger points of the flood defence and helped identify the most pressing needs for improvements. However, funding of water management, investment in infrastructure, reservoirs, polders, monitoring and data transmission is still inadequate. The political elites and the general public are reluctant to endorse high expenditure bringing beneficial results in the uncertain (possibly remote) future. Urgent needs in other areas, which are likely to give fast, and tangible benefits, are given higher priority now. The efforts dedicated to flood defense system decrease with time lapse after the great flood. This illustrates an universal principle of hydro-illogical cycle.

Floods are natural events and will continue to occur in future. Strategies for flood protection and management may modify either flood waters, or susceptibility to flood damage and impact of flooding. One can basically follow one of three options: protect (attention: absolute protection does not exist), accommodate (live with floods, learn from them) or retreat (permanently relocate inhabitants of flood-prone areas). A mixed strategy, being a combination of two, was taken after the Great Flood of 1997 in Poland: “protect and accommodate”. Many a flood victim would be interested in permanent relocation from flood-prone areas if an appropriate offer was made to them shortly after the flood (e.g., programme of acquisition of unsafe lands). However, in comparison to the pre-1997

situation, the flood defenses have been largely improved, including some non-structural measures.

5. Flood, Politics and the Media

In 1989, huge changes to the political and economic system in Poland began. The country entered a period of transition from the rule of a communist party and centrally planned economy towards democratic political system and a market economy. A need to overhaul many sectors became evident. Virtually every sector such as mining, industry, agriculture, transportation, army and police, education, health and social welfare, and others, requested more and more public money. Under such circumstances, and in the long-term absence of really disastrous floods, the expenditure on flood protection and preparedness was low. Flood vulnerability and hazard were not considered seriously by decision makers, political elites and the general public. The flood of July 1997 came after a long period without large floods. It came when the nation was pre-occupied with President Clinton's visit to Warsaw, the perspective for the country to join NATO and, predominantly, with the forthcoming parliamentary elections in September 1997.

A lot of politics has been associated with the 1997 flood. When the waters were rising, on 7 July 1997, the then Prime Minister, Mr Cimoszewicz, flew into the flood area and issued a sober statement, broadly disseminated by the media, that those who had not been insured could not expect compensation for their losses. Admitting that the state would provide assistance to flood victims, he said that there were no significant reserves in the central budget, which could be used to this effect. However, a few hours after this declaration, the flood became really destructive, devastating the town of Kłodzko. Two weeks later, the Prime Minister apologized to the Nation for his undiplomatic statement, which had been largely inadequate to the grimness of the situation that subsequently developed. In his address to the Parliament he said: "When I visited endangered terrains on the 7th of July in order to assess the situation, it seemed that the flood had dimensions known from earlier experience and one could combat it with conventional means. What started to happen to the upper Odra a few hours later exceeded not only alarm stages, but also the scale of existing imagination about the power of the element." The original statement of the Prime Minister and the inefficiency of performance of the authorities in combating the flood were violently criticized by the opposition.

Testing public opinion in polls demonstrated that the nation was particularly critical of the central government, and this criticism may have

contributed to the defeat of the ruling coalition in the parliamentary elections in September 1997, as surmised by some international observers. Also provincial authorities, which underestimated the danger and did not make a proper use of the available forecasts, were strongly criticized. The flood proved a considerable capacity of local authorities, whose performance was commonly perceived more favourably.

The Great Flood of 1997 was extensively covered by the Polish media. For several weeks, it was the dominating topic in press, radio and TV. Over four weeks the flood was the theme of the cover story of the opinion-making weekly magazine POLITYKA (cf. Fig. 2). TV programmes, including regular news and special information bulletins from inundated areas, and live broadcasts from the Anti-Crisis Committee meetings, were numerous and gained high audience.

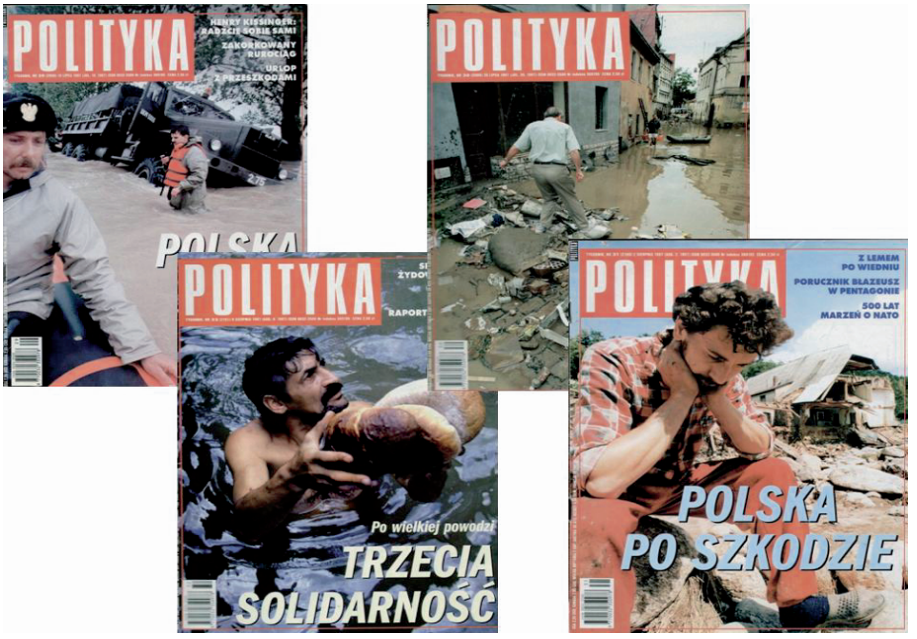

Figure 2. Over four weeks in summer of 1997, the Great Flood was the theme of the cover story of the opinion-making weekly magazine in Poland, POLITYKA

The flood theme was intimately interwoven into the election campaign in the media. Politicking around the flood were quite common. In the election campaign, it was not so much the quality of the argument that counted, but rather the socio-technical criteria of gathering public support. Real or assumed errors of the ruling coalition were used in the pre-election campaign of summer 1997. Flood was assumed to be a relatively simple phenomenon, hence many journalists, politicians, and other public

personalities, including those of the highest echelons, considered it appropriate to share their, typically negative, opinion on the flood defence action via the media. As a result, a part of the broad public could have had the (false) feeling that it was possible to avoid flood losses and that only the inefficiency of the authorities led to the disaster.

6. Concluding Remarks

The Great Flood of 1997 was the greatest flood on record in Poland, both in hydrological terms (peak stage and discharge at many gauges, inundated area in the drainage basin of the Odra) and in economic terms (material losses). It was the effect of exceptionally intensive precipitation covering a large area (cf. Fig. 1). This very rare hydrological event was superimposed on the complex, changing, socio-economic system of a country-in-transition.

Can the 1997 flood be attributed to climate change? Search for a cause of a particular flood is an ill-posed statement, in the context of natural variability. However, one could examine the probability of exceedence of threshold levels. Is the flood risk likely to increase in the warming climate? There are a number of studies (cf. IPCC, 2001), in which increase of intense precipitation in observed records was documented. The extremes in precipitation are likely to be impacted more than the mean in the future, according to climate models. As the water holding capacity of the atmosphere, and thus its absolute potential water content, increases with temperature, intense precipitation may become more intense and more frequent in the warming world. The general projection is of "more intense precipitation events (*very likely, over many areas*)" in the 21st century (IPCC, 2001).

Increase in intense precipitation leads to increase of flood hazard in areas, where inundations are typically triggered by intense summer rain (cf. Kundzewicz et al., 2005). Also, during wetter and warmer winters, with increasingly more frequent rain and less frequent snow, flood hazard may increase. On the other hand, ice-jam floods are likely to become less frequent and less severe over much of the warming Europe (robust, temperature-related statement). Since snowmelt is earlier and less abundant, the risk of spring floods decreases.

Humans have been encroaching into unsafe areas thereby increasing the damage potential. By developing flood-prone areas (maladaptation) they become more exposed. However, even an over-dimensioned and perfectly maintained dike does not guarantee complete protection, as it may not withstand an extreme flood (much higher than the design flood). When a dike is overtopped or when it breaks, the damage in the inundated areas is

likely to be higher than it would have been in a levee-free case. According to Pielke and Downton (2000) climate has played an important but not determining role in the growth of damaging floods in the United States in recent decades. The increasing flood damage was found to be largely associated with increasing human development of flood plains (therein population growth and national wealth increase), with a much smaller effect from increased precipitation (Pielke & Downton, 2000).

Floods are recurrent natural phenomena and no riparian nations are immune to them. Wealthy and highly developed countries with advanced flood protection systems, such as Germany, the UK, France, the USA, Canada, and Japan, have also suffered considerable flood losses in the recent past. Even though the precise timing of future destructive floods is not known, they will continue to come. Hence, trying to live with floods is more sustainable than trying to avoid them (Kundzewicz & Takeuchi, 1999; Kundzewicz, 1999) and the time after a flood can be also regarded as the time before the next flood.

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