Floods and flood protection: business-as-usual?

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Abstract Flooding has been a major concern for people populating the vicinity of rivers and water bodies since the dawn of civilization. Despite the fascinating developments achieved in many areas during the last decades, the hazard of flooding has not been eradicated. In fact, recent floods seem to have been more abundant and more destructive in many regions of the globe and the projections for the future look gloomy. This calls for a need to re-think the strategy for flood preparedness. Traditionally, the strategy was to protect as far as was technically possible and affordable. However, since complete protection is never possible and an acceptable level of protection may be very expensive, an alternative approach is to accommodate floods, i.e. to prepare to live with floods. However, should the strategy of accommodation not be acceptable, a retreat could be a solution. Increasing flood losses clearly indicate that “business-as-usual” is not satisfactory.

Key words adaptation; climate change impacts; extreme events; floods; flood protection; global change

INTRODUCTION

Flooding, i.e. the destructive abundance of water (be it freshwater or sea water), has always been a major concern of people populating the vicinity of rivers and water bodies. For centuries and even millennia, people have been settling near rivers in order to till fertile soils, profit from flat terrain, have easy access to the water needed to sustain life, and use the river for transport. In days gone by, dwellings were typically constructed on higher land, while lower ground was used for farming. Riparian peoples benefited from benign floods and from their valuable services, water and nutrients enhancing agriculture. In short, people lived in harmony with floods.

This harmony ended when people came too close to a river with their settlements and valuable infrastructure. It is said that if one builds on a flood plain, there is no solution. Despite the fascinating developments in many areas of science and technology during the last decades, the hazard of flooding has not been eradicated. In fact recent floods seem to have been more abundant and more destructive in many regions of the globe.

Flooding are natural events and will continue to occur in the future. One can never achieve complete safety. However, the flood risk can be seriously limited if an appropriate preparedness system is built. Flood risk and vulnerability refer to the juxtaposition of two elements: abundance of water inundating areas outside the river bed, and presence of damage potential in the inundated area. The latter is usually caused by humans encroaching into flood-prone areas. In order to study the changes in
risk, it is necessary to examine changes in the probability of high flows and changes in the damage potential corresponding to these flows (stages).

FLOODS ON THE RISE?

Using data assembled by the Red Cross for the time period 1971–1995, one finds that floods killed, in an average year, over 12 700 people worldwide, affected a further 60 million, and rendered 3.2 million homeless. Since 1990, there have been over 30 floods, in each of which either the material losses exceeded one billion US$, or the number of fatalities was greater than 1 000, or both. The highest material flood losses, of the order of 30 billion US$, were recorded in China in the summer of 1998, while the storm surge in Bangladesh in April 1991 caused the highest number of fatalities (about 140 000). Flood damage in Europe in the period 1991–1995 reached the level of 99 billion € (EEA, 2001).

Berz (2001) examined the inter-decadal variability of great flood disasters (understood as such events where international or inter-regional assistance is necessary). Based on his data, one concludes that the number of great flood disasters worldwide has grown considerably: in the nine years 1990–1998 it was higher than in the three-and-half decades 1950–1985 together (Kundzewicz, 2002).

In central Europe, floods have been recently recognized as a major hazard, in particular after the 1997 Odra/Oder flood, the 2001 Vistula flood, and the most destructive 2002 flood on the Elbe, the Danube, and their tributaries. It is estimated that the material flood damage recorded across the continent of Europe in 2002 was higher than in any single previous year. According to Munich Re (2003), the floods in August of 2002 alone caused damage at a level exceeding 15 billion € (therein 9.2 in Germany, 3 each in Austria and in the Czech Republic). Further, during severe storms and floods on 8–9 September 2002, 23 people were killed in southern France (Rhone valley), while the total losses went up to 1.2 billion US$. Destructive flood events occurred in many other parts of the world in 2002. In July and August, floods and landslides in northeastern and eastern India, Nepal and Bangladesh killed 1200. A flood in central and western China in June caused 3.1 billion US$ losses and killed 500, while another in central and southern China, caused 1.7 billion US$ damage and killed 250.

Recent floods do not only exceed historic records of material losses but also records of hydrological (geophysical) variables. For instance, the maximum stage of the River Elbe at Dresden (940 cm in August 2002) was far above the previous record (877 cm observed in 1845). The peak discharge at Raciborz-Miedonia on the Odra in 1997 was twice as high as the second highest in the period of instrumental records.

WHY HAS THE FLOOD DAMAGE GROWN?

Adverse changes in flood risk and vulnerability have been observed. An important driver for global change is population growth with consequences for food, resource use, settlements, land use, etc. Flood hazard and vulnerability to floods tended to
Table 1: Reasons for changes in flood risk and vulnerability.

<table>
<thead>
<tr>
<th>Category</th>
<th>Reason</th>
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<tbody>
<tr>
<td>(a) Changes in socio-economic systems</td>
<td>Land-use change, increasing exposure and damage potential—flood plain development, growing wealth in flood-prone areas, changing risk perception</td>
</tr>
<tr>
<td>(b) Changes in terrestrial systems</td>
<td>Land-cover change—urbanization, deforestation, elimination of natural inundation areas (wetlands, flood plains), river regulation—channel straightening and shortening, embankments, damming rivers, adverse changes of conditions of transformation of precipitation into runoff</td>
</tr>
<tr>
<td>(c) Changes in climate and atmospheric system</td>
<td>Holding capacity of the atmosphere, intense precipitation, seasonality, circulation patterns</td>
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Flood risk may have grown due to a range of land-use changes, which induce changes of hydrological systems. Deforestation, urbanization, and reduction of wetlands impoverish the available water storage capacity in the catchment and increase the runoff coefficient. Urbanization has adversely influenced the flood hazard in many basins by increasing the portion of impervious area (roofs, yards, roads, pavements, parking lots, etc.). As a result, higher peaks of runoff responses to intensive precipitation are observed and the time-to-peak decreases. According to the EEA (2001), on average 2% of agricultural land in Europe has been lost to urbanization every 10 years. The timing of river conveyance may also have been considerably altered by river regulation (channel straightening and shortening, construction of embankments).

The vulnerability to floods can be regarded as a function of exposure, sensitivity and adaptive capacity. All three have been increasing (and are likely to continue to rise). However, since in many areas exposure grows faster than adaptive capacity, the vulnerability increases too. Counter-intuitively, the vulnerability of societies may grow even as they become wealthier. Since technology helps populate and develop more “difficult” areas, societies may become more exposed. High investment into maladaptation does not reduce vulnerability.

The development of flood plains is blamed as a major factor increasing the flood hazard. Under natural flood conditions, rivers and adjacent flood plains are complementary and convey the abundant floodwater. Major flood inundating unoccupied flood plains are beneficial, as groundwater recharge, irrigation and soil fertilization depend on the presence of the natural flooding. Floods constitute a hazard only where humans encroach into flood-prone areas. This has been happening recently, due to demographic growth and the shortage of land. Hope of overcoming poverty drives poor people to migrate to the vicinity of towns, where employment opportunity is better than in the countryside. Many millions live in informal settlements in endangered, flood-prone zones around towns in many developing countries. People have built and continue to build on flood plains in developed countries, neglecting the flood risk. Indeed, myriads of wrong location decisions have been taken, which lead to establishing settlements in flood-prone areas (flood plains, coast). Consequently the
flood loss potential increases, while much of the natural flood storage volume (e.g. wetlands) is lost, ecosystems are devastated and riparian wetlands destroyed.

It is estimated that one sixth of all urban land in the USA lies within the 100-year flood area. About 7% of the area of the conterminous United States is located in the 100-year flood zone and about 10% of the population live there. The latter number also approximately corresponds to the UK conditions. In Japan, half the total population and about 70% of the total assets are located on flood plains, which cover only about 10% of the total land surface of the country. The percentage of flood-prone area is much higher in Bangladesh, and inundation of more than a half of the country area is not rare. The 1998 flood inundated over two thirds of the country.

An important factor influencing the flood hazard is an unjustified belief in absolute safety of structural defences. Even an over-dimensioned and perfectly maintained dike does not guarantee complete protection, as it can be overtopped (possibly destroyed), when an extreme flood occurs.

Can the apparent rise in the flood hazard also be linked to climate variability and change? On top of the direct human impacts, climate change is indeed likely to contribute to the increase in flood risk.

The links between flood-risk growth and climate variability and change have found extensive coverage in the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC, 2001, 2001a; Kundzewicz & Schellnhuber, 2004). In IPCC (2001a) floods have been ubiquitously identified on short lists of key regional concerns.

According to IPCC (2001), over the 20th century a statistically significant increase in global land precipitation has been noted. However, from the point of view of a flood generating mechanism, increase of intense precipitation is more important than the growth in the mean. It results from physical laws that the atmosphere’s capacity to absorb moisture, and thus its potential for intensive precipitation, increases with temperature. This is a sufficient condition, caeteris paribus, for an increase in flood hazard. The increase in the proportion of precipitation falling in large events has already been observed over many areas of the mid- and high latitudes, e.g. in the USA and in the UK (IPCC, 2001).

Where data are available, changes in river flow usually relate well to changes in total precipitation (IPCC, 2001). There are a number of studies reporting that high flows have become more frequent (cf. Kundzewicz, 2003). Many increases of annual maxima and peak-over-threshold (POT) variables have been found in the river flow data in different areas, e.g. in the UK, particularly in Scotland and in southeastern England, and in the USA. However, this does not directly translate into a general finding on changes in flood flows everywhere. No globally uniform increasing trend in maximum river flow has been detected.

Regional changes in the timing of floods have already been observed in many areas, with increasing late autumn and winter floods (caused by rain) and less ice-jam-related floods, e.g. in Europe. This has been a robust result. Yet, intensive and long-lasting precipitation episodes happening in summer, especially those induced by the Vb cyclone, have led to disastrous recent flooding in Europe. However, one should be very careful of over attributing the responsibility for the occurrence of a particular flood to global changes (e.g. of climate). A particular flood may have manifested the
natural variability—virtually any maximum flow rate observed recently has been exceeded some time in the (possibly remote) past. Yet, the increased probability of floods fits well into the general image of the changing (warming) globe.

Studies of links between hydrological extremes and climatic variability (e.g. oscillations in the ocean–atmosphere system, such as the El Niño–Southern Oscillation (ENSO) lead to interesting findings. The frequency and intensity of ENSO have been unusually high since the mid 1970s, compared with the previous 100 years of instrumental records (IPCC, 2001). This is likely to have direct consequences related to changes in flood hazard, since in some regions of South America, intense precipitation (and floods) occur frequently in the El Niño phase (IPCC, 2001a).

The risk from storm surge also appears to be changing. The global average sea level rose by 10 to 20 cm during the 20th century, about ten times larger than the average rate over the last 3000 years (IPCC, 2001). Needless to say, that the sea-level rise itself is a dangerous occurrence, which jeopardizes low-lying coastal areas and leads to an increasing storm-surge risk. The rising sea level may cause permanent inundations, resulting in massive relocations of people. Global warming has the potential to trigger large-scale singular events, which could have important consequences for the risk of inundations. An example is the disintegration of the West Antarctic and Greenland ice sheets, in a time scale of multiple centuries. This would cause a significant sea-level rise (of the order of metres), leading to the permanent inundation of large, now densely populated areas. The probability of such developments in the near future is low, but should not be ignored, given the severity of their consequences.

STRATEGIES—WHAT CAN BE DONE?

In order to select a strategy for flood preparedness, one has to consider the following three options: protect, accommodate, retreat. Traditionally, people strived towards protection, as far as technically possible (perfect and complete protection is never possible) and affordable (e.g. it makes no sense to invest many millions into defences protecting properties worthy of a small portion of the investment costs). However, nowadays, one may be willing to consider another option—to accommodate, i.e. prepare to live with floods. Or else, if the strategy of accommodation is not acceptable, a retreat could be a solution.

Traditionally, flood protection measures have been structural ("hard"), such as dikes, dams and flood control reservoirs, diversions, floodways, etc. Such defences have a very old tradition, as dams and dikes have been built for more than 4000 years. Important discussions of the strategy of flood protection date back to the mid 19th century USA, when the US Congress looked into the problem of the Mississippi floods, and decided to embank the Mississippi River in a single channel isolated from its flood plain. This decision has largely influenced flood protection policy in the USA and elsewhere, leading to the transformation of rivers and reduction of wetlands.

There is a common but unjustified reliance on the safety provided by structural flood controls. However, no flood protection measure guarantees complete protection. In reality, even an over-dimensionalized and perfectly maintained dike does not guarantee
complete safety. It has been designed to withstand an $N$-year event (where $N$ can be 10, 100 etc.), so it can be readily overtopped and destroyed if a $5N$-year event occurs. When dikes break, losses in a levee-protected landscape can be considerably higher than they would have been in a levee-free case. Riparians, who have settled and accumulated considerable wealth behind a dike feel secure, but in reality they enjoy only limited protection, while occupying endangered areas.

In several developed countries, costly structural protection facilities are in place, designed to withstand rare floods, so a desired level of protection is acquired. Statutory defence standards (referring to a return period) vary in different countries, e.g. in Europe between 50- and 200-year flood for residential areas and between 5- and 25-year flood for agricultural areas. Large river dikes in The Netherlands are designed for a 1250-year flood. Reinforced dikes (super-dikes) protect major cities in Japan, such as Tokyo, Osaka, and Nagoya, where considerable wealth has been accumulated and a very high level of safety must be assured (cf. Kundzewicz & Takeuchi, 1999). Super-dikes have a width of 300–500 m and their cost may reach 100 million US$ per kilometre of length.

Since a protection system guaranteeing absolute safety, except for extremely expensive localized cases, is an illusion, one could prepare for floods by non-structural ("soft") measures, such as zoning; maintaining wetlands, washlands, and polders, developing flood mitigation systems (monitoring, forecasting, warning, evacuation, relief and post-flood recovery); flood insurance; improving capacity building and enhancing the participatory approach. Thanks to improvements in the advance time and accuracy of forecasts, it has been possible to reduce the number of flood fatalities.

Is retreat a valid option? After the 1993 flood in the USA, programmes of acquisition of land and structures at risk in the flood plain were launched and a large number of families benefited from them. However, in many countries, the strategy of retreat is not realistic. Rather than moving to a safe location, people who suffered in a flood, rebuild their houses and try to regain their livelihoods in the same place devastated by a flood. Retreat (where to?) is unthinkable in Bangladesh, where most of the country area is flood-prone, and the population density is high (and dynamically growing).

Measures of flood preparedness and management either modify the floodwater (do something with the water—reduce hazard), or a system’s susceptibility to flood damage (do something with the system—decrease exposure and sensitivity), or modify the impacts once the flood has occurred (minimize losses, optimize recovery), cf. Table 2.

There are considerable barriers to development of further structural measures. In Bangladesh, the scarcity of land is so dominant that there is virtually no room for either building new dikes, or accommodating the relocated population. In Europe and North America, there is a strong and widespread resistance to new dams.

Flood hazard mitigation can be seen in a broader context, as a part of a general sustainable development strategy. A common interpretation of sustainable development is that civilization, wealth (human and natural capital) and environment (built and natural) should be relayed to future generations in a non-depleted shape. That is, civilization and wealth should be protected, *inter alia*, from devastating floods, which destroy cultural landscapes and undermine sustainable development by breaking
Table 2 Classification of flood preparedness measures.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Description</th>
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<tbody>
<tr>
<td>(a) Modify flood waters (precautionary measures)</td>
<td>Flood defence infrastructure (structural measures): dams and flood control reservoirs, flood dikes, diversions, flood ways, improvement of channel capacity to convey a flood wave, enhancing source control via watershed management, enhancing storage–flood plains and wetlands, polders and washlands, enhancing infiltration—permeable pathways and parking lots, vegetation management (afforestation, cropping pattern avoiding bare soil during precipitation season), terracing etc.</td>
</tr>
<tr>
<td>(b) Modify the system’s susceptibility to flood damage (precautionary measures)</td>
<td>Legislation, land-use planning and management, zoning—delineation of areas where certain land uses are restricted or prohibited, development control of flood hazard areas leaving flood plains with low-value infrastructure, e.g. riparian forests which are subject to frequent flooding, buy-out of land and property located in flood plains—stimulating relocation, flood proofing (by elevation, barriers, or sealing), disaster contingency planning, preparation of flood forecasting and warning systems, flood insurance schemes, awareness raising: improving information and education on floods and on actions to take in a flood emergency.</td>
</tr>
<tr>
<td>(c) Modify impact of flooding (reactive measures)</td>
<td>Detection of the likelihood of flood formation, forecasting of future river stage/flow conditions, warning issued to the appropriate authorities and the public on the extent, severity and timing of the flood, dissemination of warning, response by the public and the authorities, evacuation, financial aid (insurance claims, loans, tax deduction, debt reduction), relief for those affected by the disaster, reconstruction of damaged buildings, infrastructure and flood defences, post-flood recovery and regeneration of the environment and the economic activities in the flooded area, review of the flood management activities to improve planning for future events (links to (a) and (b)).</td>
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</table>

Continuity. Floods constitute risk to life, health, property, infrastructure, traffic, industry, trade, businesses, etc., and reduce public confidence. However, while flood protection is necessary for the present generation to attain a fair degree of freedom from disastrous events, it must be done in such a way that future generations are not adversely affected. Many examples of flood protection infrastructures, especially large dams, have been criticised in the context of sustainable development for depriving future generations of preferable defence options and introducing major disturbances in ecosystems (cf. Takeuchi et al., 1998).

Natural flood protection measures, which do not involve large structural components, can be rated as more sustainable than structural measures. They are environment-friendly, commonly acceptable, lend themselves well to application in a trans-national context, and are more flexible than the structural measures. Hence, they are particularly useful in global change adaptation strategies. Since uncertainty in assessment of impacts of global change is high, a high degree of flexibility of adaptation strategies is advantageous.

However, structural measures may be indispensable in particular circumstances, e.g. along large rivers in major cities. Technical flood protection measures definitely have been and remain important, but clearly they are not sufficient.

Among the many quality indicators (cf. Gardiner, 1997; Kundzewicz, 1999), which lend themselves to be used in comparison of flood protection measures with respect to the agreement with the sustainability principle, the following set can be selected:
Table 3 Compliance of components of pre-flood preparedness with the principle of sustainability.

<table>
<thead>
<tr>
<th>Flood preparedness measures</th>
<th>Compliance with sustainability principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of large physical flood defence infrastructures</td>
<td>L to M</td>
</tr>
<tr>
<td>Zoning, development control within the flood plains</td>
<td>M to H</td>
</tr>
<tr>
<td>Source control, land-use planning and watershed management</td>
<td>M to H</td>
</tr>
<tr>
<td>Flood forecasting and warning system</td>
<td>H</td>
</tr>
<tr>
<td>Flood proofing</td>
<td>L to H</td>
</tr>
<tr>
<td>Disaster contingency planning and maintenance of preparedness of community self-protection activities</td>
<td>H</td>
</tr>
<tr>
<td>Installation of insurance scheme</td>
<td>L to H</td>
</tr>
<tr>
<td>Capacity building and improving flood awareness</td>
<td>H</td>
</tr>
</tbody>
</table>

H, high; M, medium; L, low.

- socio-economic and financial feasibility, related investment and operational costs;
- degree of intervention in the natural regime, stress to ecosystems and humans, use of energy and raw materials;
- safety, risk and reliability measures;
- inter-generational equity (retention of strategic adaptability and future options);
- opportunities for reversibility (flexibility) and rehabilitation.

Table 3 shows a roster of components of flood preparedness systems and the author’s rough assessment of their compliance with the spirit of sustainable development.

Improving information about floods is badly needed for awareness raising and enhancing the consultative process, which leads to a flood protection strategy. Only informed stakeholders can make rational decisions about choice of strategies of flood protection, in a cost-benefit framework; taking account of sustainability issues. Yet, misconceptions and myths about floods and flood protection are deeply rooted in society—the general public, politicians and decision-makers alike. It is of utmost importance to identify and to rectify misconceptions. Apart from misconceptions, there are counter-productive “principles”, such as a rule baptized by Klemes as the “hydro-illogical cycle”, valid across different political, social, and economic systems. Flood occurrence triggers high expenditures on flood protection. Yet, after some time without floods, projects are downscaled or suspended. How can this truth be communicated to the electorate and to decision-makers whose term of office is short?

CONCLUSIONS: BUSINESS-AS-USUAL NOT SUSTAINABLE!

Global flood damage has recently shown rapid growth, which is likely to continue in the future. It can be linked to socio-economic, terrestrial, and climatic factors. The flood hazard is exacerbated by several land-use changes, such as deforestation and urbanization, which reduce the available water storage capacity. Demographic pressure causes encroachment of settlements into hazardous locations in flood plains. Higher and more intense precipitation has already been observed in many areas of the warmer globe and this trend is expected to be even more pronounced in the future. Despite
considerable investments into flood protection, vulnerability to floods is rising, as the increase of exposure is faster than the growth of the adaptive capacity. The panoply of flood preparedness measures for the future includes a mix of structural and non-structural elements. However, since no flood defence guarantees complete protection, serious consideration is necessary of the strategy of accommodation (living with floods) or retreat from risky locations.

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