Flood Maps in the Czech Republic: Content, Perception and Information value

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Abstract. Floods are one of the most important environmental hazards in the Czech Republic. At present, flood management is more focused on non-structural flood preventive measures, which also include flood mapping. The paper analyses selected publicly available flood maps. Flood risk maps, floodplain maps and insurance maps are analysed. These maps are mainly evaluated in terms of technical performance, potential problems with maps perception by the public and enshrinement in the legislation of the Czech Republic. Results of the analysis indicate several essential problems. In the Czech Republic, floodplain maps are only based on the extent of inundation for a given scenario. Primarily, these maps are a legal construct working only with the aspect of water extent. Flood risk maps allow multi-criteria evaluation of flood risk. The imperfections of these maps are particularly of technical nature which is why it is more difficult for the public to interpret them. Insurance maps clearly define the inclusion of the place in the flood zone, but these maps shouldn't be used for other purposes of risk assessment. Examples of selected maps are demonstrated on examples of Troubky municipality (central Moravia). Despite the imperfections mentioned above, flood maps are an important part of the flood management in the Czech Republic.

1 Introduction

Natural catastrophes are a current topic in today's world. According to the statistics of World Health Organisation 100 greatest natural catastrophes in the 20th century caused damage for more than 631 billion dollars. Almost one third of this amount was the damage caused by floods [1]. „Flooding is the most lethal and destructive of all natural hazards, affecting both industrialized and developing countries alike every year“[2].

The Czech Republic is not exposed to some types of extremes (volcanoes, large-scale storms, oceanic hazards) thanks to its geographical position. The greatest natural hazard in the long term is definitely the floods. In the last two decades the Czech Republic was affected by several intensive flood events.

The first major flood event after a longer period of tranquillity in the second half of the 20th century was the flood in 1997 which hit a great part of Moravia (eastern part of the Czech Republic). The assessed damage was more than 62 billion Czech crowns [3,4]. Bohemia (western part of the Czech Republic) was affected by the flooding of a similar intensity in 2002. The damage was more than 73 billion Czech crowns [4]. Other flood situations of a minor extent occurred on the territory of the Czech Republic for example in 2006, 2009 or 2013. The flood problem has gradually evolved from a marginal area of interest during the communism period into one of the fundamental environmental topics in the Czech Republic. Some crucial strategic documents regarding the

flood problem have been created [5,6]. The flood problem has also been reflected in more general strategic documents [7]. These documents are regularly updated. The focal point of flood control systems has gradually moved on from purely technical measures that were not sufficient to provide flood protection [8,9]. A major emphasis has also been put on non-technical flood control measures. There has been a need for the improvement of flood prediction, territorial decision-making and risk communication between different subjects and entities (e.g. local authorities and inhabitants) in flood management.

Abnormal events (not only floods) in recent years have confirmed the need for spatially based information [10]. The development of geographic information systems (GIS) enabled the application of soft measures in flood management of the Czech Republic, such as flood maps/web applications. These are currently used to a different extent in the decision-making process of local authorities as well as for the planning of flood measures.

2 Aims of research and methods

What sources of information about floods having the character of map sources are currently available to the inhabitants of the Czech Republic? What sources can affect planned measures and decisions of the representatives of both public and commercial spheres as far as flood danger is concerned? The aim of this paper is to present and discuss publicly available maps (map

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sources) that inform about flood danger (flood risk) extent in a given area.

Three main types of publicly available map outputs² have been selected for the evaluation, namely:

- Floodplain maps,
- Flood risk maps,
- Insurance maps.

Each of the above-mentioned types of flood maps will be evaluated in the paper in terms of their elaboration specifics, current usage and availability. Last but not least, we will also characterize the enshrinement in Czech legislation which indirectly determines the use of a particular map in decision-making and planning processes. To enable the contents comparison, concrete examples of map outputs of different kinds shall be demonstrated using the example the municipality of Troubky (eastern part of the Czech Republic, central Moravia) which was affected by several flood events in the past (it was the most severely affected municipality in 1997) [8,11] and for which the author worked out flood hazard and risk maps and carried out field research aimed at the perception of flood risks [12]. Troubky is still one of the most endangered municipalities in the Czech Republic. According to the Flood risk management plan in the Danube basin [13], 87% of the inhabitants of Troubky live in the areas with unacceptable risk (see chapter 3.2.2). It can be used as a good example for extreme values in the analysed maps.

3 Flood maps and their meaning

The increasing vulnerability of the society is connected among others with the increase of wealth [14]. The property is often allocated in the areas susceptible to environmental hazards. The problem of the construction in flood areas is an often discussed issue [15,16,17]. One of the reasons why these dangerous areas are settled is low awareness of flood risk and loss of flood memory [18]. This has to be changed somehow. Flood maps may be one way of raising awareness of flood risk [19]. The available flood maps are mostly developed by governmental organizations and primarily used for emergency planning, spatial planning, and awareness raising [20]. Hardcopy maps bring information about flood problem by means of spatial expression with graphic presentation which can (if it is well available and understandable) significantly facilitate the acceptance and understanding of the given information by the public. Map applications add the possibility of dynamic interconnection with further information to this presentation.

3.1 Floodplain maps

² In order to achieve a clear arrangement of the text the author hereinafter uses the term „map“ for map application as well as feature layer except for the cases in which it is necessary to differentiate these terms. These outputs are generally named as flood maps.

3.1.1 General characteristics and enshrinement in legislation

Floodplain maps are one of the oldest flood maps in the Czech Republic. Strictly speaking, these are feature layers of flood areas for given scenarios without the uniform map visualisation (see chapter 3.1.2). They depict flood areas demarcated by a floodplain boundary. The specification of flood areas is stated in Act No. 254/2001 (Water Act) [21] and detailed conditions are given by the Decree No. 236/2002 [22].

In order to analyse floodplain maps it is necessary to get acquainted with the basic terms and legislation aspects of flood areas. In section 66 of Water Act [21], flood areas are defined as „administratively determined areas exposed to flooding in case of natural flood“. The extent of flood areas is determined by water law authority on the basis of the proposal made by watercourse administrator. In order to determine flood areas, the widest possible spectrum of sources is used, for example hydrological data, Base map 1:10 000, Fundamental base of geographical data of the Czech Republic, hydraulic calculations, data about the highest recorded flood, geodetic surveys or cross-sections. The structures that influence the flow rate are also recorded (section 5) [22]. The development of modern technologies enables the use of digital terrain models to update the extent of flood areas [23]. The flood areas are determined for flow rates corresponding to Q5, Q20, Q100 and the highest natural flooding [22] (e.g. Q100 means: overtime, the average culmination flow rate is achieved or exceeded once every 100 years; i.e. in any given year, there is a 1% chance of such flooding). The use of these terms brings about certain problems (see chapter 4.3).

Besides flood areas, active floodplain zones are also specified for built-up areas. "The active zone is a territory in built-up municipality areas and in areas intended for construction according to local development plans which during the floods conducts away the decisive part of total flow, thus directly endangering people's lives, health and property" (section 2) [22]. Active zone is determined by the methodology of determining the active floodplain zone [24] and stricter rules than for flood areas apply to it. The water authority may stipulate restrictive conditions for the flood plain areas outside the active zone. Locating, permitting and building structures inside the active zone of the flood plain area is prohibited except for water management structures (section 67) [21]. The law at present lacks above all the exact definition of active zone and strictly set rules of for its determination. In practice this often causes a problem with determination extent or with circumventing of the determination of active zones in the area [25].

3.1.2 Projection, availability and use

As we have mentioned above, as opposed to other types of flood maps, the graphical form of floodplain maps (colour pattern, inseparable base map etc.) is not defined by any law or any other legally binding document. The legislation only states the fact that the Ministry of the environment of the Czech Republic is

obliged to create the feature layer of flood areas for public administration information system (section 8) [22].

Feature layers of flood areas are available separately for download in format .shp on website DIBAVOD [26], where it is possible to see the data as part of the application [27]. Flood areas are accessible in other publicly available applications, e.g. on the website of digital flood plan of the Czech Republic [28] and on regional and municipal geoportals. However, different web applications show different data of flood areas (see chapter 4.2). The data is mostly used as a source for local and landscape planning and it serves to the public as basic information about flood problem in a particular territory.

3.2 Flood hazard and flood risk maps³

3.2.1 General characteristics and legislative definition

Flood hazard and flood risk maps are a relatively new institute in the Czech Republic. They represent a significant shift to multi-criteria evaluation of floods. They use not only the flood extent area (like flood maps do), but they also take into account the velocity and depth. It is especially the depth that is often mentioned as the most important factor influencing the flood [29]. They also take into account the land use of the area and its different vulnerability [30,31].

The origin of these maps is connected with the transposition of the Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (hereinafter called "Floods directive") [32] into Czech law. This directive has set three steps for the reduction of flood risk:

- preliminary flood risk assessment - definition of potentially endangered watercourse stretches,
- creation of flood hazard and flood risk maps for endangered stretches,
- creation of complex flood risk management plans.

These steps have been gradually included in Czech Water Act and fulfilled in accordance with time schedule which required the creation of maps for potentially endangered stretches by 22 December 2013. The plans for management of flood risks which include the mentioned maps have been approved by the Czech government at the end of 2015.

3.2.2 The creation process of flood hazard and flood risk maps

The methodology for the creation of flood hazard and flood risk maps [33] (hereinafter called methodology), created by T. G. Masaryk Water Research Institute, public research institution in Brno, was used for the creation of maps. The methodology not only determines a

uniform creation process but also a uniform graphic presentation. The methodology was also adhered to during the creation of the maps for the municipality of Troubky [8,31] and some corrections were made on the basis of subsequent discussion with local authorities which resulted in better legibility of the map (see chapter 4.4). The correction has been made also in the maps presented here.

The source of the methodology which is the basis for Czech methodology is Swiss Agency for Development and Cooperation [34]. Its methodology has been subsequently modified for local conditions in the Czech Republic. Besides the Czech Republic the Swiss system has been used for example in Germany (Saxony), Nicaragua or Ecuador [35].

Figure 1. Simplified scheme of flood hazard and risk mapping (R_i ...flood hazard; IP_i ...flood intensity of a given flood scenario; p_i ...probability of occurrence of flood scenario; N_i ...return period in years). Source of maps [8].

First, flood intensity maps are created on the basis of hydraulic calculations in which flow velocities and depths are determined in the studied territory. These parameters are subsequently used for the calculation of flood intensity which serves as an important input into hazard calculation (simplified scheme of the whole process of mapping is given in Fig. 1, for detailed information see [30,31]). The hazard is calculated from the flood intensity and probability of occurrence of a given scenario. The hazard is determined on the basis of a risk matrix with the use of semi-quantitative analysis

³ In view of the fact that flood hazard and flood risk maps are closely linked with each another, they are dealt with together as one kind of flood maps in this paper.

[34]. The result is a relative hazard level expressed in this case by means of colour scale. The hazard is divided in the maps into four basic categories and for every single category there are recommendations in the methodology for possible area management. The created hazard maps are then used for the creation of risk maps. The risk maps are created for the scenarios Q5, Q20, Q100, Q500 and for maximum hazard (the greatest hazard value to of all scenarios is selected for every grid here). Subsequently the area vulnerability based on its use (e.g. living, transportation infrastructure, agricultural land etc.) is determined according to the methodology and the limit of unacceptable risk for individual area categories is specified. This results in highlighting of areas exceeding acceptable risk in risk maps (the colours of other areas are softened). It is especially in these areas exceeding acceptable risk that are the most vulnerable during floods. To determine the categorisation of area use it is ideal to utilise local development plan. For small municipalities that do not have current local development plan it is necessary to use available sources supplemented by field research to determine area categories. That was the case with Troubky [31].

3.2.3 Availability and use

Flood risk and flood hazard maps are freely available in the Central data storage for flood risk and flood hazard maps [36]. Besides the advantage connected with the dynamic information addition, the web presentation also enables the possibility of colour modification according to current users' needs (e.g. opacity increase for better legibility of the background) and lowering of information utilisation of the map (switching off of certain layers). It was especially the information overload that was named as one of the biggest problems of hardcopy risk maps in Troubky [8].

As far as the use is concerned, as we have mentioned, flood risk and flood hazard maps are part of the flood risk management plans. The flood hazard and flood risk maps also serve as part of planning analytical materials, which are the basic source for local planning in the Czech Republic. As standard, these maps are also part of flood plans.

3.3 Insurance map

Flood insurance map (see Fig. 2), which was first introduced to the public in 2009 [37], enables the wide public to find out whether and in which flood zone their property or land they are interested in is situated (e.g. if they intend to buy a piece of real estate). This service is unique in its field and it's a continuously developing instrument which is based mainly on co-operation principal resulting in the development of a common system with several insurance companies working together.

The insurance of property against the influence of floods and inundations appears in Czechoslovakia as early as 1951 [38], when first floods and then also inundations are incorporated in the list of insurable

natural disasters. However, it was only the flood situations in 1997 and 2002 which after a relatively calm period in the second half of the 20th century made insurance companies change that attitude. In 1997 the damage caused by floods was calculated to approximately 63 billion Czech crowns. The amount of indemnification paid by the insurance companies was approximately 10 billion Czech crowns [3]. A significant role in the settlement of claims caused by floods was played by reinsurance companies. Although the insurance settlement amount was only approximately 16% of the total damage, some insurance companies would probably go bankrupt without the help of reinsurance companies [3]. After the flood in 2002 the change in the policy of reinsurance companies launched changes in flood management of insurance companies. Insurance companies were "forced" to ensure a more suitable risk assessment [39,40]. The company Multi Media Computer together with Swiss company Swiss Re created an instrument for the assessment of flood risks for insurance market in the Czech Republic, so-called FRAT [41]. The system was already based on GIS technology. It used the digital terrain model and it worked with six zones of flood risk. Gradually, as the demand for improved quality of input data grew stronger, the system Aquarius was created which was first used by Česká pojišťovna insurance company. The system provided a more precise demarcation of flood boundary, height accuracy improvement and also mapping of more watercourses. It only contained three zones [42]. Further development was no longer aimed only at internal use. In 2009 the flood maps were made available to the public for the first time. The Czech Association of insurance companies (CAP) was a professional guarantor of the map portal operated by the company Intermap Technologies, s r.o. The association made the electronic system of flood maps available to the public by means of the website [43]. Between 2009 and 2010 the service was subject to a charge. Subsequently the service was provided for free. Thereby even the last barrier complicating the improvement of flood awareness in this field was removed [43]. The map included in the application is divided into four terraced zones (1 – insignificant hazard, 2 – low hazard, 3 – medium hazard, 4 – high hazard). The immovable property in zone four is not normally insured [44]. Information about the given territory is provided by means of a report (see Fig. 3) which is generated for the locality specified by the client and it is sent to the selected email address.

3.3.1 Availability and use

Flood insurance map is available on Czech Insurance Association website [45]. Presumably, this application will mostly be used by users of real estate, people interested in buying a piece of real estate and last but not least, owners of real estate agencies. However, to those, as well as to other legal entities, special conditions indicated on the website apply. Czech Insurance Association also confirms interest in the application and in its statement it says that it was namely the great

interest in the service and possible discouragement of clients due to payment for the service why the service is now free of charge. Czech Insurance Association also mentions the fact that the use should only be limited to insurance purpose. Other use could be misleading as the Ministry of the Environment of the Czech Republic

points out. Insurance maps cannot be interchanged for floodplain maps. [46].

Figure 2. A preview of the insurance map [45].

Figure 3. A preview of the report [45].

4 Discussion

In the final discussion the author will express their opinions of the problems that are directly connected with the use of flood maps in practise. Attention will be paid to four main but closely linked problems: interconnection of the maps, their up-to-dateness, interpretation and technical aspect of their creation.

4.1 Interconnection of flood maps

Flood maps should not be used in practise separately without other flood information sources. It is also suitable to use more kinds of flood maps together to explain the flood risk to the public. This results from the substance of integrated flood management as it is stressed and presented (e.g. [47,48]). As for example Hagemeyer-Klose and Wagner [49] point out, flood hazard and risk

maps are essential for communication about the extension of the legally designed floodplain and the use of restriction. For risk communication it is recommended to combine different flood maps [49]. On the other hand, it is not possible to interchange the maps for the presentation of flood risk. While flood hazard maps can be helpful for updating of flood areas, insurance maps should not be used for this purpose. Citizens should strictly differentiate between insurance maps which present the risk level in the given locality in terms of insurance market and floodplain maps. These are, as mentioned above, administratively determined areas linked to Water Act. Their determination brings possible restrictions to the citizens while insurance maps "only" inform about the conditions for the insurance of real estate in the given area. The difference also consists in the fact that insurance companies use maps "only" as auxiliary material which enables them to estimate the risks better. Insurance maps are not an obligatory foundation that would globally prevent insurance company staff from insuring for example a building in the fourth tariff zone. It also depends on the concrete situation and insurance company policy (e.g. flood protection may have been built which is not reflected in the map) [50]. By contrast, the determination of flood areas in floodplain maps is based on legislation, especially in active zone areas where there are explicit legal duties in terms of construction restrictions and these cannot be neglected. However, it is especially in this area where malpractices by the state and responsible authorities occur [25], when flood areas are narrowed down on the basis of new suggestions made by municipalities, or active zones are almost eliminated, especially in the built-up areas. This can negatively influence the perception of flood risk level. The discrepancy between floodplain maps with active zones determined, or rather not determined this way and flood hazard and risk maps might lower the credibility of both kinds of map sources.

4.2 Up-to-dateness of published maps

The update times of Flood risk and hazard maps are strictly defined by European legislation (article 14 paragraph 2 [32]). Citizens should have clear information about what period of time the information in the map pertains to. As far as insurance maps are concerned, there is only one public access point to the application on Czech Insurance Association website which ensures uniformity of the information. Thus the problem with non-uniformity of the data and often unknown period of updating only occurs with floodplain maps. The feature layer of flood areas can be found, as mentioned above, in many publicly available map applications. However, the data contained in these applications are not taken over from only one source. An example can be the basin of the Bobrava river not far from the second biggest city in the Czech Republic, Brno. In some web applications there is flood area Q100 marked for this river basin [51,28], in some there is not [27]. This is not the only example of non-uniformity. Unfortunately, the determination of this

flood area is not even contained in the layers of flood areas freely downloadable in format .shp available on official website providing hydrological data [26]. On the other hand, it is necessary to mention that for example the web application DIBAVOD points out the fact that the depiction of flood areas serves just as approximate reference and it is necessary to contact locally corresponding water law authority or watercourse administrator to obtain relevant information. In spite of that it is quite unusual that it is namely the legally binding determination of flood areas, whose graphic creation is guaranteed by the Ministry of the Environment of the Czech Republic and the determination of which results in legal consequences that is the only map output where different data are publicly presented. This may be quite confusing for the wide public and may result in lack of confidence in such maps. Floodplain maps have been the object of criticism in the past namely for the fact that they did not correspond to reality [8].

4.3 Interpretation of map contents

In order for the maps to serve their purpose, it is necessary that they should be interpreted correctly by both experts and lay public. We can assume that the experts will have no problem understanding technical terms. However, with the lay public there are many studies confirming that especially the understanding of N-year frequency (e.g. Q20, Q50, Q100) is very problematic [49,52,53]. Insurance maps deliberately avoid the N-year frequency in the report and they try to describe the risk level verbally by means of hazard level rate (insignificant, low, medium, high). Floodplain maps, flood hazard and risk maps use the above mentioned term N-year frequency. The problem of understanding N-year frequency has also been noticed in the Czech Republic. The field research by means of a questionnaire survey has found out that none of the questioned inhabitants of Troubký and neighbouring villages (112 respondents in total) was able to define the term one-hundred-year flood [12]. The respondents answered for example that one-hundred-year flood is a flood that occurs once in a hundred years. Abroad, the principle of working with information about water level using gauge level proved successful as it is more comprehensible to the lay public [49]. As some authors point out, the technical terms should be reduced to minimum when communicating with lay public [49]. A good aid for better understanding of the contents of both kinds of maps can be either consistent explanation of the terms in a lay manner or comparison of N-year frequencies in individual stretches to water levels reached during historical floods (if the area was affected in the past).

4.4 Technical implementation (visualization, accuracy)

In terms of the perception of flood maps, easy legibility is an important factor [53,54]. Maps should be transmitted to users in a form that is easy to understand [30]. Hagemeyer-Klose and Wagner [49] carried out

research aimed at evaluation of eye movement and fixation times of test persons at individual points of hazard and risk maps. It was found out that the map legend is less important for laymen than for expert users. The map field itself should give as comprehensible information as possible even without the legend.

As we have mentioned above, the floodplain maps do not have a uniform graphic visualization. Different colours are used in different ways in individual web applications. The colour pattern used in the DIBAVOD viewer [27] almost corresponds with the colour pattern defined by the Methodology [33] for the categories of flood hazard which the author of the paper does not consider to be a suitable solution in view of the fact that the matters are absolutely different. The authors' experience is that in most cases blue colour shades is used for highlighting of flood areas in floodplain maps [28,55,51].

Flood hazard maps adopted the colour pattern from the Swiss original. However, the colour scale in yellow, orange, blue and red (from the lowest to the highest hazard level) does not seem to be very suitable for this purpose. This might be misleading with the hues of blue used for water depth or water extent [56,49,31]. Bad comprehensibility of blue colour in the map by local authorities was confirmed during the testing of the maps created for the municipality of Troubký [8]. A suitable alternative would be the use of classical image in green-yellow-orange-red [31,8] (compare Fig. 1 and Fig. 4).

Figure 4. A proposal of flood hazard map in green-yellow-orange-red colour scheme (lowest to the highest hazard level). Source: modified map [8].

The current image is inappropriate for risk communication with the public [49]. The risk map in itself is by definition, as it supplements information from hazard map, even more complicated to understand and to present. Some studies state that hazard maps are more useful than risk maps for most target groups [54].

Insurance maps are a speciality in terms of visualisation because their result is not a map itself but a generated report (see Fig. 3). In terms of visualisation the report is very transparent and it gives the reader clear and precise information.

The matter of visualisation is closely linked with the problem of accuracy of maps. It is always necessary to keep in mind that all maps only depict simplified reality. Maps are based on input data, mathematical modelling etc. and in spite of ever-improving technologies it is not possible to take into account all the factors entering the calculations. Moreover, hazard and risk maps in the web application [36] are shown at the most detailed scale 1:7 560 and this should be the maximum scale in which they should be presented. In addition, risk maps use local development plans for the categorization of terrain which, too, are not intended for interpretation in higher scales. The public should be acquainted with this fact so as not to misinterpret the maps.

5 Conclusion

Flood maps have become an important part of flood management in the Czech Republic. All the maps analyzed in the paper are available to the public. Two kinds of maps deal with flood risk in terms of public administration provisions while insurance maps evaluate the risk in terms of (non-) insurability of private property. The graphical presentation of contained information gives flood maps an important added value. However, this value is lowered by some deficiencies described in the discussion. With hazard and risk maps it is especially worse legibility at first glance (mainly due to unusual selection of colour pattern in hazard maps and great number of depicted pieces of information in risk maps). The main problem with floodplain maps is to be found mainly in non-uniformity of feature layer in different applications available to the public. As opposed to the above mentioned maps, insurance maps only serve a single purpose which causes fewer problems during their creation. Maps give the user clear information about the area by means of a report. However, it is important to stress the fact that no conclusions should be drawn about the risk in the area not connected to the insurance using this information. For other purposes the floodplain maps and hazard and risk maps are exclusively used.

The author of the paper believes that flood maps are a suitable instrument of flood management which can help to increase the awareness of flood risk and to provide better orientation in the given problem. In order to achieve this goal, it is not sufficient to create and maintain flood maps. It is also necessary to suitably present them during risk communication both inside the communities and in the relations between experts and lay public. Maps can be a suitable instrument of flood management but they stand independently as its solution.

An important topic for further discussion and research should be the creation of a uniform, user friendly web portal with flood information for local authorities and the public. The creation of such functional portal could contribute to better presentation of flood maps. A question also arises whether it would be suitable to use 3D visualisation of flood maps for more illustrative presentation. Without further steps improving the ease of use of these maps and enhancing their comprehensibility

it is hardly possible to suppose that the maps will be used by the public on a larger scale.

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