



# **PROTECTION AGAINST FLOODS**

## **CONCEPT OF ANTI-FLOOD MEASURES IN CENTRAL BOHEMIAN REGION**

**(Short Version)**



**EUROPEAN UNION  
EUROPEAN REGIONAL  
DEVELOPMENT FUND**



## **General Summary, Topic Survey**

In recent periods, floods caused damages within our territory, estimated in the amount of CZK 150 bill.; the amount reached CZK 70 bill. in 2002, and CZK 63 bill. in 1997. There were human casualties, as well. In 2002, 16 victims were officially reported, and as many as 60 victims in 1997. Both the government of the Czech Republic as well as central administrative bodies and naturally the Central Bohemian Region had to respond to the situation.

Experience from repeated disastrous floods in 1997, 2002 and 2006 raised increased social calling for implementation of system measures to provide protection and prevention against floods, and a forecast and warning service of the highest quality possible. In 2000, government of the Czech Republic approved Protection Strategy against Floods within the Czech Republic Territory, which has become the fundamental political document in protection against floods.

Anti-flood prevention has gained increased relevancy abroad, as well, specifically in the Federal Republic of Germany.

As part of the international programme and initiative Interreg III B, the Saxon Ministry of the Interior prepared the project ELLA (Elbe – Labe) “Preventive Anti-Flood Protection through International Land Use Planning Measures”. The project submitter chose the Central Bohemian Region, too, as one of regions hit by floods. The project was implemented in 2004 – 2006 and the Central Bohemian Region took an active part. Publication of Labe Atlas is the main outcome of the project.

In the joint declaration of the final conference of ELLA project, all 23 project partners agreed on the need to continue the steps that have been initiated, and to cooperate in the extension project in the grant period of 2007 – 2013.

The subsequent project LABEL (Labe – Elbe Vision) seeks to deepen cooperation of ELLA project partners and explores further also topics of economic development related to the river. The Saxon Ministry of the Interior is the leading partner again; out of Czech partners, Povodí Labe (Elbe River Basin Administration), Povodí Vltavy (Vltava River Basin Administration) participate besides Central Bohemian Region, and Ústí nad Labem Region, Pilsen Region, South Bohemian Region, Hradec Králové Region and Pardubice Region out of regional authorities. The project was created as part of the Operational Programme of International Cooperation, Central Europe Region, priority 3 – Responsible Use of the Environment – and is co-financed by the European Regional Development Fund.

Major activities of Central Bohemian Region consist in elaborating the Concept of Anti-Flood Measures in the Central Bohemian Region (working package No. 3 with 70.4% of the project budget planned for the package), furthermore Exploratory Study

to Evaluate Economic Benefits and Environmental Risks Connected with Improvement of Waterway Conditions in Elbe River.

LABEL project was commenced on 1 Sept 2008 and its implementation should be finished on 29 Feb 2012.

The concept of anti-flood protection in Central Bohemian Region is one of the major project outputs and shall contribute to fulfilment of the global aim of LABEL international project.

### **Concept of Anti-Flood Protection in Central Bohemian Region**

In accordance with strategy of the government of the Czech Republic in anti-flood protection and in accordance with Resolution of Central Bohemian Region Representatives from 25 Feb 2008 in connection with Central Bohemian Region engagement in LABEL international project (Labe – Elbe Vision), the Concept of Anti-Flood Measures in Central Bohemian Region was elaborated in 2008 in order to apply a systematic approach, i.e. conceptual material with a coherent overview of anti-flood protection situation within the territory of the Central Bohemian Region, and including possible ways of handling this issue within the framework of anti-flood measures within the region's territory.

The project was aimed at evaluating the current situation of protection against floods and the condition of water regime of the landscape within the territory of the Central Bohemian Region, at determining weak points and defining aims of protection against floods, including a proposal of the implementation procedure. The concept of anti-flood protection implementation of the Central Bohemian Region stems from data analysis of the landscape water regime and incorporates essential definition of the anti-flood protection issues, characteristics of the territory, partial parts of river basin, essential approaches to anti-flood protection; it also characterizes today's security of settlements along major watercourses against floods and proposes procedures to arrive at a specific solution mode.

# CONCEPT OF ANTI-FLOOD MEASURES IN CENTRAL BOHEMIAN REGION (Order of Work)

## **Chapter A. Condition of Anti-Flood Protection and Landscape Water Regime**

### ***Hydrological data:***

Basic hydrological data characterize the watercourse in the relevant profile from the viewpoint of magnitude of N-year flows ( $Q_N$ ) and especially the ratio  $Q_{100}/Q_A$ , which is the ratio of flow with repetition probability once in one hundred years and average long-term yearly flow. The values  $Q_N$  and  $Q_A$  are provided in the table “N-Year Flows in the Watch Service Profiles”.

### ***River basin areas:***

Regulation of the Ministry of Agriculture No. 292/2002 Coll. providing for river basin areas, as amended by Regulation No. 390/2004 Coll. defines the following river basin areas in the Central Bohemian Region: Upper and Central Elbe River Basin, Upper Vltava River Basin, Berounka River Basin, Lower Vltava River Basin, and Ohře River and Lower Elbe River Basin. Essential information about individual river basins is provided in the table “River Basin Areas” and shown in the graphic form.

### ***Evaluation of rainfall-flow off relationships:***

The subchapter evaluates and shows in the tabular as well as graphic form individual partial influences with impact on the course, extent or dynamics of the flood and related anti-flood protection. These are especially as follows: The inclination conditions, soil conditions, land use, erosion threat, rainfall conditions, flow off conditions, dewatering of lands, and irrigation of lands. The values  $Q_{100}$  at stations were chosen to evaluate extreme flow off conditions, and their dependence function on the river basin area was set up. Jizera River basin, surroundings of Vltava River, Litavka River, Berounka River and Doubrava River were assessed as river basins most endangered by floods based on the analysis mentioned above.

## **Chapter B. Influence of Rainfall-Flow off Relationships on the Course of Flood**

### ***Evaluation of rainfall-flow off relationships in partial river basins of significant watercourses:***

Significant watercourses are defined by Regulation of the Ministry of Agriculture No. 470/2001 Coll. Their choice is based predominantly on hydrological criteria (area larger than 50 km<sup>2</sup>;  $Q_1$  higher than 10 m<sup>3</sup>/s). Other criteria include, for example, importance for anti-flood protection, ecological exceptionality or water handling.

Assessment is focused on defining areas with accelerated flow off and insufficient retention, places that limit flow capacity of watercourse beds and alluvial plains, places with excessive silting by floating debris, and on determining built-up areas unprotected or insufficiently protected against floods.

In order to define areas with accelerated flow off and insufficient retention, methodologies from plan proposals of river basin areas were used. Analysis of flow off conditions, risky land use and inclination conditions were used as resources. Under higher water conditions, narrowing of the flow capacity profile causes heading up of water, which then floods surrounding lands and buildings; partial or complete clogging by floating debris occurs with subsequent bursting of the object or obstacle.

Such points are usually represented by bridge objects, foot bridges, culverts, fences or product lines.

Extreme flow off situations in significant watercourses are caused in an absolute majority of cases by regional rain or snow melting. In general, the flood risk is composed of three parts – the hazard (defined by the course of flood lines), exposition (location of objects within flood zones), and vulnerability (how much the objects are predisposed to damage upon flooding). Assessment of the flood risk is shown by the density of residential flat units flooded during the proposal-based one-hundred-year flood (see Map B.III Density of Flooded Residential Flat Units in  $Q_{100}$ ).

Built-up areas flooded by floods of higher frequencies than floods with an acceptable total risk level are considered unprotected or insufficiently protected zones. The recommended protection level according to flood hazard repetition probability is proposed as follows according to the Plan of Major River Basins of the Czech Republic:

- Historical town centres, historical built-up zones –  $Q_{100}$ ;
- Continuous built-up zones, industrial premises –  $Q_{50}$ ;
- Dispersed residential and industrial built-up areas and continuous cottage built-up zones –  $Q_{20}$ ;
- Isolated objects – individual protection.

Unprotected or insufficiently protected built-up zones were defined over the maps of flood zones. The number of endangered inhabitants was determined by means of analysis, as well, i.e. the number of all permanent residents in the flood zone  $Q_{100}$ . Where flood lines were not available, the flood plan of Central Bohemian Region was used as a resource, which delimits endangered objects.

The number of endangered inhabitants was used as the fundamental criterion to include communities in the primary list of built-up areas unprotected against floods, namely the value of 50. Furthermore, the following facts were examined:

- Whether target protection of the community corresponds to the actual one (especially communities with dispersed built-up zones where target protection is on the level of  $Q_{20}$ );
- Whether even upon reaching target protection, the number of endangered inhabitants during  $Q_{100}$  is not higher than 100;
- How the flood plan identifies significance of the threat (in some cases, even communities with lower numbers of endangered inhabitants were then included in the list);
- Whether the community itself is interested in implementing anti-flood protection.

118 communities total were included in the primary list; the communities are provided in the table “Primary List of Communities Unprotected against Floods” and they are also shown in the map.

#### ***Assessment of rainfall-flow off relationships in partial river basins of small watercourses:***

Watercourses not selected as significant by Regulation of the Ministry of Agriculture No. 470/2001 Coll. are identified as small watercourses. Data of Agricultural Water Management Administration, which contain “Incidence of QN Flows in Central Bohemian Region in Basins of Streams and Small Watercourses in the Period of 1881 – 2003”, were chosen as the most suitable set of data to assess incidence of floods in small watercourses.

Besides historical approach, the approach of modelling flow off values based on final profiles of IVth order basins was applied, as well, to assess possible extreme flows in

small watercourses. The outcome of the method is represented by culmination flow in the final profile of each explored basin. In respect of the fact that the calculation included the concentration time, as well, the results can be interpreted truly as flow characteristics and their potential usability could be used also to dimension objects on the watercourse. According to the culmination flows, especially the southern part of the region in the Blanice River basin and Litavka basin and along Sázava River basin is characterized by possible incidence of the most endangered basins.

The majority of floods in small watercourses are usually caused by short-term torrential rains, while the flood flow off is affected by vegetation, inclination of the area, and characteristics of the bed and inundation.

***Water measurement stations:***

Data on water stages from water measurement stations are used by the flood watch service but also to elaborate hydrological and water management balances. Water stages are converted to flows by means of measurement flow curves. The table “Water Measurement Stations Characterizing Flows in Central Bohemian Region” shows the list of stations in the Central Bohemian Region and nearby surroundings that acquire flow data at present.

## **Chapter C. Extreme Flow Off Situations**

***Evaluation of the flood incidence hazard and possible damages:***

Floods cause damage due to their kinetic force and destruction by the carried materials, usually on upper watercourses with a relatively high gradient or by waterlogging upon long-term flooding of buildings and lands in alluvial plains spills.

Chapter C. categorizes individual flood types, together with stating specific cases and underpinning historical floods.

Flood types:

- Winter (spring) floods with snow melting
- Ice floods
- Summer floods due to permanent rain – floods that occur upon rather long-term intensive rainfalls; disastrous floods in July 1997 and August 2002 in the Czech Republic were of this type. High aggregate rainfall amounts fall out, which exceed retention capabilities of the basin capacity. Water thus cannot be captured in the basin and flows off. Worsening of the development is usually caused by large area extension of the rain.
- Summer torrential (flash) floods – caused by torrential rain. During several dozens of minutes up to few hours, rainfalls occur within a locally limited area, which exceed even 100 mm. Sharp, short-term flooding of small brooks is the consequence. The hazard follows especially from the very rapid situation development.
- Special floods – floods occurring in connection with hydrotechnical facility accidents; bursting of ponds or dams is concerned most frequently.

***Significant historical floods:***

Historical floods have been processed into a summary of the most important flood conditions (see Table “Summary of the Most Significant Flood Conditions”) and completed with hydrograms of the most important floods in selected profiles of the Central Bohemian Region.

## **Chapter D. Targets of Protection against Negative Flood Consequences**

This chapter determines the goals that should be achieved in the field of increased protection against floods. In the target condition, the protection degree of endangered built-up areas should correspond to the design degree, which shall be determined as the value of acceptable total risk level of flood consequences.

Comparison of the present and target flood protection degree is shown in the table "Present and Target Protection of Communities".

### ***Anti-Flood Protection Strategy Principles:***

The document Strategy of Protection against Floods in the Czech Republic (Resolution of the government of the Czech Republic No. 382 from 19 Apr 2000) is the fundamental document, which formulates the framework of specific procedures and preventive measures aimed at increasing system anti-flood protection. Irregular incidence and variable extent of floods have an adverse effect on systematic implementation of preventive measures. As for the Czech Republic, floods represent the highest direct hazard in the field of natural disasters, and may also be the cause of serious critical situations, leading not only to extensive material damage but also human casualties among inhabitants of affected areas, while large-scale devastation of cultural landscape occurs including ecological damage. Master anti-flood protection aims is outlined by the Plan of Main River Basins in the Czech Republic in the field of legislative and economic instruments, preparation of flood plans etc. Fulfilment of principles to increase river basin retention capacity is a priority in anti-flood protection. However, this is a long-term task, to which attention is paid in conceptual materials of individual departments.

### ***Forecasting and flood watch service:***

The forecasting service informs flood bodies of the possibility of flood incidence and its possible parameters; the service is provided by the Czech Hydrometeorological Institute. The watch service is implemented by means of watch profiles of the flood service stated in the table "Watch Profiles of Flood Service in Central Bohemian Region".

### ***Affecting of the flood course and extent:***

The course and extent can be affected to a certain level only, in two ways in principle – by changing the land use and by means of retention spaces of polders and water reservoirs. This is a rather long-term aim, which shall be fulfilled gradually by changing the land use based on knowledge of erosion hazard and accelerated flow off risk. Large water reservoirs – Vltava Cascade – have an effect on Vltava River flows within the entire territory of the Central Bohemian Region. However, they do not provide absolute protection against floods even upon using all retention volumes, as was the case during the flood in August 2002, for example. Elbe River, Berounka River, Sázava as well as Jizera Rivers are uncontrollable from the viewpoint of flood flow management.

### ***Limitation of potential damage and exposure of inhabitants:***

The Directive of the European Parliament and Council 2007/60/EC from 23 Oct 2007 providing for assessment and management of flood risks determines the main framework for this purpose, with the aim to reduce adverse effects related to floods, while the flood risk means a combination of flood incidence probability and possible adverse effects. Membership countries shall finish preliminary assessment of flood risks until 22 Dec 2011. Based on the preliminary assessment of flood risks, areas of potential significant flood risks shall be determined, for which maps of flood hazard

shall be made. Flood hazard maps shall include geographic areas that may be flooded according to three scenarios:

- Floods with low incidence probability (probably  $Q_{500}$  for the Czech Republic)
- Floods with medium incidence probability ( $Q_{100}$ )
- Floods with high incidence probability, as the case may be.

Based on preliminary assessment of flood risks, membership countries shall elaborate maps of flood risks and flood hazards until 22 Dec 2013.

Flood hazard maps for  $Q_{100}$  are shown in Chapter G.4.

#### ***Flood plans:***

Flood plan is a document that contains the way of providing timely and reliable information on the flood development, way of providing timely protection of objects, preparation and organization of rescue works and provision of fundamental functions of impaired basins.

Flood plans are elaborated on the following levels:

- Flood plan of the Czech Republic
- Flood plans of administrative regional districts
- Flood plans of administrative districts of communities with extended powers
- Flood plans of administrative districts of communities endangered by floods
- Flood plans of property owners endangered by floods.

#### ***Costs of anti-flood protection measures:***

Catalogue of Measures elaborated by the company Vodohospodářský rozvoj a výstavba, a.s. (Water Management Development and Construction, joint-stock company) was used to estimate implementation costs of measures proposed by the concept author. The Catalogue of Measures has been conceived as a methodological guide in processing the Plan of the Main River Basins and River Basin Area Plans.

Costs of anti-flood protection measures are shown in relevant cards and in the summary table "Summary of Proposed Measures".

#### ***Flood prevention programmes:***

Implementation of the strategy is fulfilled by means of programmes of charged departments as part of programme financing, especially as follows:

Programme of the Ministry of Agriculture 129 120 Flood Prevention Support II

The main goal of programme stage II consists in further reduction of the threat level and flood risks in inundation zones of watercourses. The programme is focused especially on implementation of such measures that deal with the flood hazard in the most risky localities along watercourses, while preferring those areas where anti-flood measures shall bring the highest effect.

The operational programme The Environment under control of the Ministry of the Environment is focused on improving quality of the environment as one of fundamental principles of sustainable development.

Countryside Development Programme of the Ministry of Agriculture and Landscape Care Programme of the Ministry of the Environment are supplementary programmes.

## **Chapter E. Flood Protection Measures of the Area**

#### ***Watercourse bed capacities:***

Watercourse bed capacity is characterized by N-year value of the flow, which does not spill over yet. Natural capacity of the beds is usually found around  $Q_1$ , which is



not suitable for built-up areas. Modifications of watercourse beds in order to increase their capacities have been proposed predominantly in cases where local problems exist, which stem from narrow necks on the watercourse and insufficient transversal profile. Summary of the proposed measures is shown in the table "Summary of Measures to Increase Watercourse Bed Capacities".

***Inundation zones:***

Inundation zones are administratively defined zones that may be flooded upon incidence of a natural flood. The water management authority is obliged to determine their extent based on proposal of the watercourse administrator (Section 66 of the Water Act). In accordance with Regulation No. 236/2002 Coll., the proposal of inundation zones shall be elaborated for the natural flood with periodicity of 5, 20 and 100 years. At the same time, an active zone of the inundation area (zone that removes the decisive part of the total flow during floods, thus posing an immediate threat to lives, health and property of inhabitants) is delimited in built-up areas and areas intended to be built up based on land use plans. Based on Regulation No. 470/2001 Coll., as amended, 2299 km total of significant watercourses are found within the Central Bohemian Region. As at 30 Jun 2008, inundation zones were determined in 1407 km total of significant watercourses; and inundation zones were proposed but not yet determined for others in the length of approximately 330 km. Summary of the proposed inundation zones is shown in the table "Proposed Inundation Zones"; summary of determined inundation zones is provided in the table "Determined Inundation Zones".

***Areas designated for spills:***

Amendment to the Water Act from 28 Jun 2008 in Section 68 defines that zones designated for controlled spills of floods shall be those lands, which are necessary for heading up and/or accumulation of ground water by community service constructions to provide protection against floods, whose ownership right has been limited by means of agreement or procedure pursuant to Section 55a. Pursuant to Section 55a, rights in lands and buildings necessary to execute community service constructions to provide protection against floods can be withdrawn or limited by means of procedure pursuant to the Expropriation Act. Lands designated for controlled spills of floods have not been defined in the Central Bohemian Region yet.

***Areas protected against floods:***

During the past decade, increased attention has been paid to protection of built-up areas against floods in the Czech Republic, which had been caused especially by disastrous floods in July 1997, August 2002 and 2006. Currently, maximum attention is focused on strengthening prevention against floods by means of implementing efficient anti-flood measures to reduce flood risks. A rather larger number of events have been implemented in the Central Bohemian Region as part of the subprogrammes 229 062 and 229 063; the most significant ones are shown in the table "Events Implemented Under the Programme 229 060".

***Proposal of anti-flood measures:***

Reduced exposure of inhabitants and limited exposure of property and other values in priority-based application of the prevention principle is the long-term aim in protection against floods.

Primary measure is represented by not building up inundation zones and by supporting suitable land use; other factors that reduce the range of flood damage are as follows:

- Timely information on hydrological situation development
- Affecting the course and extent of floods by means of landscape measures

- Adopting structural measures to reduce the probability of flood incidence and the impact of floods
- Limitation of potential damage by determining inundation zones.

Proposal of technical measures in communities that have been determined to be unprotected or insufficiently protected against floods stems from available resources of the communities or watercourse administrators. In cases where the community had no studies or projects elaborated, master proposals were elaborated based on local investigation, together with mapping and estimation of costs. A card was made for each community, which, besides basic identification data, the total number of inhabitants exposed in the event of  $Q_{100}$  and protected by implementation of the proposed measure, potential flood damages and costs of the measures, contains description of the present and proposed condition, conclusion with recommendation of further procedure, and priority for the Central Bohemian Region. The card is completed with a map showing the measure proposal and a record from the local investigation if performed. If project documentation has been made for the community, discussed with the community representatives and adopted to the measures programme, no local investigation was performed.

## **Chapter F. Summarization of Results and Determining of Priorities**

### ***Description of flow off conditions:***

Flow off conditions in the Central Bohemian Region are affected by river basins situated in higher elevations in the areas of the South Bohemian Region (Vltava River), Pilsen Region (Berounka River), Hradec Králové Region (Elbe River), Liberec Region (Jizera River), and Vysočina Region (Sázava River).

Analysis of rainfall-flow off relationships was performed in Chapter A.2; their impact on the course of floods was discussed in Chapter B. It follows from their conclusions that Jizera River and Litavka River basins, surroundings of Vltava River and Berounka River and Doubrava River basin are most endangered by floods. Medium relative hazard can be expected in the basins of Sázava, Želivka, Cidlina Rivers and in the surroundings of Elbe River; average hazard can be expected, for example, in Mastník, Vrchlice, Blanice, Výrovka, Loděnice and Vlkava Rivers. From the viewpoint of floods in small watercourses, Sázava Region and adjacent parts of the basins and the Brdy Region are most endangered.

### ***Determining of priorities:***

Especially risks in inundation zones were analyzed within the framework of the concept from the viewpoint of the number and types of flooded objects including flooding depth categories in  $Q_{100}$ . The priority proposal of the need of anti-flood measures implementation was set up considering the need of minimizing flood damages in strongly affected areas. These are especially events that are determined as priority areas of the Plan of the Main River Basins of the Czech Republic and events incorporated by watercourse administrators in the proposal of stage II of the Anti-Flood Prevention Programme of the Ministry of Agriculture. Besides, the highest priority has been assigned also to measures that shall provide immediate protection of inhabitants during floods (for example, establishment of evacuation routes).

Events classified in category 1 – 3 of measures implementation priority are shown in the tabular form (see Table “Events Classified in Category 1 – 3 of Measures Implementation Priority”).

## **Chapter G. Risk Analysis**

### ***Economics of anti-flood measures:***

Methodology to assess anti-flood measures has been developed by the Faculty of Architecture, Czech Technical University in Prague, and serves to decide on whether grants should be awarded from the Anti-Flood Prevention Programme II. The cost and benefit method is used to assess the events, while benefits are assessed using the risk analysis method. Assessment of events of the programme “Anti-Flood Protection – Stage II” concerns predominantly constructions whose purpose is to prevent flood damage, and studies, which are intended to assess protection of the area against high water. The aim of this assessment is to form an objective and transparent procedure, which shall make it possible to classify individual projects based on their technical and financial effectiveness. The cost and benefit method is used to assess the events, while the benefits are assessed using the risk analysis method.

The flood risk shall be enumerated for the condition before implementation of the measures and after their implementation, and in general, it depends on the amount of flood damages and on the probability of their incidence based on the relationship:

$\text{Risk} = \text{Damage} \times \text{Probability of Damage}$

All realistic combinations of the amount of damages and their probabilities, starting from flows in which the damages start to occur up to extreme flows whose probability is negligible, must be considered in calculating the flood risk. Calculation of the average flood risk per one year is the result of this analysis.

### ***Register of localities unprotected against floods:***

A layer of buildings in the register of counting districts of the Czech Statistical Office was used to analyse objects in the inundation zone  $Q_{100}$ .

Summary inundation indicators:

- Total number of objects (i.e. buildings) in the community;
- Objects found in the flood  $Q_{100}$ ;
- Total number of residential units in the community;
- Residential units found in the flooded community objects;
- Number of exposed inhabitants in the community (number of inhabitants as at 1 Jan 2008).

The table “Inundation Depth” shows the number of flooded objects with the extent of their inundation depth.

### ***Estimate of flood damages in exposed localities and their summary:***

Estimate of potential damages was performed based on the risk analysis – depth and number of flooded objects, their way of use, and area characteristics. Potential flood damages are presented in the tabular form.

### ***Flood hazard maps for $Q_{100}$ :***

Floods represent a natural phenomenon, which cannot be prevented, while certain human activities (building up of inundation zones, reducing natural retention capacities of the soil) and change of the climate contribute to increased probability of their incidence. Floods can cause human casualties, damage to the environment as well as infrastructure, they can reduce economic activities and cause further negative phenomena with impacts on the human psyche. Directive 2007/60/EC providing for assessment and handling of flood risks is therefore aimed at contributing to implementation of such measures, which would reduce flood risks and risks of damages. Flood hazard maps shall show areas inundated by floods, together with

stating the extent of the flood, water depth and/or flow speeds or the corresponding flow rate.

Appendix to this chapter contains flood hazard maps for  $Q_{100}$  elaborated for the primary selection of exposed communities in the Central Bohemian Region where the inundation zones have been determined.

## **Chapter H. Conclusion**

### ***Summary of results:***

Chapter A describes rainfall-flow off characteristics of the area including hydrological data and evaluates rainfall-flow off relationships.

Chapter B evaluates the effect of rainfall-flow off relationships on the course of floods in significant watercourses as well as in small watercourses. At the same time, critical points on the watercourses – narrow points – are defined here, and built-up areas are determined, which are unprotected or insufficiently protected against floods. The primary selection contained 122 communities.

Chapter C determines the hazard of flood incidence and possible damages and assesses significant historical floods.

Chapter D determines aims of protection against floods for individual communities that have been included in the primary list and are reviewed further by the concept. Based on comparison of the existing and target protection, 115 communities were included in further examination. Furthermore, principles of the strategy of protection against floods are described, as well as anti-flood prevention programmes.

Chapter E proposes measures of protection of areas against floods; proposal of measures in the form of individual measure sheets – cards, completed with a record from the local investigation and photographic documentation is the pivotal document. The proposal is described and schematically drawn in the map with a suitable scale. The card includes basic data, as well – total number of inhabitants; out of that, numbers exposed and protected by implementation of the proposed measure; estimate of potential flood damages; and estimate of the measures implementation costs.

Chapter F determines implementation priorities of the proposed measures for the Central Bohemian Region based on summarization of the results.

Chapter G contains a general description of economic assessment of anti-flood measures and an analysis of inundation zones in  $Q_{100}$ , which was used to create flood hazard maps, register of localities unprotected or insufficiently protected against floods, and a resource to estimate flood damages.

The table “Resulting Proposals and Their Parameters” shows the resulting proposals, executed based on the inundation zone analysis and local investigation. All proposals are localized in the basins of major watercourses of the Central Bohemian Region – Elbe, Vltava, Jizera, Berounka and Sázava Rivers.

### ***Recommendation of further procedure:***

The highest number of exposed inhabitants is found in the Elbe River basin (10241) where, however, anti-flood measures are found in an advanced preparation stage or under construction (Hořín) in ten localities. Implementation of these events shall achieve target protection of 5161 inhabitants.

6146 exposed inhabitants total are found in the Vltava River basin; measures are already being prepared for Kralupy nad Vltavou and Štěchovice with 3451 exposed inhabitants total.

32 localities total with insufficient protection against floods are found in the Berounka River basin, and 6409 exposed inhabitants total were identified in the localities. Anti-flood measures are under preparation only in Beroun and Králův Dvůr on Litavka River; the greatest problems still persist in communities found directly on Berounka River where dense recreational built-up area is found, largely used as permanent residence objects.

13 communities are found in the Jizera River basin with the total of 3625 exposed inhabitants; measures in Vestec and Benátky nad Jizerou are under preparation.

7 communities total have been determined in the Sázava River basin, protected insufficiently against floods, with 942 inhabitants.

It follows from the summaries above that further attention should be paid to the Berounka River basin where feasibility studies should be made for the exposed localities, and attention should be devoted especially to Černošice town where 774 permanent residents are exposed based on data of the Czech Statistical Office; in reality, their number may be up to double.

In conclusion, it must be emphasized that a clearly efficient protection against floods caused by the hydrological regime of watercourses consists in respecting the borders of inundation zones as the limit for built-up areas, and/or gradual removing of existing built-up area objects from inundation zones.

**This project was supported by European Regional Development Fund and the budget of Central Bohemian Region.**