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WP 3.3 THE ELBE CASE STUDY BASIN

TRAINING AND DISSEMINATION WORKSHOP REPORT

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1 Introduction

The Elbe River basin covers large parts of two countries - the Czech Republic and Germany. About 2/3 of the drainage basin area (148,268 km²) is located in Germany (96,932 km²), and 1/3 - in the Czech Republic (50,176 km²), and a negligible part of the basin is located in Austria and Poland. The basin covers different geographical regions from middle mountain ranges in the west and south to large flatlands and lowlands in the central, northern and eastern part of the basin. About 25 million inhabitants live in the basin, therein 76% in Germany.

The river basin is used for various purposes. Agriculture areas occupy 56% of the drainage basin, and 25% are covered by forest. The industrial sector uses the largest amount of river water (about 70%), followed by the agricultural sector and the water withdrawals for domestic use (both about 15%). The water management in the whole Elbe basin is well developed and has a good potential to introduce Integrated Water Resources Management. However, cross-sectoral and transboundary co-operation should be substantially improved [1].

The Elbe River is experiencing all three major water-related problems [2], [3]: having too much of water from time to time (floods), too little of water often in summer season (droughts), and having water of inadequate quality. In the recent years, extreme hydrological situations were observed on the Elbe - a destructive flood in August 2002, and a severe drought in 2003. Besides, the Elbe is a major contributor of nitrogen and phosphorus loads to the Northern Sea.

The goals of the stakeholder process in the Elbe basin are manifold, from participative definition of the major research issues in the basin, through collaboration on specific problems in three selected subbsins Rhin, Jizera and Malse-Rimov, to the discussion of specific topics related to NEWATER objectives (IWRM, uncertainty, adaptive management) at the stakeholder workshops. The most important stakeholder workshop in the Elbe case study was the Workshop on “Perception of Uncertainty in Water Management by stakeholders and researchers” held in Prague 14-16 of May 2007. This Report is devoted to the description of the main results of this Workshop.

2 Objectives of the Workshop

The Workshop was focused on uncertainties in water management related to flood protection and management of water quality. The objectives of the Workshop were the following:

- to inform stakeholders about state-of-the-art research concerning flood protection, water quality and climate change and related uncertainties, and about ongoing research projects in the Elbe basin,
- to discuss the ways and strategies to cope with uncertainties in flood management and water quality management in the Elbe basin, and
- to discuss the role of research in coping with uncertainties in water management.

The following two major questions were discussed during the group discussions at the Workshop:

1) What are the realistic ways / strategies to cope with uncertainties, or to reduce uncertainties: in flood protection (also in view of climate change), and in management of water quality?
2) What is the role of research in coping with uncertainties in water management? What should research do in order to better support water managers?

3 Organisation of the Workshop

Plenary sessions and group discussions. The Workshop was organized as a combination of plenary sessions (12 invited presentations) in the morning, and afternoon discussions in two monolingual break-out groups:

(1) Czech stakeholders + scientists,

(2) German stakeholders + scientists.

Two groups discussed the same issues of uncertainty.

Languages. Presentations during the plenary sessions were in English, with simultaneous translation to German and Czech. Questions and comments were possible in English, Czech and German. The group discussions were held in Czech (group 1) and German (group 2). During the group discussions an individual translation was provided for participants not speaking German or Czech by the Elbe team members.

Issues of uncertainty for group discussions. The invitations to the workshop were send in December 2006, accompanied by a request to suggest issues for discussions during the Workshop. Besides, during the preparatory phase, several interviews with stakeholders in Czech Republic and Germany were conducted. As a result, major issues (sources) of uncertainty in flood management and in water quality managements were revealed via personal or group interviews, or via questionnaire responses by stakeholders and invited scientists before the workshop and suggested for group discussions at the Workshop (see Table 1).

Table 1. Issues of uncertainty for the group discussions

	Day I: Flood management
F1	Real-time flood forecasting
F2	Assessment of design flood with a certain return period
F3	Risk mapping and uncertainty in estimation of flood damage
F4	Uncertainty in climate change projections (especially for precipitation)
	Additional question: Communication of uncertain scientific results to decision makers and stakeholders. The role of international and interstate cooperation.
	Day II: Water Quality
WQ1	Uncertainty in estimation of point and diffuse sources of pollution
WQ2	Indicators of water quality and water quality standards
WQ3	Implementation of Water Framework Directive
	Additional question: Communication of uncertain scientific results to decision makers and stakeholders. The role of international and interstate cooperation.

The Issues of uncertainty F1 – F4 and WQ1 – WQ3 were described in advance (see Appendix 1), and the text was translated to German and Czech and given to the participants in advance to provide a basis for discussion. The uncertainties in flood management and water quality management were explained from the point of view of state-of-the-art science. The aim was to clarify during the discussions, whether stakeholders recognize all these uncertainties and deal with the same or different uncertainties in their daily operational work in water management.

4 Results of the Workshop

The first objective: to inform stakeholders about state-of-the-art research concerning flood protection, water quality and climate change and related uncertainties, and about ongoing research projects in the Elbe basin, was reached through presentations of key-note speakers on specific themes related to the Workshop topic. The themes are listed in Table 2.

Table 2. Presentations of key-note speakers at the Workshop plenary sessions

Lecturer(s) (institution)	*Title of the presentation*
Daniela Jacob (MPI-M, Hamburg)	European climate change projections – global climate change with local impact
Pavel Kabat (ESS Wageningen)	Climate change impact on water resources in Europe
Keith Beven (Uppsala University)	A nonstatistical perception of uncertainty in hydrological models
Zbigniew Kundzewicz (PIK, Potsdam)	Managing uncertainty in flood protection
Annegret Thieken (GFZ, Potsdam)	Comparison of different approaches for flood damage and risk assessment
Claudia Pahl-Wostl (USF, Osnabrück)	Adaptive management approaches to cope with complexity and uncertainty in water management
Sabine Möllenkamp, Britta Kastens (USF, Osnabrück)	River basin management meets climate change – Investigating institutional adaptation in the Elbe basin
Van der Sluijs (Utrecht University)	Uncertainty communication: issues and good practices
Marcela Brugnach (USF, Osnabrück)	Towards a relational concept of uncertainty: concepts and implications
Sarka Blazkova (T.G.M. WRI, Prague)	An overview of the Czech national Labe project
Frank Wechsung (PIK, Potsdam)	An overview of the German national GLOWA-Elbe project
Fred Hattermann (PIK, Potsdam)	Modelling of climate change impacts on hydrology in Central European river basins including uncertainty

The presentations can be found on the Elbe CS webpage of NeWater: http://www.newater.info/everyone/3045.

The second and third objectives: to discuss the ways and strategies to cope with uncertainties in flood management and water quality management in the Elbe basin, and to discuss the role of research in coping with uncertainty in water management, were realized in the group discussions. The suggested ways and strategies to cope with uncertainties and the role of research it the coping with uncertainties will be shortly outlined below following the sequence of issues listed in Table1.

F1: How to reduce uncertainties and cope with uncertainties related to Real-time flood forecasting

Uncertainties in data. *The uncertainties in data obtained from water measurements and precipitation stations have strong impact on the quality of hydrological forecasts*. Generally, incorrect forecasts may result from to the following:

- Flawed design of the hydrological and precipitation monitoring networks resulting in non-representative data;
- Problems in the monitoring network: usually measurements of snow depth and snow water equivalent are done only in open spaces and not in forested areas, and the network of measurement points is not sufficiently dense in mountainous and foothill areas;
- Specific weather conditions: formation of ice on streams.

In order to improve the quality of measured data, the following should be safeguarded:

- each network of hydrological and precipitation monitoring stations should be designed according to exact criteria, and the data obtained should be verified using hydrological forecasting models;
- sufficient number of measurements and sufficient volume of data on snow cover should be obtained from forested areas and from areas with rugged topography;
- precipitation data obtained from the network of precipitation stations should be combined with data obtained by radar measurements while adjusting the radar estimates ahead of time by taking into account the systematic distance deviations.

Forecast lead time. *Expanding the length of the forecast lead time has its limits*. Ideally, flood forecast lead times should be as long as possible, in order to provide sufficient time to take necessary measures to limit the damaging effects of flood waves. When a longer lead time is required, the forecast calculations are based on precipitation-runoff models and meteorological forecast models. This involves uncertainties and is done at the price of a less precise forecast. Therefore, with the extension of the lead time the accuracy of the forecast decreases and the uncertainty increases.

Using models. Not every precipitation-runoff forecast model provides the same degree of reliability for different types of floods in different physical-geographic environments of individual watersheds. Therefore, the hydrologic forecasting service should have a number of different forecasting models available, and it should use only the model providing the most reliable results for the given watershed in flood situations.

Increasing the number of forecast models requires an overarching modelling system. The number of profiles included in the calculations increases when forecasts of larger floods are prepared. Therefore, the individual flood flows for each of the profiles are often forecasted using different forecasting models. This increases the probability of occurrence of model-related uncertainties, and requires additional assessment. In particular, if the forecasts for individual profiles form a consecutive time sequence, the forecasting operations need to be coordinated by means of an overarching modelling/assessment system.

When increase of the lead time is needed, the increased *uncertainty can be reduced by the use of adaptive modelling*. This method consists of using repeatedly and in shorter time intervals the already known variations between the observed and the forecasted values for increasing the accuracy of long-term forecasts.

For the cases when longer lead times than those achievable by deterministic models are needed, *probability models could be used in real time forecasting* (tests are now being conducted in the USA and in the Czech Republic).

Flood zone forecast. Flood zone forecast requires accurate data on stream bed geometry and topography of the adjacent areas. Flood zone forecast is one of the final products of the forecasting services provided by the flood protection service. For that a number of distributed hydraulic models are used. Their application requires accurate data on stream bed geometry and on the topography of the adjacent areas. The modelling results respond very sensitively to the accuracy of these data. The uncertainties related to calibration and to the use of low-resolution topographic data can be reduced by using higher-resolution data.

Flood zone forecast can be improved and uncertainties reduced by using higher-resolution data on stream bed geometry and terrain topography. The uncertainty of model-based overflowing forecasts needs to be analysed by comparing the forecast data with the high-water level marks from previous floods.

Floods in the small watersheds and in the hilly landscapes. Floods in small watersheds cannot be detected by the national forecasting system. For municipalities located in small watersheds, which are or can be in danger of a sudden flood wave, there remains a likelihood of an unexpected flood that cannot be detected by any national or large-area forecasting or warning system. Also the radar measurements (although they are able to identify the nuclei of heavy-rain formations) still cannot provide information about the torrential rain events.

In small watersheds installing an automatic warning system (alert system) with a link to a permanently staffed service centre (fire-fighting station, police etc.) can be a good solution. Based on an alert signal when the threshold precipitation limit or water limit is exceeded, the relevant service can warn the population at risk.

Flash floods in hilly landscapes may result in enormous erosion. In the small hilly watersheds unsuitable farming activities (growing of corn, potatoes, etc.) may result in enormous erosion in case of flash floods. As a result, buildings and other facilities in flood-impacted municipalities may become destroyed. In this case, local warning system is not helpful for solving the problem.

The uncertainty regarding flood hazards (soil erosion) in small hilly watersheds with unsuitable farming activities can be eliminated by adopting preventive, mostly structural (i.e. requiring investments) measures and by achieving an agreement between the relevant farmers and the municipality.

The role of research in coping with uncertainties was outlined as follows:

- focus on the development of forecasting methods for difficult flow situations, in particular for the situations with formation of ice,
- development of adaptive modelling methods and probability models for application in real time flood forecasting, especially when an increase in the lead time is required,
- better validation of the flood zone forecasts using historical flood data,
- spatial and temporal accuracy of flood forecasts has to be improved,

- practice oriented research projects are more useful for stakeholders, and should get higher priority in funding.

Role of communication. Uncertainties related to the flood forecasts should be communicated to stakeholders and inhabitants, people should not believe in exact numbers, they have to be aware about involved uncertainties and should not expect exact forecasts. The model-related uncertainties have to be discussed by stakeholders and modellers.

F2: How to reduce uncertainties and cope with uncertainties related to Assessment of design flood

Data. Hydrologic design data are an indicating and indispensable type of information required for water management, planning, construction and operational projects. Usually data describe the maximum flood rates characterised by the average probable repeat time (or so-called return period). Sometimes such estimation is needed for the non-gauged profiles, which by themselves are highly uncertain. *The main source of uncertainty is usually relatively short time series of historical data in comparison to the return period to be estimated.* For example, recently the safety requirements in some European countries associated with some waterworks that need to be protected against extreme floods were modified. This resulted in the requirements to calculate design flood rates with the return period of up to 10,000 years. It is clear that such estimates will be highly uncertain.

Using models. *Both statistical and deterministic models involve uncertainties.* In the extrapolation methodology the model-based approach is starting to prevail. The methods include not only statistics-based approaches, but also deterministic models based on transformation of extreme precipitation into a theoretical design flood wave in the given physical-geographic environment, sometimes in a hydrologically not-observed watershed. One of the disadvantages of the statistical approache is that the assumption that an N-years maximum precipitation will cause an N-years maximum flood may not always be correct. The deterministic models also involve uncertainties from different sources.

The deterministic models have an apparent advantage that their outputs can be verified by comparison against flood waves that actually occurred. However, this is valid only for the gauged watersheds and for the cases of floods with a higher probability of occurrence (e.g. 10-years flood). However, for non-gauged watersheds as well as for extremely large floods a number of assumptions must be accepted, bringing a number of uncertainties into the design flood wave calculation. Then the overall uncertainty will include the following partial uncertainties resulting from:

- inaccuracies in determining physical-geographic characteristics,
- assumptions concerning precipitation distribution in time and space,
- uncertainties in the model's ability to simulate flood response,
- effects of changes in land use and human interventions into the watershed's hydrological processes,
- anticipated climate change.

Estimation of maximum precipitation contributes to the quantification of flood risks. In the past few years, a new method of calculating probable maximum precipitation (PMP) and the related probable maximum flood (PMF) has been developed and applied in a number of countries (USA, China, the Czech Republic, etc.). In the Czech Republic PMP values were calculated for the entire territory of the country using recorded precipitation peak values. This new process contributes to the identification of uncertainties connected to the analysis of flood risks.

Modelling results are probabilistic in nature. The development of models for determining design flow rates has brought a number of advantages as well as new uncertainties. For example, different sets of parameters may yield almost identical results, and the model results are dependent on input data and their accuracy. For this reason evaluation of the model uncertainty related to input data and parameters is needed. For the verification of the model outputs other information from the watershed, such as seasonality of floods, precipitation and snow fall records, flow rate duration line should be used. The comparison of design flow rates from the same watershed obtained by different methods also provides an ambitious opportunity. Despite of all advantages of the modelling method, the obtained design characteristics will continue to be probabilistic, and they should be treated accordingly.

Possibilities of decreasing uncertainties in determining the theoretical design floods are the following (the role of research is also indicated):

- Misinterpretation of the influence of factors in the physical-geographic environment can be reduced to a certain extent by a competent use of the GIS tools;
- The uncertainty in spatio-temporal distribution of precipitation can be decreased by applying sufficiently long time series of precipitation data, appropriate climate interpolation methods, and a deep understanding of meteorological processes during which extreme precipitation with N-year return period occurs (research);
- The model ability to simulate runoff response can be partially verified on historical flow rate waves (research), which are recorded in a case study or in a similar watershed;
- The influence of human interventions must be studied using modelling approaches that take them into account (research). It is possible to adjust the model parameters on the basis of collected data and according to the anticipated future development scenarios;
- According to the conclusion IV of the IPCC report (International Panel on Climate Change), the intensity and frequency of floods will increase in most European regions with 66 – 90% probability. For this reason it is necessary to examine the effect of climate warming on changes in precipitation and runoff processes on the watershed scale using appropriate models and available regional scenarios of climate change and land use change (research). The reliability of design flow rates calculated on the basis of these scenarios will be to a large degree dependent on the probability of these scenarios.

Besides, some site-specific recommendations for the Elbe basin were made:

- historical data on previous floods should be carefully analyzed in order to reduce uncertainties in flood management,
- statistical estimation of extreme hydrological values for the Elbe should be done also for the lower part of the basin,
- when flood protection is considered, the Elbe river basin should not be divided into parts using an arbitrary approach (e.g. based on administrative boundaries), but a common strategy across state and administrative boundaries should be used,
- uniformly estimated water levels for 100 years flood (HQ100) are necessary for all German states (Länder).

F3: How to reduce uncertainties and cope with uncertainties related to Risk mapping

Floods and damage. Regional type floods on large watersheds do not exhibit evenly spread damages. As a rule, the built-up areas in alluvial floodplains and in narrow mountain valleys are under the greatest danger. In addition, the influence of uneven precipitation due to orthographic effects or funnel shaped relief can increase the effects of flood damages. In winter, during the ice formations, floods can occur even when flow rates are low, especially in areas where conditions are susceptible to ice jams.

The uncertainties connected to flood protection in individual small watersheds are increased by the occurrence of flash floods from rain storms covering only small areas. However, the recording of such localised cases shows the existence of larger areas for which an increased frequency of flash floods is typical.

European Union mapping of flood risk areas. The European Union has reacted to the unsatisfactory situation in mapping of watersheds with respect to flood danger. The main goal of the proposal of the European Parliament and Council Directive about flood risk evaluation and mitigation is to conduct a preliminary evaluation of flood risk, create flood risk maps and subsequently to prepare plans for flood risk mitigation. The proposal gives the following tasks to the individual Member States:

(1) to put in effect legal and administrative regulations necessary for reaching compliance, at the latest, within two years from the date on which the Directive takes effect,

(2) to complete preliminary risk evaluation by 2011,

(3) to prepare flood danger and flood risk maps by 2013.

Flood danger mapping. These maps should record the spatial extent of flood areas corresponding to flood flow rates with a low, medium and high probability of occurrence. In the Czech Republic, the so called “active zone”, i.e. a bank where any kind of construction or business activity is prohibited, is also delineated as a part of a flood area. As an optional feature these maps can also include the recording of flood depths and the water speed during flood flows.

Flood risk mapping. This type of map indicates the number of inhabitants potentially endangered by individual type of flood, types of endangered commercial activities, pollution sources defined by Directive 91/61/EC and some categories of protected areas selected according to Directive 2000/60/EC that can be affected by floods. Completed maps will be a part of regional plans, and they will be taken into consideration during landscape development.

Mitigation and prevention of flash flood effects in small watersheds. This type of flood protection is comparable to those of large flood events, mostly with respect to the necessity of activating the smallest local governance units as well as inhabitants, which in such a situation cannot rely on the help of the state. In such cases it is necessary to try different variants of coordination, communication and cooperation as well as measures that must be included in the flood protection plans of individual municipalities.

Some site-specific recommendations for the Elbe basin were made:

- insurance agencies and firms should offer the combined insurances in order to reduce their risk and increase efficiency,
- some peculiar modern flood adaptation measures (like floating houses) do not make sense in the Elbe basin, flood and damage prevention measures (like extension of the floodplain area) are much more important,
- protection against floods using only technical control measures is not possible in the basin,
- extension of floodplain areas is necessary, but often it is not easy or not possible to realise; besides, experience shows that if more funding becomes available, money is often spent for building higher dikes, and not for the dike relocation or extension of floodplain,
- the stepwise approach of the Water Framework Directive should be also applied for the flood risk management.

F4: How to reduce uncertainties and cope with uncertainties related to Climate change projections

Gradual warming of the troposphere and the Earth's surface is a reality. This fact has been confirmed by the monitoring data and also by numerous identifiable changes in the physical climate system and in the system of biochemical cycles. The assumption that changes in temperature will be accompanied by changes in precipitation has already been verified by physical data.

Already now, analyses of precipitation records since the beginning of the 20th century show that there has been a spatially uneven increase in precipitation globally of approximately 2%. The increased evaporation caused by growing temperatures may cause imbalances in water circulation, which in turn can have negative impacts on precipitation patterns resulting in more frequent occurrence of extreme phenomena such as floods or very dry periods with no precipitation. When preparing a strategy for protection and defence against these negative climate changes, a number of uncertainties need to be addressed.

Uncertainties in the modelling of climate change. The circulation of water takes place in the context of a physical-climatic system that has a number of links and feedbacks to the system of biochemical cycles. A number of complex energy and material flows link the two systems. The resulting effects are usually non-linear and can be characterised by a high degree of spatial and temporal variations. The simulation of such a complex system using General Circulation Models (GCMs) involves many sources of uncertainties.

Uncertainties in GCMs. An improvement in the simulation capacity of GCMs will be achieved by introducing further monitoring programmes focusing on changes in climatic conditions, improvement of GCM parametrisations, and by using more detailed topography and other data on the global scale. With these improvements, it is expected that outputs obtained from multiple GCMs and based on different scenarios will be able to provide an indication of the direction of changes and the ranges of uncertainties we can expect. Given the fact that the current GCMs do not yet provide a sufficient level of reliability in projecting extreme climatic phenomena, the precautionary principle will have to be applied considering possible development scenarios. It should be also recognised that future climate changes may be faster than indicated by the current projections.

Uncertainties in regional climate modelling and hydrologic modelling of climate change impacts on the watershed scale. Although efforts to predict temporal development of climate in small geographic units using GCMs have not been successful, the Regional Climate Models (RCM) are under development. RCMs are developed on the basis of detailed regional information and GCM outputs. They may also use data analysing the conditions under which precipitation and runoff extremes occurred in the past. The largest uncertainty in implementing RCMs and in subsequent linking of hydrological models is the translation of phenomena from the macroscale to the mesoscale (individual watersheds). Decreasing uncertainties in RCMs will depend on the further development of the downscaling methods. Decreasing uncertainties in impact assessment will depend on the improvement of the ability of precipitation-runoff models to simulate the runoff response.

Integrated flood protection was suggested as a potential tool for decreasing uncertainties in the strategy against harmful effects of floods in changing climatic conditions. The modern flood protection, especially in view of the anticipated increase in flood frequency as a result of climate change, is forced to accept new paradigms – adapt to floods and living with floods. In practical terms this means that land along rivers will have to be set aside in order to widen the floodplains and to create retention basins for incidental inundation. However, in some European countries the spatial capabilities of widening floodplains are limited, especially in the case of narrow mountain valleys. Furthermore, the removal of buildings and infrastructure is a very difficult task, and in many cases it is practically impossible. Given these conditions, it is necessary to apply an integrated approach to flood protection, i.e. a combination of adaptative and preventive measures. Integrated flood protection must include a flexible system of structural and non-structural measures that can deal with unpredictable events.

The basis of prevention are *structural measures*, meaning an increase in the flexibility and efficiency of water management systems, changes in landscape set-up with the goal of increasing water retention, providing safe passage for flood waves, revitalisation of rivers and streams, construction of reservoirs, retention tanks, relief and runoff passages, limiting the degradation of water through contaminants, etc.

Non-structural, i.e. non-technical adaptive measures can be divided into:

a) *preliminary measures* (before the occurrence of the risk), such as modernisation and extention of floodplains, providing additional options for overflow in alluvial plains, enhancement of infiltration and retardation of water, agriculture practices reducing runoff, public education, development of forecasting and warning systems with the goal of increasing the lead time, etc.;

and

b) *reactive measures* (during the course of the risk), such as increasing the efficiency of water management structures in non-stationary conditions, efficient delivery of information and warnings to the populations at risk, model evaluation of flood waves and the extent of their overflow, timely evacuation of the public, post-flood recovery, etc.

Some site-specific recommendations for the Elbe basin were made:

- the accepted 15% “climate addition” for the new dikes in Thuringia seems to be an appropriate measure,
- a transition from flood protection to flood risk management strategy is needed in the Elbe basin,
- an integrated approach, or a set of different measures is needed for flood risk management, and the measures should be adjustable to expected climate change.
- the climate models should be linked to hydrological models in order to reduce uncertainty, and to take into account potential climate change impacts.

WQ1: How to reduce uncertainties and cope with uncertainties related to Estimation of point and diffuse pollution

Uncertainties in estimating pollution from point and diffuse sources and their shares in the river profiles of interest are connected with:

- the completeness of point source pollution databases created and used (complete description of all point sources of pollution, and the complete filling in of data for individual pollution sources and for individual water quality indicators),
- the frequency of measurements for the quality and quantity of discharged wastewater for individual point sources of pollution,
- the type of samples of discharged wastewater (e.g. Czech legislation allows a so-called 2-hour sample for municipal pollution sources not exceeding 2,000 EO in size),
- the accuracy of chemical analyses performed (individual laboratories are monitored by cross-checking at other laboratories),
- the method used for determining diffuse pollution sources (either by direct measurement in the watersheds without point sources, or by comparing pollutant loads from the watershed with samples of water discharged from the point sources of pollution),
- frequency of the conducted water quality monitoring (e.g. in the Czech Republic 12 or 13 samples are taken at regular intervals each year).

Water quality measurements in rivers. An assumption in processing the results of water quality measurements in rivers and streams is that the water quality samples are taken correctly and that they are also correctly analysed. The result of standard measurement of water quality in rivers and streams is typically a set of 12 to 24 water quality indicator values per year, and 12 to 24 values of water flow rates at the time of taking the sample.

With consideration of uncertainty related to point samples and the low frequency of taking samples during the year, the sample set of indicator values received is only an approximate picture of the basic set. All calculated statistical characteristics of the set (average concentration C_{pr}, average load from watershed LO_{pr}, values with probability of not exceeding 90% C_{90}) are thus burdened with a great degree of uncertainty.

Uncertainties in estimation of point source pollution. Information that would enable estimating the uncertainty of the point sources of pollution is usually not available (data are considered confidential and are published only reluctantly). If data on pollution discharge from point sources are correct (e.g. if 24-hour mixed sample is used, if the frequency is sufficient, and if the values are not underestimated for any reason), then the sum of such data carries – due to the law of large numbers – smaller uncertainty with the increasing number of sources. If small point sources of pollution with available records are of concern, the uncertainty of obtained data is not known and probably high, as the methods of measurement for small recorded point sources are unknown. If estimates of small unrecorded point sources of pollution are used, the uncertainty is high, as the unknown methods are used for estimation.

Uncertainties in estimation of diffuse sources of pollution. The diffuse sources of pollution could be determined either by direct measurement in the watersheds without point sources, or by comparing pollutant load from the watershed with the samples of water discharged from point sources of pollution.

In order to estimate the diffuse sources of pollution in a profile of interest, three assessment methods were developed in the Water Research Institute (Nesměrák 2003, 2007). All three methods are based on the comparison of the total load from the watershed with the pollution by discharges from point sources. All three methods are used to evaluate diffuse pollution in a large number of profiles in the Czech Republic. This eliminates a need to carry out direct measurements in streams without of point sources with subsequent extrapolation of results.

As the estimation of diffuse sources of pollution performed by a comparison between the total material transport from the watershed and the total load from point sources of pollution involves a high degree of uncertainty, approximately the same level of uncertainty is transferred to the apportionment of pollution sources into point and diffuse ones at the watershed scale.

During the discussion some important comments on the problem of estimation of water quality were made:

- available data on groundwater quality could be used to estimate diffuse source pollution, though uncertainties are high,
- gauging stations are not always properly located; all German states (Länder) have their own networks of measurements, and sometimes they are using different principles,
- there are huge uncertainties regarding statistical estimation of diffuse source pollution (e.g. by the model MONERIS),
- there are high uncertainties in pollution estimation during the flood events,
- environmental agencies in the German states (Länder) have no access to data of farmers about fertilization etc. (only estimates at the district level are available); more detailed data could improve estimation of diffuse pollution from agriculture.

The following specific recommendations for the Elbe basin were made:

- there should be an obligation to register and provide information about the amount of wastes (emissions) for all waste producers,
- the estimation of diffuse sources could be improved if the observational network would be dense enough, this is important but costly measure (could be not affordable),
- emissions from livestock farms should be limited (one option to estimate emissions is the number of animals per farm area, which should be restricted),
- a voluntary self-commitment of farmers on fertiliser application rates or manure use; or application of recommendations from the Nitrate Directive could be helpful for diffuse pollution control,
- training of farmers is important,
- access to data is very important (only modelling is not sufficient, especially if it based on poor databases),
- good agricultural practices should be used,
- biogas plants could be useful for reduction of diffuse pollution, though there are still some residues with high nutrient content that should be somewhere disposed,
- modelling can be helpful for estimation of diffuse sources, especially for large scale and for long time periods,
- estimation of diffuse sources using calibrated and validated water quality models coupled with hydrological catchment models could be helpful,
- models could be useful to fulfil the burden of proof (Beweispflicht) of the German states,
- support in optimization of the monitoring network would be useful,
- a joint use of monitoring data and modelling results by modellers and stakeholders (agencies) could be useful.

WQ2: How to reduce uncertainties and cope with uncertainties related to Indicators of water quality and water quality standards

Environmental indicators established in the Water Research Institute (Czech republic) as a part of the Labe II Project (Blažková, Nesměrák, Novický 1998) express the distance from the environmental targets. The indicator values are based on the ratio between the actual parameter value (concentration, load) and the target value (water quality standard, acceptable load).

According to the new regulations in Czech Republic, water quality standards are defined either as annual averages or as values for which the probability of the value not being exceeded is 90%. As the water quality standard is a constant, the indicators based on the comparison between the current pollutant concentration and a water quality standard has an uncertainty, which is equal to the uncertainty of pollutant concentration in the stream.

During the group discussions some important comments on the problem of water quality indicators were made:

- not only nutrients represent a problem, the problem of water pollution is much more complex (other pollutants are also important),
- floodplain soils are partly highly contaminated (e.g. by pollutants from mining activities), and after relocation of dikes the pollutants could be remobilised,
- contaminants transported by erosion are more difficult to control,

- mobilisation of contaminants could happen under changing boundary conditions (redox potential, soil moisture), e.g. as a result of climate change,
- pollution with chemicals becomes more important in case of reduced water discharge (e.g. in Berlin); increasing concentrations are observed during the drought events,
- biological indicators are only usable under unchanged climate conditions (climate related uncertainty),
- wastewater treatment plants are not enough effective.

The following specific recommendations for the Elbe basin were made:

- measurements should be performed for the right substances, at the right locations, and at the right times (frequency of samples); implementation is difficult and costly,
- bio-fuel production may help to reduce diffuse source pollution,
- the ‘polluter pays principle’ should be applied,
- new technologies should be developed to reduce pollution by endocrine substances.

WQ3: How to reduce uncertainties and cope with uncertainties related to Implementation of Water Framework Directive

The implementation of WFD in the basin was commented as follows:

- conflicts between inhabitants and agencies are possible in case of forced measures related to the WFD,
- there are uncertainties in implementation of WFD (guidelines from EU or government are missing), but the implementation can not be delayed,
- the time schedule for the WFD implementation hinders an adaptive implementation,
- measures to implement the WFD are defined by the environmental agencies only if data or model results justify them.

The following specific recommendations for the Elbe basin were made:

- the most problematic sites (hotspots) should have the highest priority,
- in some cases a prolongation is necessary to reach the aims of the WFD,
- implementation of the WFD is a long-term process, therefore an iterative process is needed to improve the results and reach the aims,
- more financial resources are needed to implement the WFD for all measures,
- promotion against conflicts between inhabitants and agencies is needed,
- public participation and moderation in the WFD implementation are necessary,
- professional teaching and training are necessary (e.g. as already existing in Thüringia),
- the WFD is open to implement adaptive processes (can also include climate change issues),
- models should be available for different questions and aspects related to the WFD implementation,
- model benchmarking is necessary.

5 Policy Summary

During the first phase of the NeWater project the main challenges for adaptive water management in the Elbe basin have been identified in collaboration with stakeholders. They are the following: 1) better water management related to floods and droughts in view of climate change; 2) improvement of water quality in the Elbe and its tributaries; and 3) enhancement of the transboundary Czech-German dialogue on water management.

The Prague Workshop was focused on uncertainties in water management related flood protection and management of water quality, which are related to all three main challenges. This summary includes the Policy recommendations related to flood management and water quality management.

During the group discussions the participants of the Workshop agreed that an Integrated flood protection strategy, which includes a combination of adaptative and preventive measures, is necessary in the Elbe basin. The Workshop participants made concrete policy recommendations related to **the implementation of the integrated flood protection strategy** in the Elbe basin:

- flood protection using only technical control measures is not possible in the Elbe basin, and non-structural measures in watershed and social measures are also needed;
- extension of floodplain areas is necessary in the basin, but often it is not easy or not possible to implement, therefore better planning in concrete conditions and control on provided funding are needed;
- the stepwise approach like in the Water Framework Directive should be also applied for the flood risk management;
- installation of automatic warning systems in small watersheds with a link to a permanently staff service centre can be a good flood protection measure;
- uncertainties related to the flood forecasts should be communicated to stakeholders and inhabitants; people should not believe in exact numbers, they have to be aware about involved uncertainties and should not expect exact forecasts;
- insurance agencies and firms should offer the combined insurances in order to reduce their risk and increase efficiency.

The Workshop participants suggested some concrete **recommendations on how to reduce uncertainties related to flood management:**

In order to improve the quality of measured hydrological and climate data, the following should be safeguarded:

- networks of hydrological and precipitation monitoring stations should be designed according to the exact criteria;
- spatio-temporal resolution of snow cover measurement should be improved;
- precipitation data obtained from the network of precipitation stations should be combined with data obtained by radar measurements while adjusting the radar estimates ahead of time by taking into account the systematic distance deviations.

In order to improve reliability of modelling results used for flood forecast and estimation of design floods, the following measures should be taken:

- the hydrologic forecasting service should use only the model providing the most reliable results for the given watershed in flood situations;

- for the cases when longer lead times than those achievable by deterministic models are needed, adaptive models and probability models could be used in real time forecasting;
- flood zone forecast can be improved and uncertainties reduced by using higher-resolution data on stream bed geometry and terrain topography, as well as historical data on the high-water level marks from previous floods;
- water levels for the 100 years flood (HQ100) should be estimated using an uniform approach (the best suitable model) for all German states and the Czech Republic.

The Workshop participants suggested some concrete **recommendations on how to reduce uncertainties related to water quality management:**

- there should be an obligation to register and provide information about the amount of wastes (emissions) for all waste producers;
- a voluntary self-commitment of farmers on fertiliser application rates or manure use; or application of recommendations from the Nitrate Directive could be helpful for diffuse pollution control;
- the 'polluter pays principle' should be widely applied;
- a joint use of monitoring data and modelling results by modellers and stakeholders (agencies) could be useful;
- enhancement of training of farmers is important.

Citations

[1] Newater Deliverable 1.3.2 :Adaptive water management in transboundary contexts

[2] Newater Report Series No. 18 - Deliverable D 3.3.2 : Stakeholder report defining needs for research, tools and capacity building in the Elbe basin

[3] NeWater Report Series No. 17 - Deliverable D 3.3.1 - WP 3.3 Elbe Basin Baseline Assessment of the Elbe basin

Appendix 1

Short description of the issues of uncertainty for group discussions

F1. Real-time flood forecasting

Flood forecasting is a real-time prediction of flood discharge and extent of inundation during an event. It is needed for decisions on flood warning. In small catchments it is primarily a problem of rainfall-runoff modelling involving rainfall data. In large catchments both rainfall-runoff modeling and hydraulic modeling of the channels may be involved.

Real-time forecasts are very dependent on the accuracy of input data, particularly of spatial patterns of rainfall intensities (**uncertainty**). The availability of radar rainfall data has greatly improved the potential for forecasting flood peaks. Currently, most flood warning systems are dependent on data from telemetering raingauges or radars, which are transmitted back to the forecasting centre in real time.

Any rainfall-runoff model that has been calibrated for a particular catchment (and for a certain range of discharges!) can be used in the prediction of flood discharges. The predictions may also be associated with an estimate of **uncertainty** in prediction. According to experience, **uncertainty** in both measurements and predictions of flood peaks increases with peak magnitudes.

The use of an adaptive modeling strategy could be advantageous, so that if a comparison of observed and predicted discharges reveals an error, then a strategy for adjusting the model predictions can be implemented. Such adaptation is however easier for simpler models.

It is also possible to apply neural networks using inputs that include rainfalls and previous values of discharge and a training set of historical events. However, in this case predictions made for events more extreme than those included in the training set, may not be accurately estimated (**uncertainty**).

Prediction of flood inundation (depth and area) needs a distributed hydraulic model of flows in the channel and floodplain, together with detailed topographic data. Such hydraulic models may be difficult to calibrate and implement within an adaptive framework for real-time forecasting. This is particularly difficult, if only approximate information is available on the topography of the channel and flood plain. Accuracy is very dependent on the topographic description and parameter values used in the model, leading to **uncertainty** in the prediction of floodplain storage and inundated areas.

F2. Assessment of design flood with a certain return period

The larger the flood, the lower the probability that it will occur in any one year. A lower frequency of occurrence may be represented as a longer "return period". It is important to understand properly the meaning of the return period: it is expected average length of time between occurrences of an event of a given magnitude. Therefore estimates of return periods are very difficult to check with the length of record normally available at gauges (**uncertainty**). Even a 10-year return period event would require a century or more data to obtain a robust estimate of peak magnitude, and a 100-year flood is even more difficult to estimate. For example, during this period of time characteristics of a catchment (e.g. land use/land cover) may change in a way that might have an effect the flood frequency (**uncertainty**). Besides, frequency of extreme rainfall may change due to climatic fluctuations and possibly also climate change (**uncertainty**).

Hence, flood frequency estimation is a very difficult problem. For the design purposes the most usual methods are:

1) **statistical methods** based on observed data:

1a) statistical estimation based on measured floods at a site,

1b) regionalization methods for catchments with no data,

2) **methods based on rainfall-runoff modelling**:

2a) simple event-based models or

2b) comprehensive models consisting of a precipitation and temperature simulator coupled to the precipitation runoff model

Statistical estimation: method 1a. The primary methodology for estimating flood frequency is by fitting a theoretical statistical distribution to available measurements of flood peak discharges, and using this distribution to estimate the frequencies of different flood events. Distributions used: Log normal, Wakeby, log Pearson type III, generalized logistic, etc. One of limitations is that we do not know what the correct distribution should be (**uncertainty**). Several different distributions might give acceptable fit to the data, all producing different frequency estimates in extrapolation.

Besides, the calibration may not be very robust, as most gauges do not have very long records available. They represent only a small sample from the possible distribution of floods at the site, so that the fitted distribution might be biased, and the resulting frequency distribution **uncertain**. This is especially important for long return periods.

It is also known that in some basins both land use characteristics, and the frequencies of flood-producing rainfalls have changed dramatically during the period of historical measurements.

Statistical estimation: method 1b. Each catchment is in fact unique, and therefore regionalization is always connected with a high **uncertainty**.

Modelling: method 2a. The flood with N-year return period is derived using the rainfall of the N-year return period of the duration critical for a catchment of a certain size. The antecedent wetness of the catchment (i.e. the way how to compute the effective rainfall) for the design situation is assumed (**uncertainty**) according to some rules describing a dangerous situation. Such assumptions do not need to be made when the continuous simulation method is used because a whole long series is modelled so that the antecedent conditions are computed.

Modelling: method 2b. Rainfall-runoff modeling is therefore being increasingly used for prediction of flood frequencies in combination with a rainstorm model. This is an alternative to a purely statistical estimation of flood frequency. A precipitation-runoff model, calibrated against a period of observed discharges, can be driven by stochastic inputs for periods of hundreds or thousands of years to derive a distribution of predicted flood magnitudes numerically.

The model structure and parameter estimation contribute to **uncertainty** in trying to estimate flood frequency by rainfall-runoff modeling. Although potentially a model might be able to represent any changes in the hydrological response of a catchment under more extreme conditions, there is no guarantee that a model calibrated by a prior parameter estimation or by calibration against a period of observed discharges will produce accurate simulations for extreme flood peaks.

This approach has the potential to take account of the changing nature of the hydrological response of a catchment with changing conditions and rainstorm volumes or intensities, but at the present time is associated with significant **uncertainties**.

F3. Risk mapping and uncertainty in estimation of flood damage

Risk is defined as the probability that events of a given magnitude and a given loss will occur. Therefore, risk encompasses two aspects: hazard and vulnerability. Flood hazard is defined as the exceedance probability of potentially damaging flood situations in a specified area and within a specified period of time as is given, for example, by a flood frequency curve. Flood frequency analysis is prone to large **uncertainties**, such as the length of available discharge data, considered distribution functions, estimation methods etc. (see Issue 2).

For the purpose of risk mapping and for the evaluation of proposed flood defence schemes in the framework of cost-benefit-analyses a flood frequency curve needs to be accomplished by spatial information about the flood intensity, i.e. inundation extent and depths or flow velocities. For this, a hydraulic model and detailed topographic data are needed. However, the accuracy of the results highly depends on the underlying digital elevation model (DEM) and the model parameters (**uncertainty**). With regard to different map scales (e.g. from the local to the national scale), it is unknown which modelling approach and what data quality are sufficient for which scale/application (**uncertainty**).

Besides the flood hazard, the assessment of the flood risk involves an analysis of the elements at risk. The term ‘elements at risk’ includes all elements of the human system, the built environment and the natural environment that are at risk of flooding, e.g. population, buildings and civil engineering works, economic activities, ecosystems etc. They might experience adverse consequences like fatalities, injuries or psychological stress, destruction of buildings and contents, disruption of traffic or business activities and pollution of soils etc.

The extent of the flood damage depends on the flood characteristics and on the vulnerability of the affected elements. There are, however, different aspects of vulnerability (e.g. technical, socio-economic, ecological) and there is no agreed understanding of this term (**uncertainty**). Often, the vulnerability part of risk studies is restricted to the analysis of direct monetary losses. However, the considered damage types influence the total risk estimate and might also influence a consequent decision about a suitable protection scheme (**uncertainty**). However, the importance of different kinds of damage is unknown. Further, no standard method exists for the aggregation of different kinds of damage estimates (monetary and non-monetary). Therefore, e.g. ecological gains of certain measures, like detention areas or land use restrictions, are commonly not evaluated, which might therefore lead to **uncertain or wrong decisions**. The inherent costs of **uncertain** risk estimates that are used for decision making are rarely calculated.

Damage analysis often focuses on exposure and (loss) susceptibility. Exposure analysis answers the question: “Who or what will be affected by floods?” Exposure (or damage potential) can be quantified by the number or the asset values of affected elements. Analysis of susceptibility answers the question: “How will the affected elements be damaged?” Current approaches for the estimation of direct monetary flood losses have several shortcomings which induce **uncertainties**:

1) Most of the models (stage-damage-functions) only consider the water level as influencing factor for the estimation of flood losses. The water level, however, does not explain the whole data variability.

2) Loss models are derived from micro-scale data, i.e. losses at single objects/buildings, and they are only valid for this scale. Transparent scaling procedures for applications on the meso-scale, i.e. units with homogeneous land use, have hardly been developed. Therefore, the applicability and the transferability of models are not understood well, nor is the necessary level of detail of input data and modelling approaches.

3) Flood loss estimation models are scarcely validated so that the accuracy of the results is difficult to assess (**uncertainty**).

In the framework of cost-benefit-analyses, but also in the context of climate impact assessments, the future development of the damage potential in the area under study needs to be assessed. Projections of future developments of land uses and the regional economy are, however, highly **uncertain**. This underlines that there is a huge demand for research in this field.

F4. Uncertainty in climate change projections, especially for precipitation

When discussing future climate change it is important to understand that there cannot be any prediction of the future. According to the terminology of the IPCC (2001), scenarios are rather images of possible futures, or alternative futures. They are neither predictions nor forecasts. Rather, each scenario is one alternative image of how the future might be. Scenarios are therefore (projections) into the future under the assumption that society behaves in a certain way (especially in terms of CO_2 emissions). As a result, climate change varies from scenario to scenario, and is associated with the scenario **uncertainty**.

The second important source of **uncertainty** is a not fully adequate understanding and/or reproduction of atmospheric circulation processes in General Circulation Models (GCM) (model **uncertainty** and parameter **uncertainty**). This is above all the case for precipitation events, whereas temperature shows a better reproduction. Important is also that the spatial scale of GCMs is currently between 1.0 and 2.5 degrees. Though different GCMs use the same or similar basic physical equations, they produce results, which may vary for the same scenario. However, it is worse to mention that the model **uncertainty** became much smaller over the last decade (see IPCC 2007).

For regional scale impact assessment usually results of Regional Climate Models (RCMs) are used as they provide finer spatial resolution (to avoid **uncertainties** related to scaling). Two main methods are currently in use: dynamic downscaling methods, basically having the same mathematical background as GCMs, and statistical methods, where the model "learns" from observations under certain boundary conditions in the past to make assessments for the future. RCMs use the results of GCMs as boundary conditions, but they better reflect local topographical and coastline features, which influence climate and local physical processes (especially relevant for precipitation and for the summer period, e.g. convective processes in the atmosphere). Hence, when available and validated for plausibility, RCMs scenarios should be applied for regional and river basin scale impact assessments. The finest resolution currently possible in dynamic RCMs is 5-10 km, whereas statistical methods normally produce scenarios for the net of climate stations where the statistics (correlations) of the climate pattern where derived.

Regarding projections of temperature, GCMs and RCMs behave similarly, except that GCMs reveal a larger spread. However, the differences between GCM and RCM precipitation responses for some regions are quite significant. The spread of precipitation during the summer period is larger for RCMs than for GCMs. For both, however, in terms of precipitation, the bias is twice as large as the response to climate change itself, when observed climate is used as a cross validation. Besides, it is known that projections of extreme events are more uncertain than projection of an average climate.

Regarding projections of extreme events like floods and droughts under climate change, there are scientific publications suggesting that frequency of both may increase under climate change in the Elbe basin.

WQ1. Uncertainty in estimation of point and diffuse sources of pollution

Methods for quantifying nutrient and pollutant inputs from different sources in the drainage basin are important for developing water quality control measures and programmes. Later we discuss nutrient load estimation, as for other pollutants the approaches are similar.

The most accurate estimates of nutrient loads are usually those of point sources, as nutrient discharges from both municipal and industrial sources are relatively easy to measure. Most of sewage treatment plants monitor their effluent discharges on a routine basis. Alternatively, multiplying average annual flows and average annual nutrient concentrations is used. However, certain complexities and **uncertainties** are involved, when urban runoff during storm events is added. The loads from municipal wastewater treatment plants can be also estimated using per capita annual inputs, and number of people served, though this method definitely involves higher level of **uncertainties**.

Diffuse source nutrient loads include land drainage from agricultural, urban and forested areas. Estimates of the diffuse sources can be obtained by direct measurements of runoff and concentrations coming from such areas, by measurement in tributaries draining such areas, or by indirect calculations based on unit area loads (or export coefficients). Direct measurements are most reliable, but such data are rarely available. The indirect calculations are based on an observation that under average hydrological conditions a given land use activity will export a relatively constant load of nutrients per unit land area. However, this method provides only rough estimates of annual nutrient loads. The export coefficients highly depend on hydrological conditions, and their regionalization or use in other areas are problematic. Generally speaking, the use of export coefficients involves large **uncertainties**, and should be used with caution.

Estimation of nutrient concentrations and loads can be also done using models. The models of two major types are used for these purposes: 1) empirical models, and b) simulation process-based models.

The empirical models distinguish different sources of pollution, which are estimated using direct measurements in a basin or export coefficients, and use a simple linear equation summarizing loads from a number of subareas. However, such models are usually based on sets of water quality measurements reflecting specific weather conditions, land use and management patterns, and their extrapolation to other areas and conditions may not be justified (**uncertainty**). Some empirical models include also a simple form of nutrient retention on their way from source to river network. All **uncertainties** related to the export coefficients are definitely transferred to results provided by such models.

The simulation process-based models describe mathematically the water and associated nutrient fluxes from the land surface, soil profile and groundwater. The complexity of a specific model depends on the extent to which important hydrological and biogeochemical processes are considered in the model. Though such models can represent the dynamics of ecohydrological processes much better than empirical ones, and usually include retention processes, they are also not free of uncertainties. The **uncertainties** are connected the accuracy of input data, determination of model parameters, and description of hydrological and biogeochemical processes in the model.

WQ2. Indicators of water quality and water quality standards

Water quality is assessed by measuring physical, chemical and biological indicators (i.e. conductivity, dissolved oxygen, pH, taste and odor, color, chemical oxygen demand, biological oxygen demand, nutrients, heavy metals, pesticides). The determination of the indicators is mainly connected to the direct measurements in rivers. Pollutant concentrations in the river are resulting from a long process of pollution transport from the source (settlements, sewage treatment plants, arable land) to the area of interest.

The **uncertainties** could be identified in connection to different aspects. Basically the indicators are measured in limited sets of profiles, the water quality in between or in ungauged sub-regions is not monitored and could be only roughly estimated **(uncertainty)**. The density of the monitoring network significantly influences the preciseness of the indicators measurements, and may cause **uncertainty**. Non-point sources in the basin may significantly influence water quality in the river, but their monitoring and evaluation is often difficult **(uncertainties)**. The plausibility of the indicators evaluation in water samples depends on the selected methodology, setup accuracy and experience of the staff **(uncertainty)**. The quickness of the evaluation requested in specific cases might be a factor reducing accuracy. On the other hand, delays in water samples evaluation can result in unreal outcomes.

The monitoring of the groundwater and assessment of the groundwater quality is highly influenced by the heterogeneity of the soils. The chemical reactions in soil influence the diffusion of the nutrients and contaminants **(uncertainty)**. The specific monitoring system has to be designed for different reason and different situations.

The set of water quality indicators includes more then 340 possible parameters describing the water quality. Some of them have confusing meaning under specific conditions in the basins. The unsuitable selection of such parameter for water quality monitoring may result in the unrealistic picture of water quality **(uncertainty)**. The role of some indicators in water quality monitoring is well known. They are commonly used and observed for long time. The implementation of others still needs investigation (i.e. new possible biological indicators) (**uncertainty** in connection of insufficient knowledge). The unification of water quality standards for large areas is still questionable.

In connection to the WFD the **uncertainty** of the measurement compatibility in different EU states could be found, the inter-calibration process could influence the homogeneity of existing measurement sets and evaluation methods **(uncertainty)**.

The water quality indicators, their measurements and regulation by water quality standards play an important role in economical sector. They influence the economical development in region by increasing the production costs, needs of innovation of the industry, building of waste water plants etc. The **uncertainty** in water quality indicators propagates to economy sector and causes economy **uncertainties** (i.e. acceptability of water quality standards).

WQ3. Implementation of Water Framework Directive

In simple terms the Water Framework Directive (also known as the WFD or Directive 2000/60/EC) is a legislative framework to protect and improve the quality of all water resources such as rivers, lakes, groundwater, transitional and coastal water within the European Union. The WFD was published and entered into force in December 2000. The main principle of the WFD is achievement of environmental goals (the good status of water) until the year 2015. The process consists from several stages: transposition into the national legislation, designation of river basin districts and competent authorities (2003), analysis of characteristics, pressures and impacts in all basins (2004), draft river basin plans (2008), river basin plans with relevant plans with the relevant programs of measures (2009), implementation of the programs measures (2012) and improvement of the status of waters (2015). The WFD implementation will continue until the year 2027 with evaluation of measures, updating of the existing plans and with application of second and third cycle of planning. The stages of implementation create the sequence and the successful fulfillment of one of them requires keeping of the deadlines of others (**uncertainty** in keeping the time).

WFD is complex directive, which covers the entire sphere of hydrology. The general character of the rule brings **uncertainties** connected to its implementation in individual countries. It requires implementation of new management regimes without previous practice **(uncertainty)**. Substantial changes in administrative arrangements are expected not only at the country level, but also from international point of view with cooperation of non-member states **(uncertainty)**. The new communication channels have to be established, new actors of management have to be identified. The new extent of their responsibility has to be defined.

The **uncertainty** is connected also with practical determination of basin locations, definition of the typical reference conditions, typology of water bodies, assessment of the human activities and their impact, the environmental aspects, setting of the measurements, water use etc.

The WFD introduces new conceptions, which might to support the sustainable usage of water sources. The basic requirement of WFD is implementation of cost recoverability analysis of water management services including environmental costs, with principle „polluter is paying“. Another concept represents cost effectiveness analysis of realized measures. The assessments of the economical and environmental costs in the future are highly **uncertain**, because of unreliability of the data and time distance, especially for the environmental cost analysis. The methodology of the rate of cost recoverability is using the statistical data (**uncertainty**) and questioning of the actors with presumption of true answers (**uncertainty**). The term environmental cost for economical analysis is not uniformly defined and this situation causes differences in cost evaluation (**uncertainty**).

Appendix 2
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