Differential interpretation of uncertainty in transition to AWMR: case of dams' safety in the Czech Republic

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1. Introduction

Adaptive Water Management Regime (AWRM) is an approach capable to solve many future problems in water management. Under increasing uncertainties connected with climate and global changes the technical preventive measures are no longer sufficient. Equally important becomes good governance (Pahl-Wostl 2007).

However, we must deal with inherited things, some of them can be hard to remove. Very strong tradition in solving water related problems by building dams exists in the Czech Republic. Many reservoirs were built as a flood protection in the mountains, as reservoirs for drinking water supply, for production of "clean" energy. In general, the water management in the Czech Republic is based mainly on legislative measures and the hard approaches.

Nowadays, there are 116 dams with individual reservoir capacity over 300 thousand m^3 in the Czech part of the Elbe Basin. The original purposes of reservoirs were water supply, energy production, flood protection and low flow augmentation. Additional purposes are fishery and recreation. In many cases the reservoirs became popular components of cultural landscape. More than 20 000 historical fishponds with low earth-fill dams, which are most sensitive to the overspill exist in the Czech Republic. Evidence of 78 of fishpond dam breaks exists in last 20 years in CR.

Two substantial questions arise:

1. How to improve safety of existing dams against floods?
2. Will be any new reservoirs needed? If Yes how large? How many? Where?

Answers to both questions are very important. This paper deals with the question one. Although the question looks like being only technical, the problem is very important as will be shown below and cannot be solved only by soft measures. The second question is handled in several papers (e.g. Novický 2006).

During the NeWater workshop **"Perception of uncertainty in water management by stakeholders and researchers"** in Prague, 14-16 of May 2007 (Prague workshop), the flood management issues were defined and discussed in break-up groups. The choice of issues for the group discussions was done based on previous responses of stakeholders, and interviews conducted in the Czech part of the Elbe Basin:

- Uncertainties in real-time flood forecasting
- Uncertainties related to the assessment of flood of a certain return period (design flood)

- Risk mapping and uncertainty in estimation of future damage potential
- Uncertainties in climate change projections
- Communication of uncertain scientific results to decision makers
- The role of international and interstate cooperation

2. Types of stakeholders' groups involved in problem

Different backgrounds cause different views on the problem.

Hydrology experts on water management: reservoirs are a good tool for water supply (especially as prevention of water lack during droughts), flood protection and other purposes. The impact of climate change might be so strong that no adaptation measure regarding the landscape and land use will be sufficient.

People without hydrological background: reservoirs are already here, and although they are in general barriers in transition to AWRM, we can hardly get rid of them; they must be protected against floods. Additionally we will not need many reservoirs in future. Public can be more sparing with water.

Stakeholders involved in dams' safety problem are as follows:

Policy makers are the Ministry of Agriculture of the Czech Republic and the Ministry of the Environment of the Czech Republic. The Ministry of Agriculture is responsible for the management of water bodies, public water supplies and sewerage. The Ministry of the Environment is in charge of flood protection and the protection of the environment (the related ecosystems). Both Ministries are jointly responsible for the development and implementation of water management policy.

Water boards (Povodi) are state enterprises responsible for control, monitoring and evaluation of water flow of the main river basins.

Safety of Dams Company (Technicko-bezpečnostní dohled - TBD) arranges technical and specialized support to Ministry of Agriculture.

Public wants to be safe from floods and dams' ruptures and to have enough drinking water.

NGOs warn against the possibility of the useless building of new reservoirs.

Stakeholders differ in power, interests, vulnerability and motivations. The opinion that water management must be prepared for changes (climatic or socio-economic) has been accepted by every stakeholder. The opinion that safety of dams under climate change is of high importance is also broadly accepted.

3.The Czech break group at Prague Workshop

The Czech break group concentrated mainly on problems connected with dam safety, as it followed from previous interviews.

Most important starting points were:

The River Boards have the duty to get the hydrological data once in 5 to 10 years. Then the Safety of Dams Company carries out the assessment of the dam safety. If the result shows that at the required N-year flood the dam is in danger the River Board has to take measures, which might require a large investment. The problem concerns 346 dams in the Czech Republic. A computation of the breakthrough wave must be done and an emergency plan set up. Scenarios of the damage to the dam are made.

The Safety of Dam Company requires hydrological data computed by 2 methods, usually a statistical method and a deterministic hydrological model. In important cases more rigorous and more transparent methods should be used. This means to carry out the uncertainty estimation including the uncertainty of model structure, of the parameters and of the inputs.

The stakeholders are interested in the details of the hydrological method only in the case when the results of the assessment show that the dam is in danger and a large investment will be required. The stakeholders were complaining that the data are changing – it sometimes happens that they take measures and then with new data and new assessment they have to take new measures again.

In general the stakeholders would prefer results of hydrological modeling without uncertainty. Additional interviews were carried out after the workshop and important uncertainties are described below.

3.1 Uncertainties in real-time flood forecasting

Creating conditions for a sustainable socio-economic development requires, among other things, also limiting the vulnerability of the environment by floods. In this connection, the most typical efforts in the first years of the 21st century are the efforts to improve the forecast lead-time and to increase the number of forecast sites. This, however, introduces various new uncertainties.

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. Nevertheless, in reality the forecast is limited by spatial-temporal characteristics of the area of interest, which in the case of smaller watersheds do not provide sufficient time to adopt required flood-control measures. When a longer lead time is required, the forecast calculations need to include also the water in the atmosphere, i.e. precipitation-runoff modelling needs to be used at the price of a less precise forecast.

If we require even longer lead-times, we need to include in the calculations also precipitation water that is only just being formed by atmospheric processes usually taking place in an area far away from the watershed for which the forecast is to be prepared. Forecasting these processes and their possible impacts on a particular geographic area becomes then more a matter of meteorological analyses. Therefore, the success of any efforts to achieve the longest possible forecast lead-time will depend on the improvement of meteorological forecast models.

For the time being, the “forecast for a forecast” method, i.e. the method whereby the output forecast data from a meteorological model, such as the forecasted precipitation data or other data, are used as input data for hydrological models, does not provide sufficient forecast reliability for longer lead-times and cannot be used for routine forecasting in the areas of Central Europe. It must be noted that with each extension of the lead-time the accuracy of the forecast decreases and the uncertainty increases.

As a result of the fact that the number of sites included in the calculations increases when forecasts of larger floods are prepared, the individual flood flows for each of the sites are often forecasted using different forecasting models, which increases the probability of higher occurrence of model-related uncertainties. In particular, if the forecasts for individual sites form a consecutive time sequence, the importance of the difference between the forecasted and real data increases and the forecasting operations need to be coordinated by means of an overarching modelling system. The modelling system may even include a number of different forecasting models for different types of floods.

3.2 Key uncertainties and proposals for their reduction

The uncertainty of the data obtained from water metering and precipitation stations has a strong impact on the quality of hydrological forecasts. Incorrect forecasts may be obtained due to the following reasons:

- Flawed design of the flow rate and precipitation monitoring networks resulting in non-representative data;

- In wintertime and springtime, when the depth of snow cover and its water equivalent are usually measured only in open spaces and not in forested areas and with a network of measurement points not sufficiently dense in mountainous and foothill areas;
- When ice forms on streams;
- Therefore, the following should be safeguarded:
- Each network of water flow rate and precipitation monitoring stations should be designed according to exact criteria and the representative value of the data obtained should be verified experimentally using a hydrological forecasting model;
- Ensure that sufficient number of measurements and sufficient volume of data on snow cover is obtained also from forested areas and from areas with rugged topography;
- Combine the precipitation spatial distribution data obtained from the network of precipitation stations with data obtained by radar measurement, while adjusting the radar estimates ahead of time by taking into account the systematic distance deviations.

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 sensitive results for the given watershed in flood situations.

When increasing the lead-time, 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 determination models are needed, tests are now being conducted (mainly in the USA, but also in the Czech Republic) with probability models in real time.

Flood zone forecast is one of the final products of the forecasting services provided by the flood protection service. For the preparation of the flood zone forecast a number of distributed hydraulic models are used the application of which requires accurate data on the streambed geometry and also on the topography of the adjacent areas. The modelling results respond very sensitively to the accuracy of the aforementioned data. Using higher-resolution data providing more sensitive identification of terrain inequalities can reduce the uncertainties relating to calibration and to the use of low-resolution topographic data. 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.

At municipalities located on small watersheds, which are or can be in the danger of a sudden flood wave on the stream flowing through their municipal lands, there remains an uncertainty 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 the information about when and in what amount is the torrential rain going to fall. In such circumstances, installing an automatic warning system (alert system) with a communication link to a permanently staffed service centre (fire-fighting station, police etc.) can be a good solution. Based on an alert signal sent by the alert system at the moment when the given precipitation limit or water limit is exceeded, the relevant service can warn the population at risk.

In hilly areas at small watersheds where unsuitable farming activities take place (growing of corn, potatoes, etc.) as a result of which enormous soil washing may occur if flash floods take place and consequently buildings and other facilities in flood-impacted municipalities may become destroyed. In this case, it is not possible to rely on local warnings issued by the hydrological forecast service. The uncertainty regarding the flood hazards can only be eliminated by adopting preventive, mostly structural (i.e. requiring investments), measures and by achieving an agreement between the relevant farmers and the municipality.

For negotiation between stakeholders incremental methods (based on carefully planned technical solutions) should be employed. An example of such approach is IFIM (Instream Flow Incremental Methodology, Stalnaker et al., 1994).

3.3 The uncertainty of climate change forecasts, in particular forecasts of precipitation changes and consequent flood forecasts

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: There persists an open uncertainty about whether the drivers behind these trends are the influences of human or natural origin. The one thing that has been confirmed so far is the fact that the growing scale of human intervention in natural processes that have taken place particularly in the last century does contribute to these changes. The presumption that changes in temperature will be accompanied by changes in precipitation has already been verified by physical data.

Already now, analyses of precipitation records taken since the beginning of the 20^{th} century have shown that globally there has been a spatially uneven growth of approximately 2% in precipitation. 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 the more frequent occurrence of extreme phenomena such as floods or very dry periods with no precipitations.

When preparing a strategy for protection and defence against these negative climate changes a number of uncertainties need to be addressed.

The circulation of water takes place in the context of a physical-climatic system that has a number of connections and opposing reactions 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 great degree of spatial and temporal variation in different environments. The simulation itself alone of such a complex set of systems through a global climate model (GCM) becomes a source of a number of uncertainties. If we want the GCM to take into account also the radiation effects of greenhouse gases as envisaged by various scenarios of future socio-economic development of mankind, the scope of uncertainties increases even further. Gradual improvement in the simulation capacity of GCM will be achieved by introducing further monitoring programmes focusing on monitoring the changes in climatic conditions and by using more detailed topography on a global scale. With these improvements, it is expected that outputs obtained from multiple GCMs based on different simulation scenarios will be able to at least provide an indication of the size of the uncertainties we can expect. Given the fact that the current GCMs do not yet provide a sufficient level of reliability for making spatial-temporal predictions of extreme climatic phenomena, the precautionary principle will have to be applied when considering possible development scenarios and it will have to recognised that *future climate changes may be faster than what the current projections indicate*.

Although efforts to predict the temporal development of climate in small geographic units using the GCM have not been successful, regional climate models (RCM) are under development. RCMs are developed on the basis of detailed regional scenarios, GCM outputs and also by analysing the conditions under which runoff extremes occurred in the past – the data used for the analyses may be the data recorded by measuring devices, human observations or even substitutes in the form of “proxy” data. The biggest uncertainty in implementing RCM and in subsequent linking of hydrological models is introduced by *translation of phenomena from the macro-scale to the meso-scale typical for individual watersheds***.**

Decreasing uncertainties in applying RCM will depend on the development of the downscaling method and statistical methods through which RCM is learning to estimate future states as well as on the improvement of the precipitation-runoff models’ ability to derive the runoff response.

3.4 Integrated flood protection

The course of flood catastrophes that occurred in a number of European countries in the last few years proved that the second - "Water from People" - paradigm, which prevailed due to the economic developments during the industrial era over the historically first long-term approach - "People from Water" - did not hold up. The regulating and walling in of rivers and streams has limited natural overflow, and in addition some flood dams which were not under stress for a long time given the absence of more serious flooding, subsequently broke during the extreme flood waves. This also worsened the flood situation. In modern flood protection it will be necessary, especially in the light of the anticipated increase in flood frequency as a result of climate change, to accept a third approach – "Adapt to Floods." In practical terms, this means leaving water where it is, letting it overflow and seep into the ground, decreasing its concentration and thus reducing its disastrous effects on the environment.

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:

- preliminary measures (before the occurrence of the risk), such as modernisation of flood plans, studies examining the use of alluvial plains for overflow, public education, development of forecasting and warning systems with the goal of increasing lead time, etc.
- reactive measures (during the course of the risk), for example 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, etc.

In the areas near the stream, however, the groundwater level during a flood situation would probably be at the level of the ground surface before the river goes over bank. So there is not going to be much seepage.

Moreover, in the Czech Republic the spatial capabilities of overflowing, especially in the case of narrow mountain valleys, are limited. It is, for example, not possible to relocate towns or villages. Given these conditions, we must take an integrated approach to flood protection in our battle against the adversary effects of floods, i.e. apply a combination of adaptation and preventive measures.

4. Conclusions

Uncertainty in transition to AWMR could be not only social-economic but also technical, e.g. uncertainties of dams` safety resulting from hydrological models.

It is necessary to stress that the effects of every suggested measure has to be quantified and uncertainties assessed by a transparent way so that all stakeholders can understand and take part in the decision making.

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