Simulation Games on Flood Operational Management: a Tool for the Integrated Strategy of Flood Control

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Dispečerské simulace řízení povodně: nástroj pro integrovanou strategii protipovodňové ochrany

Publikace se zabývá možnostmi využití simulačních her ve vodním hospodářství. Nejdříve je uveden teoretický přehled simulačních her a jsou probrány možnosti jejich klasifikace. Následně jsou uvedeny příklady simulačních her, které byly vytvořeny pro potřeby vodního hospodářství.

Následuje přehled simulačních her ve vodním hospodářství, které byly vytvořeny a použity v ČR. Všechny dosavadní realizace simulačních her ve vodním hospodářství ČR jsou podrobně zhodnoceny a jsou zde uvedeny hlavní poznatky a zkušenosti z těchto her. Dále jsou popsány možnosti přístupu k hodnocení simulačních her.

Hlavním tématem publikace je hodnocení dispečerské simulační hry, která se odehrála 11. listopadu 2008 na půdě státního podniku Povodí Ohře. Celá akce byla realizována v rámci projektu EU NeWater v případové studii Labe. Hlavními organizátory byly Povodí Ohře, státní podnik, VÚV TGM v Praze a ČHMÚ Praha a Ústí nad Labem.

Cílem této dispečerské simulační hry bylo ukázat značné nejistoty a někdy neúplnosti vstupních informací pro rozhodování často v časové tísni a zdůraznit potřebu vzájemného porozumění a úzké spolupráce všech zúčastněných odborníků a institucí během skutečné povodňové situace.

Dispečerské simulační hry představují progresivní formu přípravy na povodňovou situaci, kde se skupiny složené z účastníků povodňové situace s různorodým zázemím snaží co nejlépe manipulovat s vodohospodářskou soustavou za podmínek, které jsou nastaveny tak, aby se co nejvíce podobaly možné reálné situaci.

Tato dispečerská simulační hra byla hodnocena z vodohospodářského a sociologického hlediska. Vodohospodářské hodnocení spočívalo v porovnání výsledků všech týmů, včetně ukázky reakce na dostupné hydrologické předpovědi ve vybraných profilech a nádržích.

Hlavním cílem sociologického hodnocení bylo především získat zpětnou vazbu od účastníků hry i pozorovatelů v centru řízení hry, zjistit postoje a očekávání členů hráčských skupin, zhodnotit přínosy dispečerské simulace a poskytnout doporučení pro příští opakování dispečerské simulační hry.

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m a.s.l.	meters above sea level
CHMI	Czech Hydrometeorological Institute
CVUT	Czech Technical University
M	million
Qmax	maximum flow
UNESCO	United Nations Educational, Scientific and Cultural Organization
WM	water management
WRI	Water Research Institute
WW	water work (a dam and corresponding reservoir)

1 Introduction

1.1 The focus of the publication

Floods have been an issue for the human race over the course of its history. Unfortunately, it is physically impossible to get prepared for a catastrophic flood in such a way as to avoid any damage.

Catastrophic floods which cause great damage, have led to general requirements for instituting protective measures. However, people tend to underestimate the importance of disasters that occur once every 70 years or more. Floods are natural phenomena of a stochastic nature, i.e. flow rates of a certain size occur, on average (!), after the corresponding time period. It should be noted that when 100-year flooding occurs in a given place in one year, it can also (with the same probability) occur the next year.

Moreover, according to a report by the Intergovernmental Panel on Climate Change (Bates et al. 2008) more frequent occurrences of extreme climate events including floods with catastrophic consequences can be expected globally.

The scenarios of future development are projections of the development which may occur, in case that human society behaves in a certain way. However, it is necessary from the point of a "precautionary principle" to prepare for the worse alternative.

Floods are the result of specific meteorological and hydrological conditions, which we cannot influence. Nevertheless, the devastating consequences and the damage floods may cause are affected by many socio-economic factors. These factors may be partially altered, and it is desirable to do as much as possible to mitigate the effects of a potential flood situation.

The experience gained from previous floods (especially from the floods in 2002) confirmed that the integration and cooperation between all the participants of the flood situation may significantly reduce the negative impact of flooding.

One of the means to improve the integration and cooperation between the participants in the flood situation is called "cooperative learning" (Slavin 1980). Cooperative learning is learning in a group that works to achieve a specific objective, as in the case of floods, the maximum reduction of the consequences of flooding.

There are many tools of collaborative learning. The simulation games played by teams proved to be a very good alternative. The effectiveness of simulation games is much higher than that of passive methods of learning. Individuals participate in the simulation game with all the given characteristics, skills, habits and prejudices, and also with various interests on the given issue.

Standardized and unformulated conditions, attitudes, and reactions meet at the simulation game. The objectives and the available information are defined in a limited way as in real life, especially the amount and quality of the information.

The basis for successful progress and benefit for all simulation game participants is the dialogue in the preparation of decisions, which tend to have a high degree of uncertainty even with the maximum possible use of technical means.

A simulation game focused on operational flood management is a concrete application of Integrated Water Resource Management (IWRM) principles.

IWRM can be defined from different points of view. Independent information network Global Water Partnership defines the IWRM in the following way:

IWRM is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment.

Integrated Water Resources Management is a cross-sectoral policy approach, designed to replace the traditional, fragmented sectoral approach to water resources and management that has led to poor services and unsustainable resource use. IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource, and of social and economic importance.

1.2 The presentation of material in this publication

First, the theory connected to simulation games is presented with regard to their use in operational management (chapter 2). The overview of simulation games in water management follows (chapter 3). The history of simulation games in water management of the Czech Republic, and relevant lessons learned are presented in chapter 4. Chapter 5 presents approaches to the evaluation of a simulation game session. The case study – the simulation game session organized by the Ohře River administration in the framework of the EU Project NeWater (http://www.newater.info/) is presented in chapter 6.

At the beginning of chapter 6, the simulation game setup is described. It is followed by a presentation of a simulated water management system and hydrometeorological episode. Later on, the schedule of the simulation game workshop and relationships among different actors during the game are discussed. In the end, the evaluation of the game session from a water management point of view, and evaluation of participatory processes is presented.

2 Simulation Games: Overview and Classification

2.1 Introduction

The management of a reservoir system is particularly difficult in extreme situations such as large floods. In the event of floods, it is absolutely necessary for the responsible persons to decide quickly. The ability of rapid and accurate judgment of stress situations requires preparation and training (Kowalski-Trakofler and Vaught 2002).

It is known that the effectiveness of passive methods of learning is very low with a value of only 10–20%. Visual methods such as reading and the use of charts or pictures, only reaches about 30% of the transmitted information, which remains in the memory.

The joint action of the two groups of methods (audiovisual perception) has an effectiveness of around 50%. Individual discussions are up to 70% effective. The most efficient method seems to be participating in a common activity: up to 90% of the information remains in the memory (e.g. Aldrich 2005).

The learning methods, when individual participants in the learning process have to cooperate with the aim of achieving a better common outcome, such as cooperative learning are among the most effective learning methods (Stevens et al. 1991).

This category of learning methods includes simulation games that are currently in wide use e.g. as a training tool for decision makers, who can test the effects of their decisions without fear of risk impact of their potentially bad decisions (Bertsche et al. 1996).

Simulation games have a very long history. Games like chess and Go have evolved from war games in the Far East for more than a thousand years. Modern war games originated by the end of the 18th century in Prussia as training tools for staff officers. War games were broadly used by all armies in World War II.

The simulation game technique was used for the training of fictional or real crisis situations during the Cold War. The rapid development of business simulation games started in the 1950's. For more details on business simulation games see sec. 2.4.

2.2 The game theory

The game theory deals with the resolution of situations which have at least two participants. Participants have different or even opposing interests. The situations are described and solved mathematically. Analysis and discussion are used to reason out the behavior of each participant, which ensures that the result will be optimal from the perspective of each participant in the process.

In practical applications of game theory pattern of behavior of the process participants leads to optimal results.

The solution of conflict situations that will be advantageous for each participant, or the least unfavorable for them, is always influenced by the objectives of the other participants.

This means that it is not only a simple optimization process, but the selection of the most appropriate solution from all sets of solutions, which could be achieved.

2.3 Structure of a simulation game

Simulation, competition and playing, are three components of a simulation game (Greenblat 1975). Their intersections compose seven groups of activity (*Fig. 2.1*).

Simulation creates a modeled situation. Modeled situations can vary from a very abstract activity to a completely specified one. Many different forms of simulation exist: e.g. mathematical formulas, models of physical or social systems, role playing, film, literature, painting etc.

Competition (competing, fights) can be going on between two or more subjects in interactions with different intensity. Some examples of competition are elections or trade relationships.

Playing (not competition, not simulation) is an activity regulated by a set of conditions and rules which lead to getting the desired status of a game system at the end of the game.

The conditions accepted by the participants often represent an ineffective way of achieving a game goal (e.g. it is easily possible to put a golf ball in the hole without hitting it by a club). The motivation to play is to achieve different goals (entertainment, creative activity, stress relief).

An example of a competitive simulation (simulation-competition) can be the decision-making. Which of the two showroom layouts will be more effective? It is a competition between the simulated options, not playing.

Uncompetitive games (simulation-playing) simulate reality, but the competitiveness factor is missing.

Competitive games (playing-competition) are broadly played – mathematical games, word games, and sports games. Simulation is not a component of most competitive games.

Competitive simulation games (simulation-playing-competition) are sometimes called educational, because they are most often used for the acquisition of new skills and knowledge. These experiments

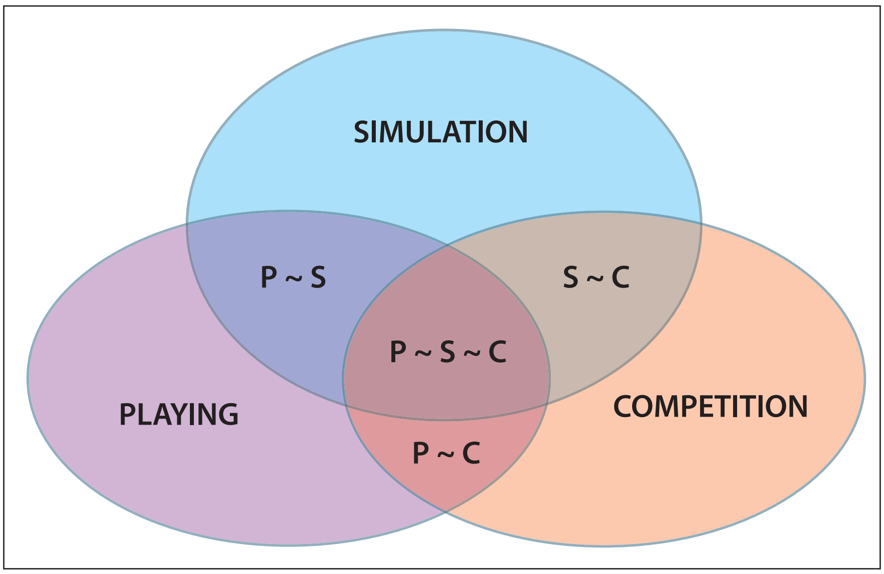

Fig. 2.1 Components of a simulation game

deal with problems of management strategy and allocation of limited resources (human, time, financial etc.). They are a simulation because they imitate reality. The participants respect rules and conditions, so they are both games, and competitions, because the results of the participants are evaluated and compared reciprocally.

The possibility of using a simulation game as a learning device becomes apparent when comparing it with alternative methods of system analysis used in water management.

The game theory solves conflicts by reciprocal effects of rational and perfectly informed individuals (see sec. 2.2). Simulation games deal with similar problems. The fundamental difference is that in a simulation game real human beings participate. They are given characters and they represent their own abilities, prejudices and interests. As in reality the objectives and purposes are not defined fully; the information on the system and its surroundings are limited, uncertain and sometimes even temporarily unavailable.

2.4 The classification of simulation games

Functionally, simulation games can be divided into interactive (direct or indirect) and simultaneous simulation games (standard and special models).

Interactive simulation games simulate relationships among individual participants or their groups that represent different interests, companies, state departments, customers etc.

Conflict situations are solved by the direct communication of participants. Conflict situations are not the only topic of the simulation game, it is possible to assess desired collaboration, coordination etc.

The common analysis of emerging situations is the most valuable. In the case of a direct interaction game, the participants discuss the common decision. In the case of an indirect interaction game, the members of the group provide their opinion without communicating with the others, and the choices or decisions are a task for the leader of the game.

The simulation games can be used in water management for research of the different possibilities of reservoir system operations, for design or verification of dam operation protocols, for initiation of collaboration of various authorities etc. (e.g. Eger et al. 2009). The overview of simulation games in water management is presented in chap. 3.

In the case of simultaneous simulation games the decision is upon the game participants (groups of participants). Such games are very suitable for training and educational purposes. Independent results of participants or their groups are mutually compared and analyzed. The natural competitiveness of participants stimulates their activity.

The decision-making of participants is usually arranged by a computerized mathematical model.

Regarding different aspects and organizational arrangements, simulation games can be classified in the following ways:

- According to the purpose (education, training, research, an analysis of system maneuverability),

- According to the level of management and number of levels (industry sector, company, water management system etc.),
- According to the number of game steps (small simulation game up to 5 steps, medium 6–12, big more than 12),
- According to the number of decisions in one step (small up to 10 decision in 1 step, medium 11–20, big more than 20),
- According to the time length of the modeled event (short – hours, days, medium – months, big – years),
- According to the type of modeled event (in the water management e.g. – flood, drought, contamination accident).

2.5 Concluding remarks

The simulation games need to be tailored to the desired objective in order to be successful. Simulation games prepared only generally, without taking into account the background and the abilities of the potential participants, have limited chances to be successful. Smaller, specifically focused simulation games are more effective than larger, more complex ones.

3 Simulation Games in the Water Management Sector

A wide range of simulation games is used in water management. Examples of simulation games used in water management, either for training of professionals, better involvement of different stakeholders, or raising public awareness, are presented in this overview.

River Wadu Role-playing Game (Lenselink and Jurriëns 1993): this game was originally developed as a training tool for students. The topic of the game is problems related to irrigation projects. Many following games are focused on professional training and are based on these same principles.

Irrigation Management Game (Burton 1989): this demonstrates the interdependence between crop growth, farm localization within the irrigation system, work performed by staff of the irrigation department and water supply. In the beginning, it was a simple cardboard game which evolved into a professionally produced package. This game is used for a simulation of very diverse climatic, political or organizational conditions.

Rehab Irrigation Game (Steehuis, Oaks et al. 1989): this game was designed for the simulation of irrigation system rehabilitation. Some of the games structural components were inspired by an existing irrigation system in Burkina Faso. Unlike the Irrigation Management Game, the objective of this game is to provide a safe, non-stressful environment.

WATER (Kos and Přenosilová 1999): this game was developed in CVUT, Prague, Czech Republic. The topics of the game are conflicts among water power production, flood regulation and environment conservation. The conflicts are simulated at a multipurpose water reservoir. The following game **WRENCH** involves conditions of climate change.

Njoobaari Ilnoowo Game (Barreteau, Bousquet et al. 2001): this game was originally designed for the simulation of irrigation systems in Senegal. The main objective of the game is to answer the question, "does the effectiveness of irrigation systems depend on types of coordination among individual farmers?" Then, the aim is to find out how to improve the cooperation.

Water for Space Game (W4S) (Carton, Karstens et al. 2002): this game was developed in the Netherlands. The aim of this game is diverse: to provide visualization of different approaches to water management, to improve communication among stakeholders, like land use planners, farmers or water boards, and to show the related social and economic uncertainties. This game is suitable for the building of a common vision.

FIRMA Watergame (Hare, Gilbert et al. 2001): this game was originally developed to provide new support for the management of the water supply in Zurich. The game is on-line based and uses an internet forum. The nature of the game allows for an extended game time (e.g. two weeks) and anonymity of the players. On the other hand it is difficult to obtain feedback from the players. It is necessary to organize a meeting with the players and to provide professional mediation, to be able to evaluate the outcomes of the game.

DESAFIO DAS ÁGUAS and **ESTATUTO DA CIDADE** (Camargo et al. 2007): these two games are examples of simulation games focused on water management in a Brazilian urbanization context.

FLOODRANGER (http://www.discoverysoftware.co.uk/FloodRanger.htm): this game enables players to explore the effectiveness of different flood management, housing and employment strategies within modeled landscapes that respond realistically to climate change.

FLOODSIM (http://floodsim.com/): this on-line game is aimed to raise awareness of the issues surrounding flood policy and to increase citizen engagement through an accessible simulation. It puts the player in control of all flood policy decisions and spending in the UK for 3 years.

4 Operational Simulation Games in the Water Management of the Czech Republic

4.1 Introduction

In principle, all the operational simulation games focused on flood management described below are based on same concept: The game participants control the outflow from reservoirs in order to influence the development of the flood and reduce the damages caused by flood and reported from gauge stations.

Many operational simulation games have been realized in the Czech Republic between 1982–1992 in cooperation with the Ohře River basin administration, Hydroprojekt (the state enterprise focused on planning in water management), and the Civil Engineering Faculty of the Czech Technical University in Prague during the UNESCO international hydrological course at the Czech University of Life Sciences in Prague. The objectives of the simulation games were mainly flood situations on the rivers Ohře and Vltava (Blažek 1987).

Intensive development of new reservoirs in the 2nd half of the 20th century caused a natural need for the collaboration in water management systems. The 1st International symposium of the Water management system was initiated by Prof. Votruba, and organized in Karlovy Vary (Karlsbad) in 1972.

42 leading scientists from 17 countries (including the USA and USSR) and 156 Czech and Slovak scientists participated in the conference. In the same time, the 2nd edition of the Directive Water Management Plan was nearing finalization. The chapter focused on water management systems was part of the Plan.

Three main topics were on the program of the Symposium:

- General issues of water management systems,
- Methods and procedures of design, and the operation of water management systems,
- Economic issues connected with water management systems.

Most of the contributions dealt with research issues related to water management system construction, theoretical approaches and case studies. The operational management in real time was not discussed (Blažek 1972).

However, flood situations provoke the need for operational management of water management systems. Nevertheless, the measurement and transmission equipment was not sufficient. Hydroprojekt has coordinated all the relevant activities since 1976, and in 1978 it developed the Comprehensive policy of Operational Water Management. The Policy was approved much later in 1986.

Between the years of 1975–79 the 1st part of the operational management system of the Ohře River administration was built. The operational management system was finished in 1982.

In the years 1980 to 1999, all the river administrations in conjunction with the Czech Hydrometeorological Institute (CHMI), developed and constructed an automated system including real time monitoring, transmission and processing, all in real time, for operational management of water management systems.

CHMI has used the mathematical prognosis model HYDROG (see also sec. 6. 4) since 1997, and all the river administrations are now fully equipped with operational management systems.

4.2 Important components of Flood Protection in the Czech Republic

River Administrations (River Basin Boards) are governmental organisations that administrate river basins, maintain 32 000 km of water courses, operate hydraulic structures (dams, weirs, locks), monitor water quality in water courses, compile water management plans and delineate flood prone areas.

The term dispatcher is used here for the flood operational manager or control room staff member responsible for the operations on dams of given water management system.

The Degrees of Flood Protection Activities are defined by Water Act Amendment (Act No. 254/2001 Coll.) as follows:

Degree one (state of alert) begins in case of natural flood danger and ends when the causing factors of such danger disappear; it requires that increased attention be paid to the watercourse or some other source of the flood danger, the activities of the flood warning and watching services are commenced; at water management structures, this degree begins when the limit values of observed variables or safety parameters of the structure are reached or when unusual facts which could lead to special flood danger are being detected.

Degree two (state of danger) is declared when the danger of a natural flood becomes reality; it shall also be declared when the limit values of the observed variables or safety parameters of a water management structure are being exceeded; the flood protection authorities and other participants involved in the flood protection are being activated as well as relevant technical means, and measures for flood mitigation as specified in the flood protection plan are being implemented.

Degree three (state of emergency) is declared in danger of the occurrence of high damage and in situations when lives and property in the flood plain areas are endangered; it shall also be declared, simultaneously with initiation of emergency measures, when critical values of the observed variables or safety parameters of a water management structure are being reached; protection and, if required, rescue activities and evacuation are organised.

4.3 The origins of simulation games in the water management of the Czech Republic

4.3.1 The first flood simulation game

The 1st flood simulation game was organized by Ohře River administration in cooperation with the Water Research Institute (WRI) in March of 1982, in Celná.

The topic of the simulation was winter flooding. The modeled winter flood was caused by snowmelt alternatively in combination with rain. The modeled water management system was the simplified water management system on the Ohře River containing specifically the water works Skalka, Jesenice and Nechranice.

The total catchment of the area of 5,600 km^2 was divided into seven subcatchments; they each had from 400 to 700 km^2. Only the catchment below the water work Nechranice was distinctively larger (2,030 km^2).
During the simulation game, 16 limnigraphs, 10 precipitation and 4 air temperature monitoring stations were observed. The structure of the simulated water management system is presented in *Fig. 4.1*.

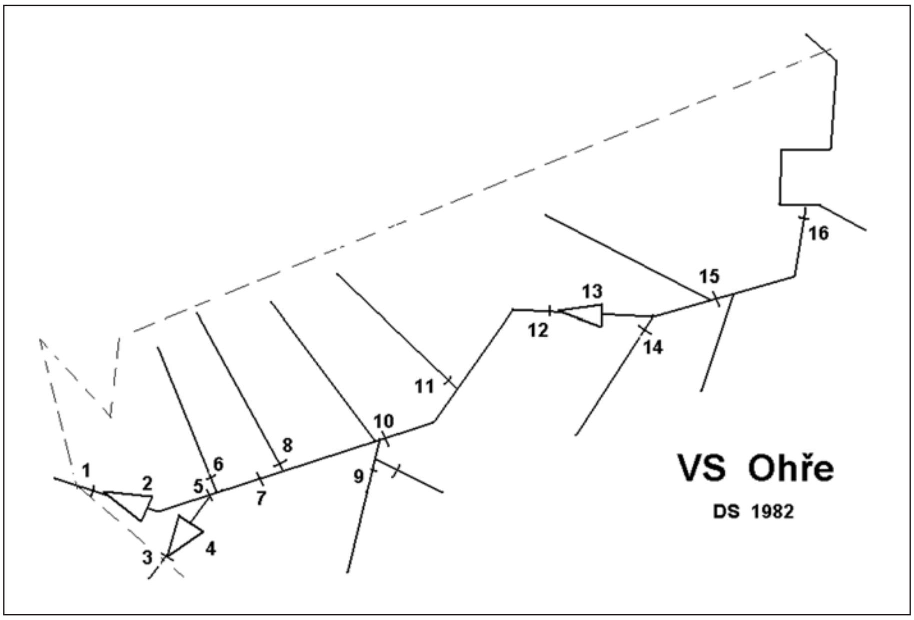

Fig. 4.1 The structure of the water management system on the Ohře River simulated in spring 1982

The modeled time period was ten days: during the first five days snow melted and it rained (from 44 to 107 mm in five days), then a sudden drop in temperature arrived with ice on the watercourses. Culminating flows corresponded to between 10-year and 20-year flows. Hydrometeorological forecasts were prepared by the CHMI branch in Ústí nad Labem once per day.

Participants were divided into several groups according to their professional background: dispatchers (operational managers), hydrometeorologists, heads of water administration and so called surroundings. The representatives of water management authorities, dam safety surveillance and supervision, and the representatives of mines (as the subject most threatened by flood) played surroundings.

Equipment breakdowns and human factor mistakes were implemented as risk factors in the simulation game.

The basic time frame was six hours. The shortening to three and later even to one hour periods, was requested by the participants when complex situations occurred. The simulation game leader ordered the time frame of twelve hours because of unintended prolongation of the game session. The simulation game was ended after the simulation on the 6th day. Consequently the ice on the watercourses was not simulated.

The simulation went on for 14 hours (one and a half days). The prepared lectures were not presented, but the method, game progress and results were broadly discussed by the participants. The final evaluation of the game session took place only during a meeting on the 9th of June, 1983.

4.3.2 The second flood simulation game

The 2nd simulation game was organized again in cooperation with the Ohře River administration at Celná in April, 1984. The modeled water management system was the Bílina River and the Nechranice reservoir on the Ohře River. The modeled situation was a summer flood with a recurrence time of up to 100 years. The modeled flood was caused by several days of continuous precipitation in combination with water saturation of the soil.

The modeled water management system was constituted by the water works at Nechranice, Jirkov, Jiřetín, Újezd, and the pumping stations Rašovice and Stranná, feeder from the Ohře River and Ervěnický corridor (rerouting of the river with the use of pipes, only two years old at that time).

The capacity data of the above listed objects, the rules of operation and hydrological data from the main flow gauging stations (including the flood protection activity degrees) were available for the game participants.

The low density of monitoring network was pointed out in the instructions by placing the center of the precipitation episode causing the flood, amongst the existing monitoring stations. The idea was based on previous experiences with a flood on the Jílovský creek in 1974.

The participants were unpleasantly surprised by the sharp increase of flows, because the monitoring stations reported only unimportant increases.

A very important and dangerous situation was when the emergency state was announced only by staff at the pumping station in Jiřetín, because of a dangerous increase of the water level in the reservoir. The operational management was not yet continuous at that time.

This finding led to organizing operational management in situations with forecasted potential storms, to a more detailed definition of some critical variables etc.

The simulation game session lasted seven and half hours. The simulated Hydrometeorological episode lasted 102 hours. The game was divided into 25 timeframes, each with five decisions. In critical moments the participants asked for shorter timeframes (up to one hour).

The participants engaged enthusiastically, and a broad discussion occurred immediately after the end of the game. All of the experiences and findings were implemented into operations and in planned development of the water management system by the Ohře River administration.

4.3.3 Concluding remarks

Both presented simulation games were interactive, non-competitive simulation games. Existing simplified water management systems were simulated. Game participants represented real organizations with their interests (sometimes opposing by nature). The opposing interests had to be overcome by cooperation during the game session. The main opponent in both games was independent natural phenomenon – flood.

The game sessions were prepared carefully and with perfect knowledge of simulated issues. The handouts corresponded well with the water management system equipment at that time. The leader of both game sessions Jan Kubát succeeded in keeping the attention of all the participants for the entire playing time.

Summarizing the results of both simulation game sessions, they contributed to the improvement of cooperation between the Ohře River administration, and other stakeholders in the system of flood protection.

4.4 Operational water management games in the period of 1986–1992

4.4.1 Flood simulation game for the water management system of the upper Ohře River

The Czechoslovak Hydrology Committee invited in 1984 Ing. V. Blažek and Ing. J. Kubát to organize a similar game session for the UNESCO hydrological course at the Czech University of Life Sciences in Prague.

The main purpose of the simulation game had to be educational, so the simultaneous, competitive form was chosen, with all the participants playing the role of dispatchers.

The water management system of the upper Ohře River was chosen for the game. The system was composed by four water works (Skalka, Jesenice, Březová and Stanovice) and three flow gauging stations (Citice, Karlovy Vary on Teplá River and Kadaň), where the damage functions were observed. The whole modeled catchment has an area of approximately 3,600 km^2. The flow gauging stations subcatchments have an area from 400 to 700 km^2. The catchments of the flow gauging stations on the Teplá River have areas from 100 to 300 km^2 (*Fig. 4.2*).

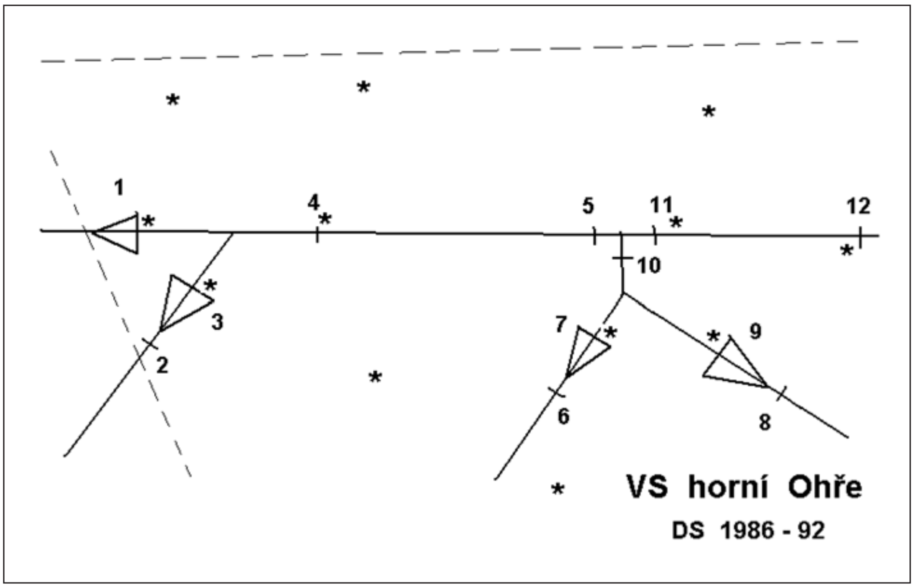

Fig. 4.2 The structure of the water management system on the upper Ohře River simulated between 1986–1992

In this water management system, it is possible to show illustratively, the common impact of the reservoirs on near or distant flow gauging stations, and also the distinct differences in the manageability of individual water works. The causing precipitation (40–110 mm) lasted for 36 hours. It caused Q_{30} (30-year flow) at the Citice flow gauging station, on the Teplá River Q_{50} and Q_{100} at the Kadaň flow gauging station.

The participants got information about the state of the water management system every six hours, i.e. precipitation in the last six hours, data from flow gauging stations, water levels and volumes in reservoirs.

In every second step the synoptic map was displayed and a meteorological prognosis for the next 12 hours was announced. Precipitation prognoses were not announced by CHMI in that time.

The participants were divided into groups and then presented their collective decisions about the outflows from the water works.

The hydrological response software allowed even the input of wrong data about the water management system state. The idea was to check whether the participants found the errors. The maximum flows at gauging stations and the respective of the damage functions were evaluated (*Fig. 4.3*). The overflow of maximum water levels (443.00 m a.s.l.) in the reservoir Skalka was penalized by one point per 1 cm.

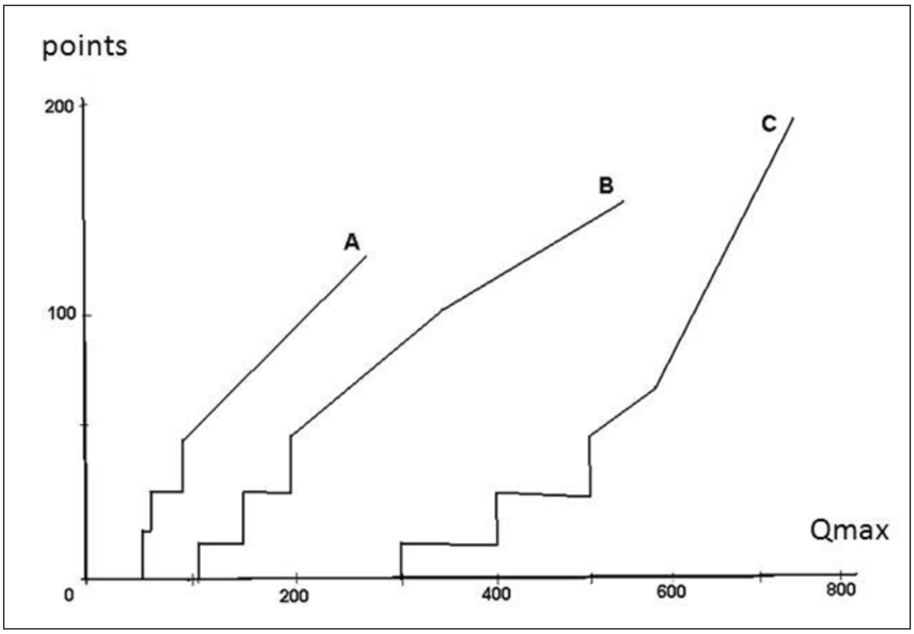

Fig. 4.3 The damage functions at the flow gauging stations (defined only for simulation purposes)

This simulation game was played during three game sessions. First, it was played by employees of Hydroprojekt, and then by interested Czech professionals from different organizations. Finally, it was played during the UNESCO hydrological course at the Czech University of Life Sciences.

4.4.2 The flood simulation game for the Czech part of the Elbe River basin

The simulation game about the water management system of both the rivers Labe and Vltava (the Czech part of the Elbe River basin) was prepared for the next UNESCO hydrological course in 1988.

The simulated water management system contained 19 flow gauging stations on rivers (5 of them waterworks), 30 precipitation monitoring stations and three flow gauging stations with the damage functions for results evaluation (*Fig. 4.4*).

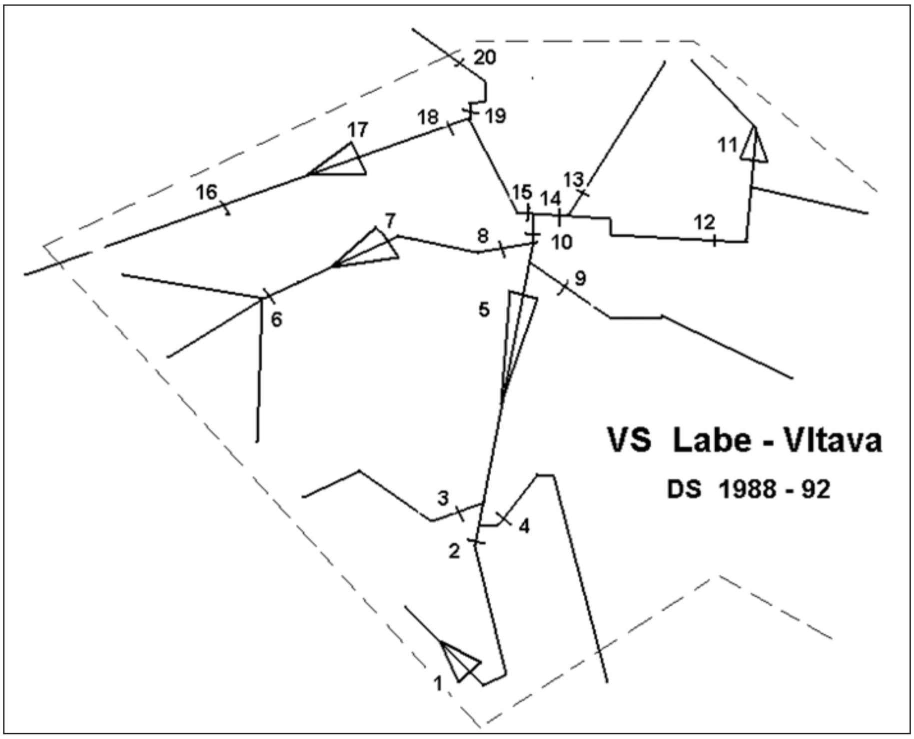

Fig. 4.4 The structure of simulated water management system of the rivers Labe and Vltava

4.4.3 The flood simulation game in 2008

The new simulation game of operational flood management on the Ohře River water management system was prepared. The game was played during a two day workshop (11th and 12th November 2008) at the Ohře River administration headquarters (Povodí Ohře, Chomutov). The main objectives were: 1) to enhance the understanding and cooperation between different stakeholders preferably during the flood event, 2) to demonstrate clearly the uncertainties connected to using the meteorological forecasts and the difficult decisions which have to be taken by the stakeholders and 3) to check the possibilities for using the game for the training of experts and water management students.

The simulation game setup, simulated water management system and hydrometeorological episode, the schedule of simulation game workshop including relationships among different actors during the game, the evaluation of the game session from an expert point of view and evaluation of participatory process are presented in chapter 6.

4.5 Lessons learned from the simulation games in the water management of the Czech Republic

This section presents findings from the game sessions described above. These games were mainly focused on operational flood management on the reservoir systems.

Eighteen simulation game sessions were organized so far. Two of them were interactive, 15 simultaneous and one was mixed.

The Bílina River management system was simulated once. The water management system of the Ohře River was simulated twice, and the water management system of the upper Ohře River was simulated eleven times. The water management system of the rivers Labe and Vltava were simulated four times.

Generally, the preparation of an accurate simulation game is not an easy task. It is very challenging regarding financial and human resources. Usually, it takes several years of work to properly prepare and test such a game.

The base of the game preparation is always its purpose. The qualifications and specializations of the participants are determining factors when the purpose is training. The specification of the problem corresponds with the specialization of participants. Consequently, the knowledge and procedures to be learned are defined.

The issues, structure of roles, interactions and specific events have to be defined when the purpose of the game is research or training of operational management. For instance if the topic of the game is operational flood management it is important to consider the distribution of precipitation and volume (recurrence time) of the flood. In case the game simulates complex issues it is important to exclude questions and relationship which are not essential.

Then it is possible to start the preparation of the simulation game documentation, i.e. selection of the water management system, which can be real, simplified or more complex. Then the simulated flood is defined. It is convenient to situate a smaller flood at the beginning of the game for better understanding of the game by participants, and to distract their attention from the main issue of the game.

The game documentation contains instructions for the organizers (the leader of the simulation game and his/her assistants), for participants concerning their roles at interactive simulation games, program of hydrological response etc.

The game instructions describe specific information about the water management (reservoirs) system and its surroundings, the characteristics of roles, rules of relationships and the approach to the evaluation of game outcomes.

The definition of time frames is very important. The virtual time frames define the time of simulated events. The real time frames must correspond well with virtual time frames, i.e. participants must have enough time for their decision and they must have a chance to correct their potential previous bad decisions.

Definitions of both virtual and real time steps are determined by the purpose of the simulation game, and by the physical and technical characteristics of the simulated water management systems.

The whole game session period is recommended to be 3–5 hours long. The virtual time step with several interactions and 4–8 decisions requires usually 15–20 minutes of real time. Consequently the game should have 12–18 virtual time steps.

Interactive simulation games should be entertaining without animosity. Participants are fully concentrated on finding optimal solutions for the game task.

Simultaneous simulation games can involve a restriction on time allowed for decisions. In case of violation of the time limit the participant loses control of the water management system in the given time frame. Such an approach allows for modeling the limited time that dispatchers have for their decisions in real life during stressful situations (e.g. flood). The choice of game design depends on the desired objective.

5 The Approaches to the Evaluation of a Simulation Game

5.1 Introduction

There are several different approaches to evaluating a specific simulation game session. The evaluation of the game session is determined by the purpose for which the simulation game was created.

The original purpose of simulation games was for the training of professionals. For such training to be effective, it has to be followed by de-briefing and evaluation of simulation results. Usually, the "ideal" decisions are presented and game participants can compare them with their own decisions.

Over the course of time, with a higher importance of collaboration among different stakeholders in water management (see sec. 1.1), it became more important to evaluate systematically the simulation games from participants' point of view, and to evaluate the simulation game sessions as participatory processes.

Generally, the operational games can be evaluated from two points of view:

- expert view (objective, technical),
- social science view (subjective view of individual participants and their feedback).

Both approaches are important for the evaluation of the effectiveness of the given simulation game, and also for successful future game sessions.

Evaluation from an expert point of view is defined by the activity that is to be trained by the simulation game. An example of an evaluation of a flood simulation game session from this point of view is given in sec. 6.6.1. The effectiveness criteria for evaluating a game session as a participatory process is described in the following sec. 5.2 and an example of such an evaluation is given in sec. 6.6.3.

5.2 The criteria for evaluating a game session as a participatory process

The criteria for the evaluation of a participatory process may be divided into two types (Rowe and Fewer 2000):

- Acceptance criteria are related to the effective construction and implementation of the process.
- Process criteria are related to the acceptance of the process by its participants.

The acceptance criteria are:

Representativeness (the participants should comprise a representative sample of affected stakeholders), independence (the participation process should be conducted in an unbiased way), early involvement (the potentially interested persons should be involved as early as possible), influence (the output of the process should have a genuine impact on future policy) and transparency (the process has to be transparent so that its participants can see what is going on and how decisions are being made).

The process criteria are:

Resource accessibility (participants should have access to the appropriate resources in order to be able to successfully fulfill their brief), task definition (the nature and scope of the participation task should be clearly defined), structured decision making (the appropriate mechanisms for structuring and displaying the decision-making process should be provided), cost-effectiveness (the process should be cost-effective).

6 Flood Simulation Game Session 2008

6.1 Introduction

The decision-making during operational flood management on a system of reservoirs is an extreme case of water management: the important decisions have to be made in very short time, especially when the response time of a catchment is very short (e.g. several hours). Such decision-making is very challenging and has to be trained (Kowalski-Trakofler and Vaught 2002).

During the flood the control room staff communicates with meteorologists and hydrologists on one side in order to get as accurate as possible forecasts of precipitation and flows, and, with the regional and local authorities who are responsible for the measures taken on the other side.

The simulation game provides the opportunity for these different stakeholders to enhance their reciprocal cooperation and train for a potential real flood situation.

The greatest challenge in a flood situation is to estimate the time of the rainfall end, as most of the difficult decisions depend on it. The management of the system requires a detailed knowledge of the system, experience and skills. For developing such skills, active methods such as simulation games are more effective than passive ones.

The other game participants such as decision makers from the local and regional administration, can take part and get acquainted with the reservoir management problems, and discuss their concerns (about the evacuation etc.) with the control room staff.

The simulation game of operational flood management was created, and the game session was organized, in the framework of Case Study Elbe of the EU project NeWater (www.newater.info) led by the Potsdam Institute for Climate Impact Research and in the framework of the Project SP/2e7/229/07 of the Ministry of Environment of the Czech Republic.

The main organizers of the simulation game session were the Ohře River administration, TGM WRI and CHMI, branch Praha and branch Ústí nad Labem. This simulation game models the system of four reservoirs in the Ohře River catchment (Czech Republic, Germany).

The simulation game session was organized during a two day workshop (11th and 12th November 2008) at the Povodí Ohře headquarters (Ohře River catchment water administration, governmental organization) in the town of Chomutov, Czech Republic.

The objectives of the simulation game were the following:

- demonstrate clearly the uncertainties connected to using the meteorological forecasts and the difficult decisions which have to be taken by the stakeholders (local decision makers, officers from the ministries, and representatives of enterprises which may be endangered by flood situation);
- enhance the understanding and cooperation between stakeholders with their various interests and the control room staff;
- check the possibilities for using the game for the training of students.

6.2 The simulation game setup

The water management system considered in the simulation game consists of four reservoirs: Skalka, Jesenice, Březová and Stanovice (a detailed description of the water management system is in sec. 6.3). The operation of these reservoirs is aimed at protecting e.g. a well-known spa Karlovy Vary (Karlsbad) from floods.

The simulation game is designed to be played by teams. The teams have to operate the dams of four reservoirs during the flood situation in such a way, that the impact of the flood is as reduced as possible. The teams are formed by people with different backgrounds. Specifically here, the members of each team were representatives of local and regional authorities for crisis management, responsible for decision making during floods, and experts in the operations of dams.

Generally, the game is demanding as far as preparation is concerned. The game software should work in longer timeframes than what is used in reality, so that the consequences of each decision are evident in a small number of following steps. The output of the software should be similar to the output of the real operation software, but have to be simplified so that they can be quickly understood by non-professionals. The information on input and output of the individual steps should illustrate properly the procedure and the involved uncertainties. The equipment is intended to serve in the future for other game-training workshops with different types of users (the control room staff, decision-makers and students).

The simulation game has to have an "optimal solution" to be useable for training purposes. The optimal solution means the optimal operation of dams, i.e. the impacts of the flood are as low as possible and the operation procedures are followed. The optimal solution is used for debriefing purposes after the simulation game.

The simulation game was designed to be played during 8 hours. It was one of the preliminary demands by potential participants of the simulation game. A shorter time would not be sufficient regarding the realistic simulation of the operation of the dams and on the other hand a longer game time would be tiresome for non-expert participants.

The tasks for the playing teams were the following:

- to operate the dams in an optimal way,
- to decide about warnings and evacuations,
- to deal with unexpected situations.

The precipitation episode was selected and artificially increased with regard to the possible effect of climate change (details in sec. 6.4).

The meteorological situation that led to the simulated flood was supposed to be introduced before the simulation game. During the game the playing teams got the meteorological and hydrological forecast in the relevant timeframes. These materials were prepared by the Regional prognostic center of CHMI, branch Ústí nad Labem in the same form as they are prepared in practice.

The simulation game was led from a "game headquarters", where the simulation game leaders evaluated gradually obtained results, simulated the background (media, public, unexpected situations).

The simulation game was based on the so-called hydrological response. The hydrological response is the reaction of individual water management system components on operations at dams. In the simulation game the hydrological response was simulated and then provided to the teams in the same form as it was provided to control room staff during the real flood situation.

The computational tool was the rainfall-runoff model HYDROG, which is standardly used by the Ohře River administration for operational water management. The simulated hydrometeorological episode lasted 213 hours. It was divided into 10 time frames, 12 or 24 hours long. The choice of how long the individual time frames would be was based on the analysis of possible operations during the hydrometeorological episode.

After the simulation of each time frame, the simulation game was stopped every 10 or 20 minutes.

The teams then were supposed to analyze the current state of the catchment and the water management system, taking into consideration available materials (meteorological and hydrological prognoses in a standard format of operational practices).

After the time dedicated to analyses, the playing teams ordered operations on individual reservoirs of the water management system, and in the next 20 minutes the hydrological response was calculated individually for each team.

Then the simulation started again, and it ran until it reached the next time point dedicated to analysis and decision-making. Then the teams analyzed the current situation and ordered new operations. The entire simulated game was played in this manner.

Alternatively, the simulation of unexpected situations could be added in selected time frames (e.g. the need for the evacuation of people, or obstacles in the watercourse).

The communication tools were provided to each playing team. They had at their disposal two telephones and an e-mail, which they used for communication with the other actors of the simulation game.

The next tool was the visualizing software environment (example on *Fig. 6.1*). It showed the development of the hydrometeorological episode individually to each team.

This tool was constructed on the basis of the operational management software environment, standardly used by the Ohře River administration.

Web cameras were used for observation of playing teams by the simulation game leaders and hydrology response staff, to watch on-line reactions in individual time frames and to monitor the cooperation among individual members of the playing teams.

Many different handouts were prepared that were provided to the playing teams before, and also during the game (mostly forecasts and game instructions), e.g. results of the two meteorological models Aladin and GFS, which were prepared by CHMI. The meteorological analysis of models was also provided to playing teams.

Based on these results the hydrological forecasts were prepared and provided to playing teams. The hydrological forecasts were influenced by uncertainties of the meteorological forecasts.

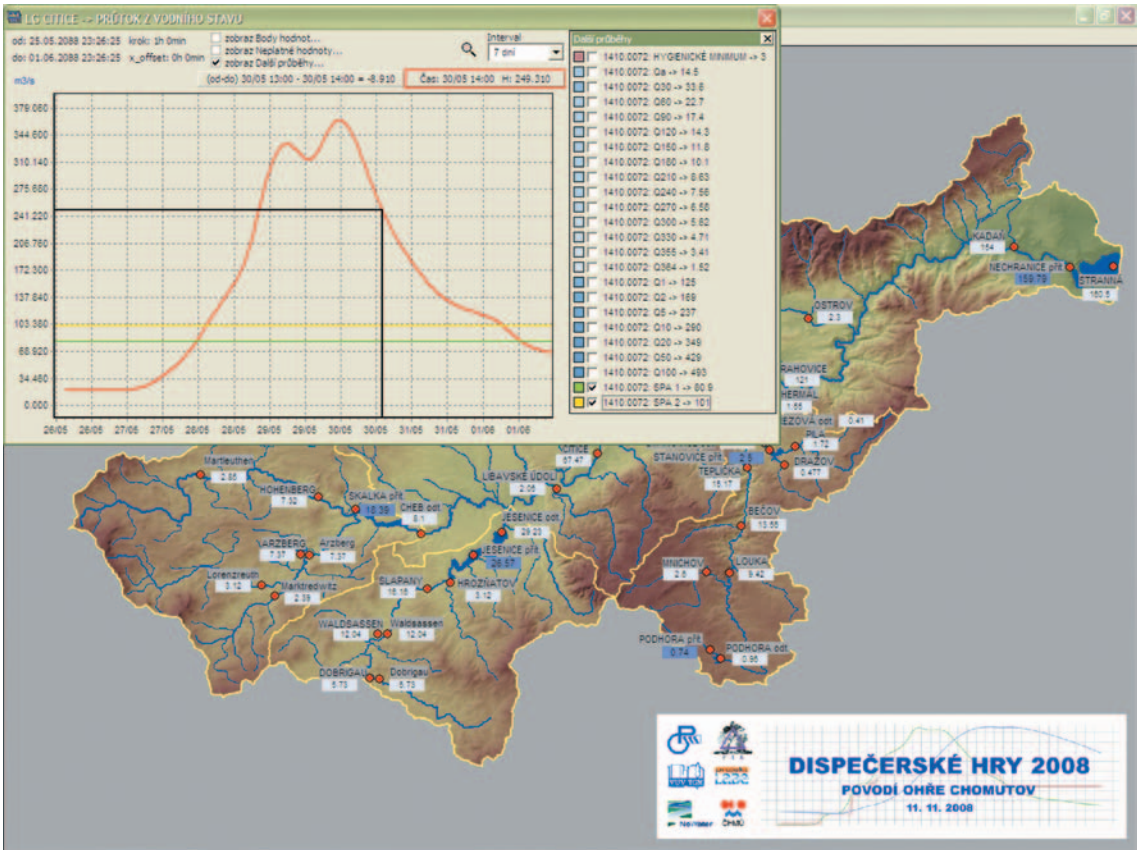

Fig. 6.1 The example of output of the visualizating software environment

The forecasts were prepared with the intention of getting as close as possible to a real situation, when the information available to the decision makers is heavily influenced by uncertainty in numerical models. This intention was achieved in an approach to the preparation of a simulated hydrometeorological episode and materials for the playing teams. The hydrometeorological situation was prepared by the CHMI branch in Prague, and forecasts by the prognostic department of the CHMI branch in Ústí nad Labem.

6.3 Description of the simulated reservoirs system

As stated above, the simulated system of reservoirs consists of the water works in Skalka, Jesenice, Horka, Březová, Stanovice and Nechranice. The outlet for these reservoir systems is at the dam of the Nechranice reservoir (*Fig. 6.2*). The modeled reservoir system has an area of 3,617 km^2.

Usually, the volume of a reservoir is divided into distinguishable areas. The nomenclature of these areas used here, is as follows.

Constant storage volume

Storage volume: water is stored here during the periods with higher flow and released from here during the dry periods.

Manageable protective volume is filled up with water during flood situations; it is between the level of storage volume and the spillway crest.

Unmanageable protective volume is defined by height of overflow above a spillway crest.

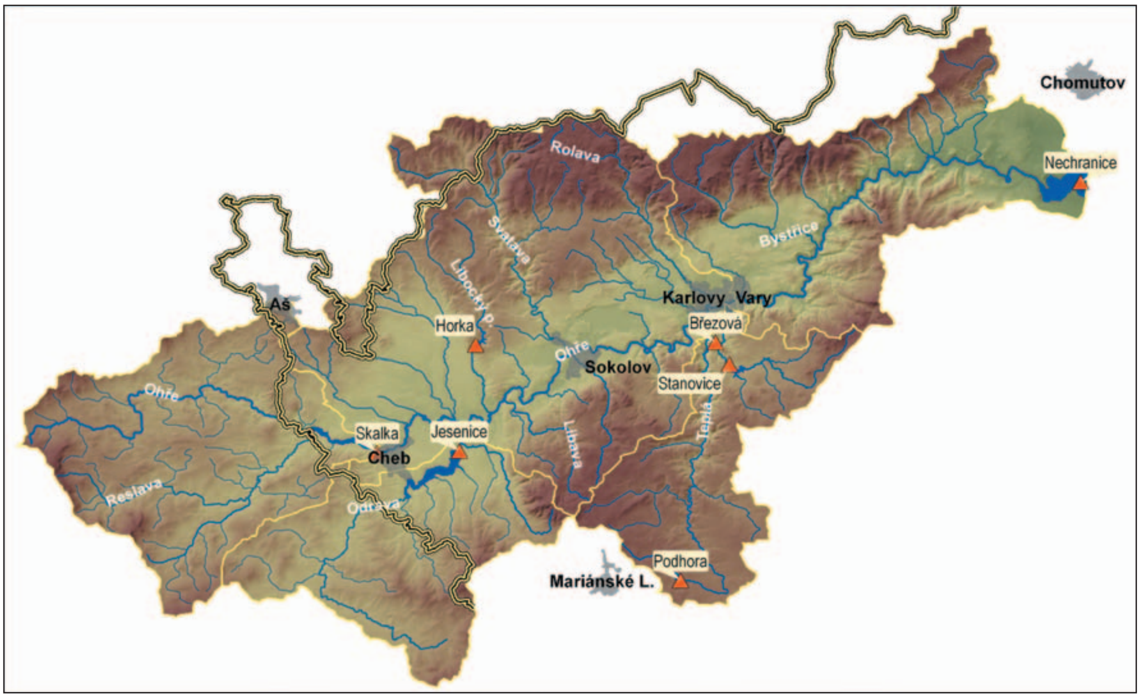

Fig. 6.2 The simulated water management system on the Ohře River

6.3.1 Skalka Water Work

Skalka Water Work is built on the 242.41 km point of the river Ohře in the Karlovy Vary Region near the town of Cheb.

THE PURPOSE AND THE CAPACITY

Skalka Water Works (WW) was built between the years 1962–1964, as a component of the Skalka-Jesenice water management system.

The main purpose of the water work is a balancing of the flow, in cooperation with the Jesenice WW. The increased flow is needed for water consumption by downstream power stations, industry plants and ensuring the necessary minimum flow in the river.

The other important purposes of the Skalka WW are partial protection of downstream areas against floods, and the reduction of the impact of accidental water quality worsening in the Ohře River. Additional purposes of the Skalka WW are power production, recreation and water sports activity.

Minimum outflow is 1.0 m^3/s, harmless outflow is 30 m^3/s.

HYDROLOGIC DATA

The catchment area is 671.7 km^2, mean long-term annual flow is 6.21 m^3/s, 355-day flow is 950 l/s, 100-years flow is 277 m^3/s.

TECHNICAL PARAMETERS

The reservoir dam is straight, earth filled and rocky, with an upstream concrete impenetrable jacket. The elevation of the crest is 444.60 m a.s.l., the length of the crest is 115 m, its width is 4 m, and the elevation of the crest above terrain is 14.6 m.

Bottom outlets: 2 × DN 1,200, the capacity at the level of storage volume is 2 × 12.4 m^3/s.

Safety spillway is a crest, dammed up with moving stop gates into two parts: the left part of the spillway is dammed up with a lifting segment, the length of the spillway is 9.5 m, the elevation of the fixed spillway is 435.60 m a.s.l., the dam height of the segment is 7 m, its capacity is 390 m^3/s. The right part of the spillway is dammed up with a hollow flap gate, the elevation of the reclined gate is 438 m a.s.l., the length of the spillway is 7 m, the dam height of the gate is 4.6–4.8 m, its capacity is 169 m^3/s.

The total capacity of the spillway at maximum water level is 559 m^3/s.

Reservoir			
	water level [m a.s.l.]	volume [M m^3]	area [ha]
Constant storage volume:	435.60	0.911	
Storage volume:	442.20	13.659	
Manageable protective volume:	442.60	1.349	
Unmanageable protective volume:	443.60	3.636	
Total volume:	443.60	19.555	378

6.3.2 Jesenice Water Work

The Jesenice Water Work is built on 4.17 river km of the watercourse Ohře in the Karlovy Vary Region near the town of Cheb.

THE PURPOSE AND THE CAPACITY

The Jesenice WW was built in the years 1957–1961. It is a component of the water management system Skalka-Jesenice.

The main purpose of the WW is a balancing of the flow in cooperation with the Skalka WW. The increased flow is needed for water consumption by downstream power stations, industry plants and ensuring the necessary minimum flow in the watercourse.

The other important purposes of the Jesenice WW are partial protection of downstream areas against floods and reducing the impact of accidents at waste water treatment plants. An additional purpose of the Jesenice WW is power production.

Minimum outflow is 400 l/s, harmless outflow is 12 m^3/s.

HYDROLOGIC DATA

The catchment area is 406,5 km^2, mean long-term annual flow is 3,53 m^3/s, 355-day flow is 450 l/s, 100-years flow is 138 m^3/s.

TECHNICAL PARAMETERS

The reservoir dam is straight, earth filled with a clay seal layer on the upstream side; the elevation of the crest is 443.07 m a.s.l., the length of the crest is 753.1 m, its width is 11.0 m, the elevation of the crest above terrain is 20.47 m.

Bottom outlets: 2 × DN 1,400, the capacity at the level of storage volume 2 × 16.0 m^3/s.

Safety spillway is sideways, fan. The length of the spillway overflow edge is 90.7 m; the elevation of spillway crest is 439.70 m a.s.l., the capacity at maximum level is 167 m^3/s.

Reservoir			
	water level [m a.s.l.]	volume [M m^3]	area [ha]
Constant storage volume:	427.30	2.145	
Storage volume:	439.20	47.119	
Manageable protective volume:	439.70	3.486	
Unmanageable protective volume:	440.70	7.400	
Total volume:	440.70	60.150	760

6.3.3 Horka Water Work

The Horka WW is built on 10.4 river km of watercourse Libocký potok at the villages of Krajková, Habartov and Nový Kostel, in the Karlovy Vary Region.

THE PURPOSE AND THE CAPACITY

The Horka WW was constructed in the years 1966–1970. Its main purpose is the accumulation of water for the drinking water supply for the town of Sokolov, and ensuring the necessary minimum flow in the watercourse. An additional purpose is the partial protection of downstream areas against floods. Minimum outflow is 100 l/s, harmless outflow is 5 m^3/s.

HYDROLOGIC DATA

The catchment area is 69.17 km^2, mean long-term annual flow is 670 l/s, 355-day flow is 91 l/s, 100-year flow is 75,5 m^3/s.

TECHNICAL PARAMETERS

The reservoir dam is straight and earth filled. The elevation of the crest is 507.30 m a.s.l., the length of the crest is 236 m, its width is 5.45 m, and the elevation of the crest above terrain is 40.7 m.

Bottom outlets: 2 × DN 800, the capacity at the level of storage volume 2 × 8.7 m^3/s.

Safety spillway is ungated, shaft, with circular diameter of 11 m, the elevation of the spillway edge is 504.7 m a.s.l., and the capacity at maximum water levels is 140 m^3/s.

Reservoir			
	water level [m a.s.l.]	volume [M m³]	area [ha]
Constant storage volume:	481.60	2.450	
Storage volume:	504.70	16.78	
Manageable protective volume:			
Unmanageable protective volume:	506.32	2.120	
Total volume:	506.32	21.35	130.24

6.3.4 Podhora Water Work

The Podhora WW is built on 55.2 river km of the watercourse Teplá, at the villages of Ovesné Kladruby and Teplá in the Karlovy Vary Region.

THE PURPOSE AND THE CAPACITY

The Podhora WW was built in the years 1952–1956 as a component of the Podhora-Mariánské Lázně water management system. The purposes of the reservoir are the accumulation of water to supply the town of Mariánské Lázně and nearby municipalities, water accumulation for agriculture, and ensuring the necessary minimum flow in the watercourse downstream.

An additional purpose of the Podhora WW is partial protection of downstream areas against floods. Minimum outflow is 27 l/s, harmless outflow is 4.5 m^3/s.

HYDROLOGIC DATA

The catchment area is 19.65 km^2, mean long-term annual flow is 282 l/s, 355-day flow is 27 l/s, 100-year flow is 27.7 m^3/s.

TECHNICAL PARAMETERS

The reservoir dam is straight, earth filled and homogenous. The elevation of the crest is 693.49 m a.s.l., the length of the crest is 280 m, its width is 4.4 m, and the elevation of the crest above terrain is 10.18 m.

Bottom outlets: 2 × DN 500, the capacity at the level of storage volume 2 × 1.47 m^3/s.

Safety spillway is ungated, direct, crest. The longitude of the spillway crest is 20 m, the elevation of the crest is 691.18 m a.s.l., the capacity at maximum water level is 30.5 m^3/s.

Reservoir			
	water level [m a.s.l.]	volume [M m³]	area [ha]
Constant storage volume:	686.70	0.119	
Storage volume:	691.18	2.041	
Manageable protective volume:			
Unmanageable protective volume:	692.17	0.872	
Total volume:	692.17	3.032	95

6.3.5 Březová Water Work

The Březová WW is built on 8.21 river km of the watercourse Teplá, at the village of Březová in the Karlovy Vary Region.

THE PURPOSE AND THE CAPACITY

Březová WW was built in the years 1931–1935. It is a component of the water management system Stanovice-Březová.

The most important purpose of the WW is the protection of the town of Karlovy Vary against floods, ensuring the necessary minimum flow in the watercourse, and to flush the watercourse periodically. Additional purposes of the WW are power production, regulated trout farming and increasing the flow below the WW dam for organized canoe races.

Minimum outflow is 220 l/s, harmless outflow is 90 m^3/s (applied to the gauging station Jánský most).

HYDROLOGIC DATA

The catchment area is 294.2 km^2, mean long-term annual flow is 2.49 m^3/s, 355-day flow is 230 l/s, 100-year flow is 140 m^3/s.

TECHNICAL PARAMETERS

The reservoir dam is straight, concrete, gravity. The elevation of the crest is 433.95 m a.s.l., the length of the crest is 228.8 m, its width is 8.4 m, and the elevation of the crest above terrain is 24.95 m.

Bottom outlets: left DN 2,100, right 2 x DN 1,500, capacity of the left bottom outlet is at the level of storage volume 47.06 m^3/s, capacity of the right bottom outlets is 2 × 23.50 m^3/s at the level of storage volume.

Safety spillway is ungated, direct, crest with overflow surface of five fields, the length of the spillway is 66 m, the elevation of the spillway crest is 430.15 m a.s.l., the capacity at maximum water level is 179.8 m^3/s.

Reservoir

	water level [m a.s.l.]	volume [M m^3]	area [ha]
Constant storage volume:	422.70	1.046	
Storage volume:	424.50	0.518	
Manageable protective volume:	430.15	4.698	
Unmanageable protective volume:	431.40	0.989	
Total volume:	431.40	5.687	76.8

6.3.6 Stanovice Water Work

The Stanovice WW is built on 3.2 river km of the watercourse Lomnický potok, at the village of Stanovice in the Karlovy Vary Region.

THE PURPOSE AND THE CAPACITY

The Stanovice WW was built in the years 1972–1978. It is a component of the Stanovice-Březová water management system.

The main purpose of the Stanovice WW is water accumulation for the water supply of the town of Karlovy Vary and nearby municipalities, ensuring the downstream necessary minimum flow in the watercourse, and protection of Karlovy Vary against floods.

Additional purposes are management of the ice regime on the Teplá watercourse, power production and fishing.

Minimum outflow is 58 l/s, harmless outflow is 13 m^3/s.

HYDROLOGIC DATA

The catchment area is 92.1 km^2, mean long-term annual flow is 560 l/s, 355-day flow is 50 l/s, 100-year flow is 90 m^3/s.

TECHNICAL PARAMETERS

The reservoir dam is straight, earth filled, rocky with an upstream asphalt seal. The elevation of the crest is 519.50 m a.s.l., the length of the crest is 258 m, its width is 8.25 m, and the elevation of the crest above terrain is 57.5 m.

Bottom outlets: 2 × DN 800, the capacity at the level of storage volume 2 × 10.8 m^3/s.

Safety spillway is ungated sideways; the length of the spillway is 22 m, the elevation of the spillway is 515.30 m a.s.l., the capacity at maximum water level is 221 m^3/s.

Reservoir			
	water level [m a.s.l.]	volume [M m^3]	area [ha]
Constant storage volume:	483.00	1.650	
Storage volume:	513.35	20.164	
Manageable protective volume:	515.30	2.406	
Unmanageable protective volume:	518.00	3.580	
Total volume:	518.00	27.800	142

6.3.7 Nechranice Water Work

The Nechranice WW is built on 103.44 river km of the watercourse Ohře, at the villages of Březno and Chbany in the Ústí nad Labem Region.

THE PURPOSE AND THE CAPACITY

The Nechranice WW was built in the years 1961–1968.

The main purpose of the WW is ensuring the necessary minimum flow in the watercourse, increasing of the river flow for the water supply to industry, agriculture, energy production and remediation, flood protection and power production.

Additional purposes are the elimination of the impacts from accidents, influencing the unwanted ice phenomenon on the lower Ohře River, water sports, fishing and recreation. The minimum outflow is 8 m^3/s; harmless outflow is 170–200 m^3/s.

HYDROLOGIC DATA

The catchment area is 3,590 km^2, mean long-term annual flow reaches 30.8 m^3/s, 355-day flow is 4.6 m^3/s, 100-year flow is 753 m^3/s.

TECHNICAL PARAMETERS

The reservoir dam is straight, earth filled. The elevation of the crest is 274.50 m a.s.l., the length of the crest is 3,280 m, its width is 9 m, and the elevation of the crest above terrain is 47.5 m.

Bottom outlets: 2 × DN 1,800, the capacity at the level of storage volume 2 × 50.7 m^3/s.

Safety spillway is a crest with three fields, dammed by segments. Two hydrostatic segments have 15.0 m; the elevation of the overflow edge of lowered segments is 268.00 m a.s.l. The capacity of both fields at maximum water level is 714 m^3/s. One lifting segment in the central field has 13.0 m, the elevation of gated segment is 263.00 m a.s.l., the capacity of central field at maximum water level is 479 m^3/s, and the total capacity at maximum water level is 1,193 m^3/s.

Reservoir

	water level [m a.s.l.]	volume [M m^3]	area [ha]
Constant storage volume:	235.40	2.650	
Storage volume:	269.00	233.215	
Manageable protective volume:	271.90	36.562	
Unmanageable protective volume:	273.05	15.205	
Total volume:	273.05	287.632	1,338

6.4 Description of a simulated hydrometeorological episode

A modeled hydrometeorological situation is based on a real hydrometeorological situation that occurred in May of 2006. The experienced situation was used for the calibration.

The experienced meteorological situation was modified in such a way that culminating flows reached values of very low probability in monitoring stations. The motivation was the training for an extreme situation which has not happened yet. The precipitation 48-hours totals were between 120 and 220 mm.

The precipitation amounts were increased to 120–250% against the values from May 2006.

The highest precipitation sums were simulated in higher parts of the catchment. This resulted in reaching 50-year to 100-year flood levels at the Jesenice WW, and exceeding 100-year flood levels on the upper Ohře River above the Skalka WW, and in the Teplá River catchment above Březová WW. In the lower parts of the Ohře River, flows up to 20-year flood levels were simulated.

The precipitation causing the simulated floods was derived from the weather situation during May–June of 2006.

This existing real situation, originally in 2006, was documented by reanalysis of the surface pressure field, the field of geopotential height at isobaric levels 500, 700 and 850 hPa, the field of air temperature at isobaric levels 500 and 850 hPa and the relative humidity field at isobaric level 700 hPa.

Describing the original situation from May 2006, the driving air pressure systems were the significant area of a low pressure system above Scandinavia and an area of high pressure with the center on the west of Portugal.

The individual frontal systems penetrated from the North Atlantic Ocean crossing approximately over Iceland, then Scotland, North Germany and finally Denmark.

The partially different distribution of the pressure systems established behind the last cold front on the night of May 28th to the 29th of 2006. The center of the low pressure system moved above Saint Petersburg in Russia, and the center of the dominate anticyclone (high pressure area) moved north near Ireland.

Cold and relatively moist air flowed into Central Europe from the north. Rain showers formed in the air, especially in the mountainous areas. The showers were spatially and temporally very variable. The maximum precipitation occurred consequently on the area administrated by the Ohře River administration during a crossing of frontal waves in May 27th and 28th of 2006.

The question arises as to why the meteorological situation from May 2006 was selected for the simulation game. The reason is very simple. The Ohře River catchment was not recently struck by a "bigger" flood in contrast to the other catchments in the Czech Republic. However, such flooding could have potentially occurred in May 2006. It was not even necessary to change the surface pressure field to substantially increase the precipitation sums.

Northwest air currents with relatively high advection of moisture and with areas of upward motion strengthened close to peaks of individual frontal waves, guarantee significant precipitation in the route of these waves.

Consequently, the slight modification of movement or number of wave peaks was sufficient. Waves on the frontal boundary may arise in such situations e.g. by movement from smooth sea to substantially coarser land.

The series of precipitation sums in 1 hour time increments prepared by CHMI, were then used as input data for modeling of the river flow.

The rainfall-runoff model HYDROG was used for the calculation of flow in all the gauging stations standardly monitored by the Ohře River administration. HYDROG was also used for a calculation of the hydrological response.

The Ohře River administration uses the HYDROG for forecasting of inflows into the reservoirs and optimization of operational management. The whole model consists of 7 hydrological models with a total area 3,617 km^2 with an average detaility 0.88 km^2.

An example of the difference between the flood in May 2006, and the flood of the simulation game is presented in *Fig. 6.3*. The inflow into the Skalka reservoir observed in May 2006 reached the 5-year flood. The modeled flood hydrograph has two peaks and exceeded the 100-year flow.

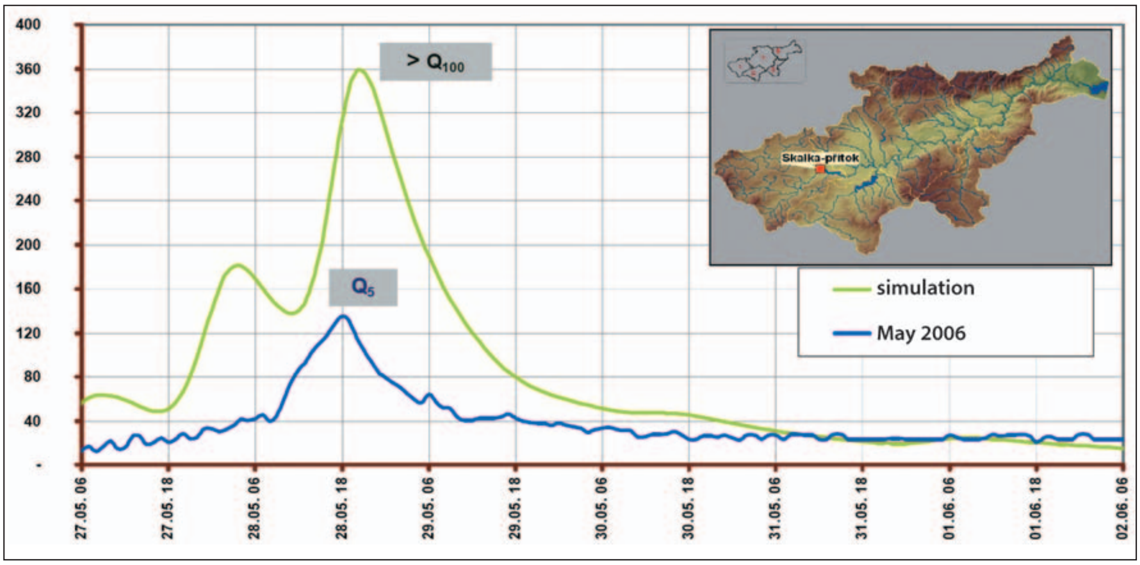

Fig. 6.3 The comparison between the simulated and original inflow into the Skalka reservoir

6.5 Schedule of the workshop

The evening before the simulation game (12th November 2008)

The introduction presentation for experts on operation of dams took place in the afternoon. The dispatchers had an opportunity to familiarize themselves with all of the game materials and game instructions.

The introduction presentation for other participants let them know the motivation and the simulation game session purpose.

The future playing team members got to know the environment, the simulation game instructions and the expected course of the game. Most importantly, they met their team-mates during the informal evening.

The participants were asked to fill out the 1st part of the questionnaire about their expectations and supposed benefits of the simulation game (for details on participatory process evaluation see the sec. 6.6.2).

All members of playing teams got information about the equipment of the rooms, where they would operate with the reservoir system, i.e. with hardware and software available for the simulation game.

Some of the experts on the operation of dams used this opportunity and made preparations for the simulation game. They got all the introduction game materials in advance by e-mail (technical description of the reservoirs, dam operation protocols etc.).

Introduction presentations (morning of 13th November 2008)

Before the simulation game itself, the game introduction presentations took place.

All the workshop participants got information on issues with meteorological and hydrological forecasts and all necessary organization instructions.

The simulation game (13th November 2008, from 10:00 to 17:00)

The simulation game was launched at 10:00: all the members of the playing teams were in their operation rooms, and the observers and evaluators observed from the simulation game headquarters.

There was a flexible lunch break during the simulation game. The simulation game ended shortly after 17:00 and all workshop participants (playing team members, observers, game leaders, and hydrology response staff) gathered at the conference room where refreshments were available.

Four playing teams, each with seven members, participated in the simulation game. The members of each team included:

- Representatives of local and regional authorities for environment (3 in each team) or crisis management (2 in each team) responsible for decision making during flooding (warning, evacuations etc.). These team members provided local knowledge;
- Experts in the operation of dams providing the technical knowledge. These were the employees of water administrations in other parts of the Czech Republic and members of the relevant control room staff (dispatchers, 2 in each team).

The researchers were interested in the optimization of the operational management of the water management systems during a flood assessed their flood management models (Sovina 2009).

The structure of the main relationships during the simulation game is presented in *Fig. 6.4*.

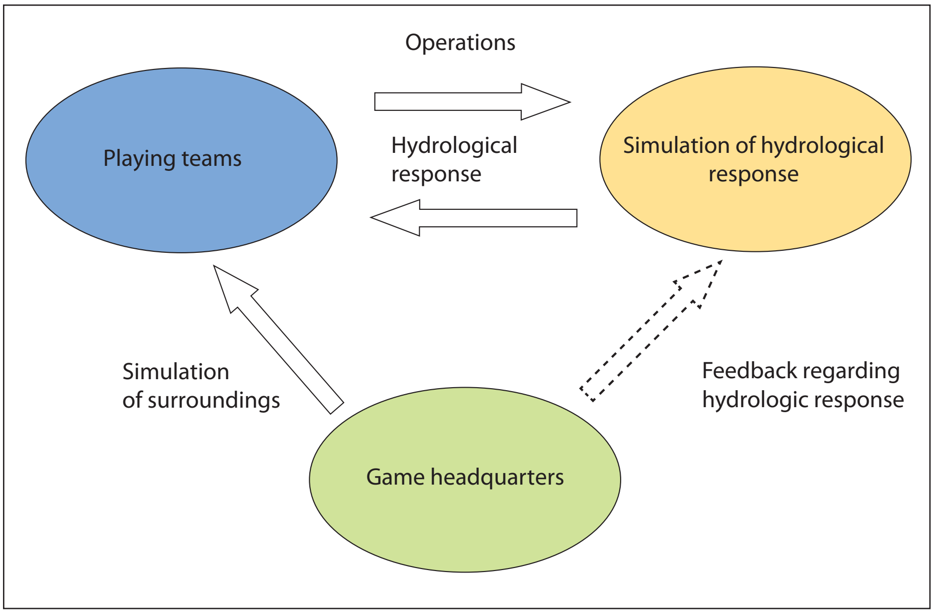

Fig. 6.4 Relationships during the simulation game

The commentary on the operations of the individual playing teams was provided at the simulation game headquarters. Presentations and a broad discussion on flood related issues also took place.

The members of the simulation game headquarters communicated with the playing teams and provided feedback to the hydrology response staff (workers of the Ohře River administration) regarding the technical issues of the simulation.

Simulation response staff provided the data about the dam operations effects to the playing teams.

Individual playing teams agreed on the roles of their members and ordered dam operations. The roles of individual team members stemmed from their different backgrounds.

Some of the team members – representatives of local and regional authorities brought their own laptops and used them for the simulation game purposes.

Generally the representatives of local and regional authorities provided local knowledge, and dispatchers provided the expert knowledge. The learning in groups occurred in three dimensions:

- Cooperative learning about the operations of water management systems during a flood (the representatives of local and regional authorities);
- Training of expert skills and learning expert knowledge in an unknown environment (dispatchers);
- Cooperative learning and training integrating the cooperation of different stakeholders in a flood situation.

After the end of the simulation game (13th November 2008, evening)

When the playing teams ended the operations, they were asked to fill out the 2nd part of the questionnaire, where they expressed their opinion on the course of the simulation game and its benefits.

The results of the operations of the individual playing teams were presented at the simulation game debriefing (for details see the sec. 6.6.2). The members of each playing team presented their view on the simulation game and made recommendations for future simulation game sessions.

The reception for all participants of the simulation game was organized later in the evening, where the Director of the Ohře River administration (*Povodí Ohře, s.p.*) Ing. Jiří Nedoma gave a speech. The first results of the participatory process evaluation were also presented.

6.6 Evaluation

6.6.1 Water management evaluation

After every significant flood people think about whether everything was done for the mitigation of flood destructive impacts, and if anything can be done better in the future. Naturally, after more significant floods these discussions are more emotional.

In the same way, the simulation game participants discussed their individual decisions during the game and compared their strategies with strategies of the other playing teams.

In this section, we present the description of individual decisions of each playing team during the decision-making processes. The effects of the decisions are then compared, and examples of the reaction on available hydrological forecasts in selected flow gauging stations and reservoirs (*Fig. 6.5*) are presented.

Fig. 6.5 Localisation of selected flow gauging stations

Water management system Skalka, Jesenice, Horka, Citice

All playing teams did the operations without any significant errors on this water management system.

1st decision-making – 27th May, 00:00

State of the water management system: Water from the Skalka reservoir is released down to a level of 441.50 m a.s.l. (about 70 cm lower = 2 M m^3). The inflow is constantly below 10 m^3/s.

The water level in the Jesenice reservoir is up to 5 cm above the level of storage volume. The inflow into the reservoir is ca. 7 m^3/s.

The latest prognosis B1 from the 26th of May at 12:00 allows for an estimate for the next 12 hours: 10–15 mm, then on the 27th of May 30–50 mm. Meteorological forecast reports on May 27th and 28th include heavy precipitation, probably reaching the 3rd degree of flood protection activity.

Decision-making Skalka: All the playing teams release 45 m^3/s. It corresponds to the 2nd degree of flood protection activity).

Decision-making Jesenice: Playing teams 1, 3 and 4 order 10 m^3/s, and team 2 orders 18 m^3/s. It corresponds to the 2nd degree of flood protection activity).

Results: The water level in the Skalka reservoir is very similar for all the playing teams. Playing team 2 reached the elevation of storage volume; the water levels of the other playing teams almost did not change. All the decisions reached were correct in the current situation.

2nd decision-making – 27th May, 12:00

State of the water management system: The inflow into the Skalka reservoir increased by 50–55 m^3/s in the last 12 hours. The inflow into the Jesenice reservoir reached 15 m^3/s.

The precipitation prognosis G2 from the 27th of May at 12:00 for the next 12 hours is 40–70 mm. The prognosis for the 2nd of May is 50–80 mm.

Meteorological forecasts D1 and E1 support the precipitation prognosis.

Hydrological prognosis F1 from the 2nd of May at 6:00 supposes from the 27th at 10:00 an increased inflow into the Skalka reservoir till the 28th of May at 4:00 of 200 m^3/s, then a moderate decrease, and from the 28th of May at 12:00 until the 28th of May at 21:00, an increase to 270 m^3/s.

The hydrological prognosis then supposes the permanent decrease of the inflow into the Skalka reservoir.

The prognosis supposes a fluent increase of inflow into the Jesenice reservoir from the 27th of May at 12:00 through the 29th of May at 3:00 of up to 90 m^3/s, and then a decrease is supposed to occur.

Decision-making Skalka dam: Playing teams 1 and 2 suggest a sequential increase of outflow from 45 to 150 m^3/s. Playing team 3 suggests an increase to 80 m^3/s. Playing team 4 remains on 45 m^3/s outflow.

Decision-making Jesenice dam: In this step, the playing teams 1, 3 and 4 keep a constant water level in the reservoir. Playing team 2 released all water from reservoir.

Results: At the Skalka reservoir, playing teams 1 and 2 overtake the inflow increase by 3–6 hours. It is a very effective strategy. Playing team 3 is by ca. 6 hours behind the inflow and fills up about half of the available storage. Playing team 4 filled up all available storage volume.

Regarding the observed heavy precipitation in the previous step and the prognosis, the decisions of playing teams 3 and 4 seem to be weak.

3rd decision-making – 28th May, 00:00

State of the water management system: The inflow into the Skalka reservoir at first increased to 180 m^3/s and then decreased again to the previous value 140 m^3/s. The inflow into the Jesenice reservoir slowly increased up to 25 m^3/s.

Decision-making Skalka dam: Playing team 1 increases the outflow rapidly to 200 m^3/s. Playing team 2 gradually increases the outflow to 170 m^3/s, playing team 3 increases the outflow to 140 m^3/s and playing team 4 increases the outflow to 165 m^3/s.

Decision-making Jesenice dam: Playing team 1 increased the outflow to 46 m^3/s. The capacity of the dam outlet devices is overcome. The other playing teams kept the 18 m^3/s outflow.

Results at Skalka reservoir: Playing team 1 distinctively released water. Playing team 2 kept the water level constant. Playing team 3 increased the water level to about 25 cm; playing team 4 increased it about 70 cm (they did not succeed in the compensation of the long-term plan to keep an outflow of 45 m^3/s in the previous steps).

Results Jesenice reservoir: The decision of playing team 1 led to getting at the water level of the storage volume. The other playing teams slowly filled the manageable protective volume.

4th decision-making – 28th May, 12:00

State of the water management system: The inflow into the Skalka reservoir reached 140 m^3/s. The inflow into the Jesenice reservoir reached 45 m^3/s.

The hydrological prognosis M3 from the 28th of May at 06:00 predicts the culmination of 400 m^3/s by 21:00 and then a subsequent decrease. The inflow into the Jesenice reservoir is supposed to culminate on the 29th of May at 06:00. The value of the inflow has to be 140 m^3/s.

The precipitation forecast N4 is available. It predicts 30–45 mm during the next 12 hours. No significant precipitation is predicted on May 29th.

Decision-making Skalka dam: Playing team 1 keeps the outflow of 200 m^3/s, playing team 2 increases to 230 m^3/s, playing team 3 increases to 160 m^3/s and playing team 4 keeps 165 m^3/s.

Decision-making Jesenice dam: Playing team 1 keeps the outflow of 45 m^3/s, playing teams 2 and 4 keep 18 m^3/s, playing team 3 increases to 26 m^3/s (3rd degree of flood protection activity).

Results at Skalka reservoir: Playing team 1 reached the level of storage volume, playing team 2 reached a level of 442.50 m a.s.l., playing teams 3 and 4 reached the maximum allowable level of 443.60 m a.s.l. However, the inflow did not culminate yet. The decisions of playing teams 3 and 4 are not understandable.

Results at Jesenice reservoir: Playing teams 2, 3 and 4 reached the unmanageable protective volume and overflew the dam. The maximum outflows via overflow reached 70–80 m^3/s. Playing team 1 has the water level ca. 40 cm below the overflow edge. It is an effect of their wrong decision in the 3rd step. Playing team 1 later also has an overflow of up to 60 m^3/s.

It is significant that the decision-making in this step is crucial for the management of outflow from the Skalka WW. Playing teams 1 and 2 have an available protective volume of ca. 7.6 M m^3 before the decision.

According to the prognosis M3 the flood wave above the capacity of 200 m^3/s should have a volume of 9.3 M m^3. The wave above 250 m^3/s should have a volume 5.3 M m^3.

It is possible to estimate that the flood wave above the initial flow of 140 m^3/s corresponds approximately to the precipitation sum in the middle of the range of the N4 prognosis. It is possible to decrease the flow to ca. 220 m^3/s with a free volume of 7.6 M m^3. Playing teams 1 and 2 decided in a very experienced way.

The actual flood wave was distinctively different from the M3 prognosis. The maximum inflow reached 355 m^3/s. Moreover, the shape of the actual simulated flood wave was distinctively narrower with a substantially smaller volume. It would be possible to lower the flood wave up to ca. 160 m^3/s by using the available protective volume as it followed from information before the 5th decision-making point.

In real operational management situations this flood wave would have been recognized on May 28th around 18:00. In such situations, when the precipitation has ended, it is suitable to lower the outflows as much as possible. The motivation is to separate the culmination of outflow from the Jesenice reservoir from the culminating outflows on the tributaries.

6th decision-making – 29th May, 12:00

7th decision-making – 30th May, 12:00

8th decision-making – 31st May, 12:00

The inflows are decreasing in the whole water management system. All playing teams are releasing water from reservoirs. The flood event is ending.

The playing teams that successfully operated the dams left a large part of their available protective volume free. Consequently, the question arises whether it would be possible to use the volume for lowering the culminating flow in the Citice gauging station. Theoretically it would be possible, but the strategies of the playing teams focused exclusively on lowering the maximum outflows from reservoirs; the cooperation of the two main water works was not considered by them.

Flow gauging station Citice

The development of the flow is interesting regarding the difference of the results between playing teams 1, 3 and 4. Playing team 1 started increasing the outflows from the Skalka reservoir ca. 6 hours before the increase of the inflow into the reservoir. They simultaneously started releasing water from the Jesenice reservoir (ignoring the impossibility of an order to release 45 m^3/s and regarding the possible 30 m^3/s). Then, the culmination of the flow at the gauging station reached 400 m^3/s already on May 29th at 3:00.

The playing teams 3 and 4 reacted to the inflow into the Skalka reservoir late. This late response led to a later culmination of 370 m^3/s at Citice. The culmination of 400 m^3/s was at Citice on May 29th at 15:00. These culminations were also caused by the unmanageable overflow from the Jesenice reservoir.

Playing team 2 showed an excellent solution by delaying the biggest outflow from the Skalka and Jesenice reservoirs. By this measure they reached a long duration of a maximum flow of 350 m^3/s on May 29th from 3:00 until 24:00. Their solution was even better than the optimal solution.

Water management system Březová, Stanovice, Thermal

1st decision-making – 27th May, 00:00

State of the water management system: The inflow into the Březová reservoir slowly increased up to 3 m^3/s. The inflow into the Stanovice reservoir is 0.5 m^3/s. The water level in the Březová reservoir is approximately 20 cm below the maximum level of the storage volume. The water level in the Stanovice reservoir is at the level of the storage volume.

The precipitation prognosis B1 from May 26th at 12:00 predicted 5–15 mm for the next 12 hours. It predicted 35–60 mm on the 27th of May.

Decision-making Březová dam: Playing teams 1 and 2 gradually increased the outflow to 20 m^3/s. Playing team 3 increased the outflow to 5 m^3/s and playing team 4 increased it to 40 m^3/s.

Decision-making Stanovice dam: Playing team 3 increased to 13 m^3/s and the other playing teams increased to 5 m^3/s.

Results at Březová reservoir: The decision of playing team 2 caused the water level to be within the storage volume. The decision of playing team 4 caused the water level to be lowered to the level of constant storage volume. The decisions of playing teams 1 and 3 caused the water level to be raised 50 cm above the storage volume.

Results at the Stanovice reservoir: All playing teams released water from the reservoir.

2nd decision-making – 27th May, 12:00

State of the water management system: Inflow into the reservoirs Březová and Stanovice reached 15 m^3/s, respectively 5 m^3/s.

The hydrological prognosis F1 from the 27th of May at 06:00 predicts a culminating flow at the Březová dam of 75 m^3/s on the 29th of May at 15:00. It predicts a culminating flow at Stanovice of 35 m^3/s on May 27th at 17:00.

The precipitation prognosis G2 from May 27th at 12:00 expects 40–55 mm in the next 12 hours. It predicts 55–80 mm on May 28th.

Decision-making Březová dam: Playing team 1 kept the outflow of 20 m^3/s, playing teams 2 and 4 changed to 10 m^3/s. Playing team 3 gradually changed to 40 m^3/s.

Decision-making Stanovice dam: Playing team 1 increased to 10 m^3/s, the other playing teams increased to 13 m^3/s.

Results at Březová reservoir: Playing team 2 reached the level of constant storage volume. The other playing teams are on the level of storage volume.

Results at Stanovice reservoir: All playing teams released water from the storage volume.

3rd decision-making – 28th May, 00:00

State of the water management system: The inflow into the Březová reservoir reached 40 m^3/s. The inflow into the Stanovice reservoir is 22 m^3/s.

The precipitation prognosis G2 predicts heavy precipitation.

Decision-making at Březová dam: Playing team 1 increased to 60 m^3/s. Playing team 3 increased to 50 m^3/s. Playing team 4 increased to 54 m^3/s (3rd degree of flood protection activity). Playing team 2 jumps from 70 to 40 and then to 54 m^3/s.

Decision-making Stanovice dam: Playing team 1 increased to 27 m^3/s. Playing teams 2 and 3 kept 13 m^3/s and playing team 4 increased to 22 m^3/s.

Results at Březová reservoir: Playing team 1 keeps the water level at 426.30 m a.s.l., playing team 2 stays at the level of constant storage volume. Playing team 3 is near the level of storage volume. Playing team 4 keeps 428.30 m a.s.l.

Results at Stanovice reservoir: The playing teams 1, 2 and 3 are near the level of storage volume.

The increased outflow from the Březová reservoir is a correct decision without a doubt. Keeping the water level in the protective reservoir is risky when heavy precipitation is expected. The protective reservoir volume of the Stanovice reservoir is sufficient for the maximum expected precipitation.

4th decision-making – 28th May, 12:00

State of the water management system: The inflow into the Březová reservoir reached 60 m^3/s. The inflow into the Stanovice reservoir decreased to 20 m^3/s.

The hydrological prognosis M3 from May 28th at 06:00 predicted the culmination of the inflow into the Březová reservoir 127 m^3/s on the 27th of May at 00:00. The culminating inflow into the Stanovice reservoir is 57 m^3/s on the 28th of May at 21:00.

The precipitation prognosis N4 from the 28th of May at 12:00 predicts 45–60 mm in the next 12 hours.

Decision-making Březová dam: Playing team 1 kept 60 m^3/s. Playing team 4 kept 54 m^3/s. Playing team 2 increased to 77 m^3/s (3rd degree of flood protection activity). Playing team 3 increased to 65 m^3/s of outflow.

Decision-making Stanovice dam: All the playing teams keep the outflow at previous values.

Results at Březová reservoir: Playing team 2 reached the water level of 428.20 m a.s.l. The decisions of playing teams 1 and 3 led to the water level at the overflow edge. The reservoir is full and water overflows 105 m^3/s for playing team 4.

Results at the Stanovice reservoir: All the playing teams have a big reserve in the protective reservoir volume.

The decision-making was crucial in this step. The M3 prognosis predicts a culminating flow of 130 m^3/s on the 29th of May at 00:00. In contrast, all playing teams remain in an interval between the 2nd and 3rd degree of flood protection activity, i.e. 53–78 m^3/s.

However, the actual culmination of ca. 180 m^3/s came already on the 28th of May at 21:00. The playing teams should deeply analyze the available prognoses, trends, volume of flood wave and protective volume. The outflow ordered by the playing teams should be much bigger.

5th decision-making – 29th May, 00:00

State of the water management system: The inflow into the Březová reservoir rapidly increased until the 28th of May at 18:00 by 160 m^3/s. The culmination inflow was 170 m^3/s at 21:00 and now is 160 m^3/s. The culmination inflow into the Stanovice reservoir was 40 m^3/s at 18:00. It is 28 m^3/s now.

Prognoses M3 and N4 are valid, and additional precipitation is not predicted.

Decision-making Březová: There is no decision to be made because all playing teams are in a situation of unmanageable overflow.

Decision-making Stanovice: Playing team 1 ordered to close the outlet (0 m^3/s). Playing team 4 decreased to 1 m^3/s. Playing teams 2 and 3 stayed at 13 m^3/s.

Results at the Březová reservoir: The outflow of playing teams 1 and 3 reached the value of 130 m^3/s. Playing team 2 reached ca. 100 m^3/s. Playing team 4 reached 145 m^3/s.

Results at the Stanovice reservoir: No playing team used a large part of the protective reservoir volume.

In this step, playing teams 1 and 4 finally closed the outlet from the Stanovice reservoir. Unfortunately, playing team 2 forgot about the cooperation between the reservoirs. They could have had excellent results at the Thermal flow gauging station.

6th decision-making – 29th May, 12:00

7th decision-making – 30th May, 12:00

8th decision-making – 31th May, 12:00

The decrease of inflow occurs in the whole water management system. All the playing teams release water from reservoirs.

Flow gauging station Thermal

Gauging station Thermal is situated on the Teplá River in the town of Karlovy Vary (Karlsbad). The development of flow into the Thermal gauging station shows the difficulty of managing this water management system. The outflow response during torrential rains is very short.

Even the optimal solution reached the overflow higher than 100 m^3/s at the Březová reservoir for four hours (the overflow culminated in 110 m^3/s for an hour) at keeping the outflow from the Stanovice reservoir only at 13 m^3/s. That led to a culminating flow of 118 m^3/s at the Thermal gauging station.

Whole Water management system of the upper Ohře River

The Drahovice flow gauging station has a catchment area of 2,856 km^2. 1,534 km^2 of it is controlled by the water works, the part of the catchment in the downstream reservoirs is 1,322 km^2, i.e. 46%. Consequently, the possibilities to control the flow in this gauging station are very limited. In practice, they are reduced only in an effort to decrease the maximum flow into both gauging stations at Citice and Thermal.

From the development of the flow at the Drahovice gauging station, it follows that none of the playing teams considered this station. It is the right approach: Skalka and Jesenice are too far away; they control 38% of the catchment area. Březová and Stanovice control 13% of the catchment area. Moreover, the defined fictive damage functions almost do not consider the flow in this gauging station.

However, it is interesting that the strategy of playing team 1 showed to be the most inconvenient for the flow in the Drahovice gauging station: maximum flow was 600 m^3/s. Playing team 2 had a culmination flow of 540 m^3/s because of the combination of culminations in the tributaries. Playing team 4 reached the maximum flow of 525 m^3/s here. Playing team 3 reached 510 m^3/s and the optimal solution was 505 m^3/s of flow.

Damage functions

The competiveness factor of the simulation game calls for the comparison of results from the playing teams after a unified criterion.

The most suitable for this purpose are the economic damage functions that express the damages caused by the flood, and financial expenses induced in the inundation zone depending on the highest flow in the relevant flow gauging station. The damage functions used here are fictional; they were defined only for the purposes of the simulation game. They are not based on any analysis of local conditions. The results of the playing teams are presented in *Table 1*. The result of optimal operations (Optimal) is also presented for comparison.

Table 1 The damage function results of individual teams

TEAM	CITICE		THERMAL		DRAHOVICE		DAMAGES
	Q_{max}	Damage	Q_{max}	Damage	Q_{max}	Damage	Total
1	410	330	139	890	605	132	1,352
2	355	303	110	600	540	121	1,024
3	375	313	139	890	515	117	1,320
4	400	325	151	1,010	525	119	1,454
Optimal	370	310	118	680	505	115	1,105

6.6.2 Evaluation of the participatory process

The main objective of the participatory process evaluation was to obtain feedback from the simulation game participants and observers in the simulation game headquarters, to find out perceptions and expectations of the playing team members, to evaluate the benefits of the given approach of the simulation game on operational flood management, and to provide recommendations for the next simulation game in water management.

The method of the participatory process evaluation

The social science evaluation was carried out by using the questionnaire survey among the participants of the simulation game and by observations made during the course of the game.

The game participants were asked to fill out the questionnaire based on the criteria of participatory process effectiveness as they were defined by Rowe and Frewer (2000, 2004). For details on the effectiveness criteria for the evaluation of participatory processes see sec. 5.2.

The questionnaire contained closed question – statements, where respondents expressed how much they agreed or disagreed with the given statements. The questionnaire also contained open questions, where the respondents could express their opinions more broadly. The questionnaire was divided into two main parts:

- 1st part: expectation and preparation for the simulation game,
- 2nd part: experienced benefits of the game, evaluation and the overall impression from the workshop.

The questions were focused mainly on the evaluation of benefits gained by individual game participants, i.e. how much the simulation game contributed to an improvement of communication and collaboration among flood situation stakeholders, betterment of their knowledge and consequently better preparedness for possible future flood situations.

The second part of the questionnaire also contained questions about evaluation of the progress of the game itself and the overall organization of the workshop from the participants' point of view.

The objective of such an evaluation of the progress of the simulation game is to obtain feedback from members of the playing teams for the betterment of the simulation game instructions and its structure for a more effective future simulation game session.

From a quantitative point of view the questionnaires were evaluated in the following way.

The following possibilities with corresponding point values were given for every statement:

- I absolutely disagree 1
- I mostly disagree 2
- I partially agree 3
- I mostly agree 4
- I absolutely agree 5

The arithmetic mean was calculated with the point values and so the prevailing position of the respondents was found. Border values for the prevailing attitudes of the respondents were: over 4.6 "I absolutely agree", from 3.6 to 4.6 (including) "I mostly agree", from 2.6 to 3.6 (including) "I partially agree", from 1.6 to 2.6 (including) "I mostly disagree" and under 1.6 "I absolutely disagree".

Results and discussion of the participatory process evaluation

Statements and question in the questionnaire were focused on scopes of interest:

1. Improvement of the collaboration and communication,
2. the understanding of players own and other stakeholders' roles during a flood situation,
3. the betterment of the knowledge related to flood situations and change of view on the floods and
4. the evaluation of the simulation game from the players' point of view.

Firstly, the results of the questionnaire survey before the game are described. Then, the results of the survey after the game are presented. The results are then compared and in the end we present the evaluation of the simulation game workshop progress from the point of view of the playing teams' members.

The questionnaire respondents were:

- experts for operation of dams providing expert knowledge (dispatchers),
- representatives of local and regional authorities for environment and crisis management (authorities)
- the researchers interested in optimization of operational management of the water management system during a flood assessing their flood management models (developers).

The number of 35 respondents filled out the 1st part of the questionnaire. 28 respondents filled out the 2nd part of the questionnaire and 23 respondents filled out both parts of the questionnaire.

Queries before the start of the simulation game

Improvement of the collaboration and communication

Dispatchers who filled out the 1st part of the questionnaire were far more skeptical than the other respondents about the question of collaboration improvement after the workshop (see *Table 2*).

Overall, respondents presumed before the simulation game that after the workshop their collaboration with the other stakeholders during a flood situation would improve. For all the results see *Table 2*.

Table 2 Question 1, 1st part of questionnaire (before the game)

STATEMENT	I expect improvement of collaboration between myself and other stakeholders after this workshop			
	All	**Dispatchers**	**Authorities**	**Developers**
I absolutely disagree	0	0	0	0
I mostly disagree	5	3	0	1
I partially agree	7	4	2	1
I mostly agree	11	0	9	1
I absolutely agree	7	0	6	1
Sum of responses	30	7	17	4
Prevailing opinion	**I mostly agree**	**I mostly disagree**	**I mostly agree**	–

Respondents were also asked about on change of the overall situation among the stakeholders, i. e. whether the workshop would contribute to improvement of collaboration and understanding among the stakeholders of a flood situation. The opinions before the game are presented in *Table 3*.

Comparing *tables 2* and *3* one can see that the respondents were slightly more optimistic about this question than the previous one and expressed that the workshop would contribute to the improvement of the overall collaboration among the stakeholders.

It is probably caused by the fact that the water management experts (dispatchers) saw the workshop more as an opportunity for their professional skills training, than an opportunity for the improvement of their communication with other stakeholders of the flood situation.

On the other hand, the other stakeholders (non-professionals in the operational flood management) presumed that they would learn about the operational flood management and that it would improve collaboration among them and other stakeholders of flood situation.

Table 3 Question 6, 1st part of questionnaire (before the game)

STATEMENT	The workshop will contribute to the improvement of the overall collaboration and understanding among the stakeholders			
	All	**Dispatchers**	**Authorities**	**Developers**
I absolutely disagree	0	0	0	
I mostly disagree	1	0	0	1
I partially agree	6	2	2	1
I mostly agree	9	2	6	
I absolutely agree	14	3	8	2
Sum of responses	30	7	17	
Prevailing opinion	**I mostly agree**	**I mostly agree**	**I mostly agree**	–

The understanding of each player's own and other stakeholders' roles during a flood situation
Table 4 presents the attitudes and opinions of respondents before the game regarding their understanding of their own role and the role of others during the flood situation. Overall, respondents presumed that the simulation game would help them understand other stakeholders' role during a flood.

The dispatchers agreed with this statement partially. It is logical because the role of the dispatchers during a flood is very clear and from their water management professional point of view, the importance of understanding other stakeholders' roles during a flood is lower than the importance of professional training.

One of the motivations for organizing a workshop on the flood simulation game was to better understand one's own role during a flood. The related question was intended mostly for the respondents, who

Table 4 Question 3, 1st part of questionnaire (before the game)

STATEMENT	I suppose that the simulation game will better my understanding of the roles of the other stakeholders during a flood			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	1	0	0	1
I mostly disagree	2	1	0	0
I partially agree	5	2	2	1
I mostly agree	11	3	8	0
I absolutely agree	11	1	7	2
Sum of responses	30	7	17	4
Prevailing opinion	**I mostly agree**	**I partially agree**	**I mostly agree**	–

Table 5 Question 4, 1st part of questionnaire (before the game)

STATEMENT	I suppose that thanks to the simulation game I will better understand my role during a flood			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	3	2	0	0
I partially agree	7	2	1	1
I mostly agree	8	1	6	1
I absolutely agree	8	0	10	1
Sum of responses	26	5	17	4
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

are not professionals in water management (authorities). *Table 5* presents the opinions of respondents before the game.

The respondents predominately supposed that thanks to the simulation game they would better understand their role during a flood.

The improvement of knowledge related to flood situations and a change of view about floods
Regarding the improvement of knowledge related to flood situations and the change of view about floods, the simulation game was focused mainly on participants representing the local and regional authorities for environment or crisis management (authorities).

Around two thirds of these respondents absolutely agreed with the statement that the simulation game contributed to their understanding of floods and their management. The results are presented in the *Table 6*.

Table 6 Question 2, 1st part of questionnaire (before the game)

STATEMENT	I suppose that thanks to the simulation game I will better understand floods and operational flood management			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	1	0	0	1
I mostly disagree	4	4	0	0
I partially agree	4	1	1	1
I mostly agree	4	0	4	0
I absolutely agree	16	1	12	2
Sum of responses	29	6	17	4
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

Regarding the change of view about floods, the dispatchers did not anticipate that their view after the game would change. This corresponds to the assumption that this question concerns in particular the other members of the playing teams. According to these respondents, the simulation game has contributed to their change of perspective on the issue of flooding. An overview of the answers before the simulation game is shown in *Table 7*.

The answers of the respondents to the question, "what are their specific expectations from the simulation game?", match their background. Dispatchers supposed that they would get acquainted with a different catchment area and welcomed the opportunity to practice operational management of floods.

The other game participants expected to get acquainted with the issue of flooding regarding their operational management, operations of the water works and a reciprocal coordination among flood stakeholders.

Table 7 Question 5, 1st part of questionnaire (before the game)

STATEMENT	I suppose that the workshop will change my views on the issue of flooding			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	3	3	0	0
I mostly disagree	5	3	0	1
I partially agree	12	1	7	3
I mostly agree	6	0	6	0
I absolutely agree	4	0	4	0
Sum of responses	30	7	17	4
Prevailing opinion	**I partially agree**	**I mostly disagree**	**I mostly agree**	–

Queries after the simulation game

Improvement of the collaboration and communication

The improvement of communication was the focus of the 2nd question of the questionnaire's 2nd part. From the results it seems that according to the opinions of the respondents the communication among the water management stakeholders would improve (see *Table 8*).

Table 9 shows the position of the respondents after the end of the simulation game, in the specific case of the management of floods.

The workshop contributed to the improvement of the overall collaboration and understanding among the stakeholders (see *Table 10*).

Table 8 Question 2, 2nd part of questionnaire (after the game)

STATEMENT	I believe that thanks to the workshop I will now better communicate with other water management stakeholders			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	1	0	0	0
I mostly disagree	0	0	0	1
I partially agree	7	3	4	0
I mostly agree	6	1	5	0
I absolutely agree	13	1	8	2
Sum of responses	27	5	17	3
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

Table 9 Question 3, 2nd part of questionnaire (after the game)

STATEMENT	I believe that I will now better cooperate with other water management stakeholders			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	1	0	0	1
I partially agree	7	3	3	0
I mostly agree	7	2	4	0
I absolutely agree	13	1	10	2
Sum of responses	28	7	17	3
Prevailing opinion	**I mostly agree**	**I partially agree**	**I mostly agree**	–

Table 10 Question 16, 2nd part of questionnaire (after the game)

STATEMENT	The workshop contributed to the improvement of the overall collaboration and understanding among the stakeholders			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	3	0	1	0
I partially agree	5	1	2	0
I mostly agree	10	3	5	2
I absolutely agree	12	2	8	2
Sum of responses	30	6	16	4
Prevailing opinion	**I mostly agree**	**I mostly agree**	**I mostly agree**	–

Table 11 Question 4, 2nd part of questionnaire (after the game)

STATEMENT	I have a better understanding of my role during a flood			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	1	0	0	0
I mostly disagree	1	1	0	0
I partially agree	8	1	6	0
I mostly agree	9	2	7	0
I absolutely agree	5	0	3	2
Sum of responses	24	4	16	2
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

The understanding of a player's own and other stakeholders' roles during a flood situation

According to the respondents to the questionnaire, the simulation game contributed to their understanding of their own role during a flood (*Table 11*). Some of the dispatchers did not express their opinion on this issue, because they assumed that it was not relevant for them.

The respondents answered very similarly in the case of understanding their role during a flood, as is shown in *Table 12*.

Table 12 Question 14, 2nd part of questionnaire (after the game)

STATEMENT	I have a better understanding of the role of the other stakeholders during a flood			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	3	1	0	1
I partially agree	4	1	3	0
I mostly agree	10	3	6	1
I absolutely agree	11	1	8	1
Sum of responses	28	6	17	3
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

The improvement of knowledge related to flood situations and a change of view about floods

These questions concerned respondents other than the dispatchers. The results regarding the understanding of floods are shown in *Table 13*.

The change of view on the issue of flooding was also an important objective. An overview of the answers after the simulation game is shown in *Table 14*.

Table 13 Question 13, 2nd part of questionnaire (after the game)

STATEMENT	I now better understand floods and operational flood management			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	3	1	0	2
I mostly disagree	2	1	0	0
I partially agree	4	1	3	0
I mostly agree	11	0	9	1
I absolutely agree	6	1	5	0
Sum of responses	26	4	17	3
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

Table 14 Question 15, 2nd part of questionnaire (after the game)

STATEMENT	My view on the issue of flooding changed			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	3	1	1	1
I mostly disagree	7	3	2	1
I partially agree	4	0	3	0
I mostly agree	8	0	8	0
I absolutely agree	4	0	3	1
Sum of responses	26	4	17	3
Prevailing opinion	**I partially agree**	–	**I mostly agree**	–

Comparing the opinions of participants before and after the simulation game, it is obvious that the opinions did not change. It means that the participation in the simulation game gave them what they expected.

The evaluation of the simulation game workshop progress from the playing teams' members' point of view

Specific perceptions and expectations of participants stemmed from their background: Dispatchers mostly expected gaining experience from another catchment area. The other participants expected to gain information on flooding issues, better orientation in operational flood management in the region, and an understanding of the water administration body during a flood.

An important expectation mentioned by respondents was a better understanding of the operational flood management.

A significant aspect was training for better preparedness of an actual flood situation (*"In the case of an actual flood I will orientate better and know what to do."*) and verification of their own personal preparedness for a flood situation and, more generally, stress management.

Summarizing the opinions expressed in the questionnaires, the specific expectations of the simulation game participants corresponded well with the motivation for organizing the game session (see sec. 1.1).

The first question of the questionnaire's 2nd part (after the end of the game), concerns whether the simulation game took place in accordance with existing legislation. According to the respondents, the simulation game took place mostly in accordance with existing legislation. The respondents did not declare any specific objections.

Regarding the organization of the workshop, the respondents largely agreed that they received the necessary information in advance. Specifically see *Table 15*.

One of the important criteria for the success of the simulation game sessions is whether the individual participants have the possibility to affect its progress to the extent which they would like. From the

Table 15 Question 5, 2nd part of questionnaire (after the game)

STATEMENT	I received the necessary information relating to the workshop in advance, so I was able to prepare			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	1	0	1	0
I partially agree	3	1	1	0
I mostly agree	7	4	3	0
I absolutely agree	15	1	10	2
Sum of responses	26	6	15	2
Prevailing opinion	**I mostly agree**	**I mostly agree**	**I mostly agree**	–

Table 16 Question 8, 2nd part of questionnaire (after the game)

STATEMENT	I had no chance to influence the progress of the game to such an extent as I would like			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	15	4	7	2
I mostly disagree	5	0	4	1
I partially agree	5	1	4	0
I mostly agree	3	1	2	0
I absolutely agree	0	0	0	0
Sum of responses	28	6	17	3
Prevailing opinion	**I mostly disagree**	–	**I mostly disagree**	–

Table 17 Question 26, 2nd part of questionnaire (after the game)

STATEMENT	The purpose of the workshop was well explained by the organizers			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	0	0	0	0
I partially agree	0	0	0	0
I mostly agree	9	2	6	0
I absolutely agree	19	4	11	3
Sum of responses	28	6	17	3
Prevailing opinion	**I absolutely agree**	**I absolutely agree**	**I absolutely agree**	–

answers of the respondents it is seemed that they did. The overview of opinions expressed is presented in *Table 16*.

A very important factor of the game simulation is an explanation of its purpose by the organizers. Regarding this issue, the simulation game session was, according to the respondents, very successful. For the details see *Table 17*.

It is very important that individual members of the playing teams would not be bombarded with information during the simulation game. They need not be bombarded by information in order to be fully engaged in the game.

From *Table 18* it appears that the simulation game was able to overwhelm the participants with information.

The respondents suggested that the next version of the simulation game on operational flood management should have a reduced time lag between the game steps and consequently the simulation game would depict the real situation more closely.

Table 18 Question 20, 2nd part of questionnaire (after the game)

STATEMENT	During the game I was bombarded with information, so it was hard for me to engage			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	11	3	4	2
I mostly disagree	9	2	7	0
I partially agree	6	0	6	0
I mostly agree	1	1	0	0
I absolutely agree	1	1	0	1
Sum of responses	28	7	17	3
Prevailing opinion	**I mostly agree**	**I mostly agree**	**I mostly agree**	–

The respondents also suggested new components for the simulation game: simulation of connection to various flood commissions, simulation of flood protection activity degrees announcement, the possibility to watch the situation in inundation zones at individual flows and a connection to risk analysis in inundation zones.

From the answers of the respondents it seems that they were not confused and they did know what to do. The details are presented in *Table 19*.

The roles of playing teams' members should not be identical to their roles during the actual flood, because one of the purposes of the simulation game is getting to know others roles during an actual flood. The answers from the respondents corresponded well with this supposition (*Table 20*).

Table 19 Question 12, 2nd part of questionnaire (after the game)

STATEMENT	Sometimes I was confused during the game and I didn't know what to do			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	12	3	8	1
I mostly disagree	8	1	4	1
I partially agree	5	1	4	0
I mostly agree	2	1	1	0
I absolutely agree	1	0	0	1
Sum of responses	28	6	17	3
Prevailing opinion	**I mostly disagree**	–	**I mostly disagree**	–

Table 20 Question 18, 2nd part of questionnaire (after the game)

STATEMENT	I had no chance to influence the progress of the game to such an extent as I would like			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	3	0	1	1
I mostly disagree	10	1	7	1
I partially agree	7	3	4	
I mostly agree	3	1	2	
I absolutely agree	3	1	1	1
Sum of responses	26	6	15	3
Prevailing opinion	**I mostly disagree**	–	**I mostly disagree**	–

Table 21 Question 9, 2nd part of questionnaire (after the game)

STATEMENT	I had no chance to influence the progress of the game to such an extent as I would like			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	1	1	0	0
I partially agree	2	0	1	0
I mostly agree	7	1	5	1
I absolutely agree	18	4	10	2
Sum of responses	28	6	16	3
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

Team collaboration on solutions of common problems was one of the important factors contributing to the effectiveness of the simulation game. This criterion was fulfilled, as it is shown in *Table 21*.

Another important factor is that most of the decisions made during the game were the result of an agreement among all the members of the team. This criterion was also fulfilled as is shown in *Table 22*.

Table 22 Question 17, 2nd part of questionnaire (after the game)

STATEMENT	Most of the decisions made during the game were a result of an agreement among all the members of the team			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	1	0	0	1
I mostly disagree	1	1	0	0
I partially agree	4	1	3	0
I mostly agree	12	4	6	1
I absolutely agree	10	0	8	1
Sum of responses	28	6	17	3
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

Answering the question, "What was the best part of the game?" the respondents mentioned the perfect organization, the possibility to try operational management of the water management system during a large flood, good communication, the presence of extremely experienced dispatchers and qualified reactions from the representatives of the regional and local authorities. An interesting response was also that the best thing about the simulation game was the idea of organizing it.

Answering the question, "What was the second best thing about the simulation game?" the respondents mostly mentioned refreshments, excellent organization and the clearness of the simulation game. The respondents also mentioned the simulation of complications during the flood (details in the sec. 6.6.2).

Answering the question, "What was the worst part of the simulation game?" the respondents mostly stated "nothing" or they skipped the question.

Importantly, the respondents mentioned that they had not had an opportunity to watch the parallel work of flood commissions before, and that it was difficult to engage at the beginning of the simulation game. The problem was also an overly long time frame at the beginning of the simulation game and the short time allowed for decisions.

Answering the question, "What was the second worst part of the game?" the respondents stated that it was difficult for them to keep focused during the whole simulation game.

The respondents would happily participate in a similar workshop in the future. Members of the playing teams supposed that they would recommend a similar workshop to their colleagues. The specific results are presented in *Table 23* and *Table 24*.

Table 23 Question 10, 2nd part of questionnaire (after the game)

STATEMENT	I will happily participate in a similar workshop in future			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	1	0	0	1
I mostly disagree	1	0	0	1
I partially agree	4	1	1	
I mostly agree	8	3	5	
I absolutely agree	14	2	11	1
Sum of responses	28	6	17	3
Prevailing opinion	**I mostly agree**	–	**I mostly agree**	–

Table 24 Question 11, 2nd part of questionnaire (after the game)

STATEMENT	I will recommend a similar workshop to my colleagues			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	1	0	0	0
I partially agree	1	0	1	1
I mostly agree	7	1	4	0
I absolutely agree	19	5	12	1
Sum of responses	28	6	17	1
Prevailing opinion	**I absolutely agree**	**I absolutely agree**	**I absolutely agree**	–

Table 25 Question 6, 2nd part of questionnaire (after the game)

STATEMENT	From my point of view the workshop fulfilled its purpose			
	All	Dispatchers	Authorities	Developers
I absolutely disagree	0	0	0	0
I mostly disagree	1	0	0	1
I partially agree	1	1	0	0
I mostly agree	10	4	4	0
I absolutely agree	14	1	11	2
Sum of responses	26	6	15	3
Prevailing opinion	**I mostly agree**	**I mostly agree**	**I mostly agree**	–

According to the respondents, the workshop fulfilled its purpose (details in *Table 25*).

Most of the respondents did not answer the question about what was missing from the workshop to fulfill its purpose or they stated that nothing was missing.

However, the respondents mentioned that it would be good for future simulation game sessions to add a decision making process of flood commissions and that generally the connection to authorities was missing.

According to the responses, the simulation game participants liked the game and the workshop made a good impression overall. Specifically, the respondents stated that they had not known what to expect, however they were positively surprised or that they liked the simulation game and that it fulfilled their expectations completely.

For a future simulation game session it would be good to add a simulation of the connection to flood commissions and to shorten the time periods between the decisions, especially at the beginning of the game. Generally, it is necessary to respect the backgrounds of the individual game participants.

Regarding the participatory process effectiveness criteria, the simulation game was successful. The simulation game workshop contributed to the improvement of integration and collaboration among different stakeholders of a flood situation.

The representatives of the local and regional authorities improved their understanding of their roles during a flood and they also improved their knowledge concerning flood related issues. Most of the respondents will happily participate in similar future workshop and will recommend it to their colleagues.

6.7 Concluding remarks

The objective of the simulation game session was not searching for the best possible strategy of managing this specific flood or the comparison of individual playing team results.

The simulation game session was meant to show the substantiality of uncertainties and the incompleteness of input information for decisions needing to be made in real time under stress. It also showed a need for the mutual understanding and tight cooperation of all the stakeholders.

The simulation game was verified to be easily playable, was played according to schedule without any technical problems, and all of the objectives were achieved.

The simulation game session pointed out that this water management system has to be managed with full attention, when it is needed in short time periods (approximately 1 hour each), with experiences from former flood situations and current information from monitoring stations in the catchment, prognoses and capabilities of both water works combined.

The participants could see the range of uncertainties dispatchers have to deal with and in particular the impacts of bad or late decisions.

7 Conclusions

Generally, the preparation of an accurate simulation game is not an easy task. It is very challenging in regards to both financial and human resources. Usually, it takes several years of work to properly prepare and test such a game.

The issues, the structure of roles, interactions and specific events have to be well-defined when the purpose of the game is research or training of operational management. For example if the topic of the game is operational flood management, it is important to consider the distribution of precipitation and volume (recurrence time) of the flood. In case the game simulates complex issues it is important to exclude questions and relationships which are not essential.

The definition of timeframes is very important while preparing a simulation game focused on operational flood management. The virtual timeframe defined the time of simulated events. The periods of real time must correspond well with virtual time, i.e. participants must have enough time for their decisions and they must have a chance to correct their potentially previous bad decisions. Definitions of both virtual and real timeframes are determined by the purpose of the game and by the physical and technical characteristics of a simulated water management system.

The whole simulation game session is recommended to be 3–5 hours long. The virtual time period with several interactions and 4–8 decisions, usually requires 15–20 minutes of real time. Consequently, the game should have 12–18 virtual timeframes. Nevertheless, longer simulation game sessions can be successful as was shown by the simulation game on operational flood management played in November 2008 in Chomutov.

Simultaneous simulation games can involve a restriction on time allowed for decisions. In the case of a violation of a time limit the participant loses control of the water management system in the given timeframe. Such an approach allows for the modeling of the limited time that dispatchers have for their decisions during real and stressful situations (e.g. flood).

However, the choice of the game design depends on the desired aim. The simulation games need to be tailored to their purpose. Simulation games prepared in a general way without taking into account the background and abilities of potential participants have limited chances to be successful. It is necessary to respect the backgrounds of the individual simulation game participants.

Summary

Floods are the result of specific meteorological and hydrological conditions, which cannot be influenced. However, preparedness on such situation can be improved in several ways e.g. by simulation games.

First, we present the theory connected to simulation games presented with regard to their use in operational management. The simulation games need to be tailored to the desired objective in order to be successful. Simulation games prepared only generally, without taking into account the background and the abilities of the potential participants, have limited chances to be successful.

Then, the overview of simulation games in water management is presented. The history of simulation games in water management of the Czech Republic follows and relevant lessons learned are presented. The base of the game preparation is always its purpose. The qualifications and specializations of the participants are determining factors when the purpose is training. The specification of the problem corresponds with the specialization of participants. Consequently, the knowledge and procedures to be learned are defined.

The approaches to the evaluation of a simulation game session are then presented and illustrated on.

The main topics of this publication are that illustrated through case study: the simulation game session organized by the Ohře River administration in the framework of the EU Project NeWater (http://www.newater.info/).

The main purpose of the simulation game was to demonstrate clearly the uncertainties connected to using the meteorological forecasts and the difficult decisions which have to be taken by the stakeholders (local decision makers, officers from the ministries, and representatives of enterprises which may be endangered by flood situation) and to enhance the understanding and cooperation between stakeholders with their various interests and the control room staff.

The simulation game was designed to be played by teams. The teams had to operate the dams of four reservoirs during the flood situation in such a way, that the impact of the flood was as reduced as possible.

The simulation game session was evaluated from water management and social science point of view. The effects of individual decisions of each playing team during the decision-making processes were compared, and examples of the reaction on available hydrological forecasts in selected flow gauging stations and reservoirs are presented.

The simulation game session pointed out that the water management system has to be managed with full attention, when it is needed in short time periods (approximately 1 hour each), with experiences from former flood situations and current information from monitoring stations in the catchment, prognoses and capabilities of both water works combined.

The realization of the simulation game of operational flood management proved that it is effective tool for the enhancement of integration and cooperation among water management stakeholders.

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