Brandenburgische Technische Universität Cottbus

About state of development and requirements on a transboundary operational flood forecasting system in the Odra river basin

Study within the frame of the BMBF-Project

Simulation of flood events in the Odra basin with a coupled model system

(The project this report is based on was funded by the German Federal Ministry of Science and Technology under the registration number 01 LA 9906/9907. The author is responsible for the content of this publication.)

Produced by the Chair of Hydrology and Water Management
of the Brandenburg Technical University Cottbus

Project co-ordination: Prof. Dr. rer. nat. habil. Uwe Grünewald

Authors:

Dipl.-Hydr. Christine Brodersen
Dipl.-Hydr. Sabine Schümberg
Dipl.-Geoök. Anne Schmitt
Dr.-Ing. Michael Kaltofen
Dipl.-Ing. (FH) Egbert Gassert

with use of supplements of:

Institute of Meteorology and Water Management (IMGW), Wrocław
Doz. Dr.-Ing. Alfred Dubicki & Mgr. Józefa Malinowska-Małek
Maritime Research Institute (MRI), Szczecin
Prof. Dr. habil. Ing. Wladyslaw Buchholz & Dr. Ryszard Ewertowski
Czech Hydrometeorological Institute (ČHMÚ), Ostrava
Ing. Arnošt Hošek
Institute of Meteorology and Water Management (IMGW), Poznań
Prof. Dr. habil. Ing. Piotr Kowalczak

Cottbus, December 2000

Contents

1 Motivation, objectives and proceeding 1

1.1 Motivation 1

1.2 Objectives 2

1.3 Proceeding 2

2 Brief description of the Odra river basin 3

2.1 Hydrography 3

2.2 Climate and precipitation conditions 7

2.3 Discharge and floods 8

2.4 Hydraulic engineering and flood defence structures 9

3 Legal basis and responsibilities 13

3.1 Czech Republic 13

3.2 Republic of Poland 16

3.3 Federal Republic of Germany 19

3.4 International co-operation 22

4 Flood forecast and early flood warning systems 24

4.1 Fundamental requirements on flood forecast 24

4.2 State of development of operational flood forecast and early flood warning systems 27

5 Causes for floods in the Odra river basin 30

5.1 Winter half-year 31

5.2 Summer half-year 33

6 About the state of the operational flood forecast in the Odra river basin 35

6.1 Flood forecast for the Upper Odra – Czech Republic 37
6.1.1 Meteorological forecast service by the ČHMÚ 37
6.1.2 Hydrological forecast service by the ČHMÚ 38
6.1.3 Planned activities 41

6.2 Flood forecast for the Upper and Middle Odra river - Poland 42
6.2.1 Meteorological forecast service by the IMGW Wrocław 43
6.2.2 Hydrological forecast service by the IMGW Wrocław 44
6.2.3 Planned activities 47

6.3 Flood forecast for the Lower Odra river and Warta river – Poland ... 51
6.3.1 Hydrological forecast service by the IMGW Poznań ... 51
6.3.2 Situation on the Lower Odra river ... 52

6.4 Flood forecast on the Border Odra - Germany (Brandenburg) ... 53
6.4.1 Meteorological Forecast Service by the DWD ... 53
6.4.2 Hydrological forecast service in Brandenburg by the LUA Brandenburg ... 53
6.4.3 Planned activities ... 54

6.5 Flood forecast for the Lausitzer Neiße river – Germany (Saxony, Brandenburg) ... 55
6.5.1 Meteorological forecast for the Lausitzer Neiße river by the DWD ... 56
6.5.2 Flood forecast for the Lausitzer Neiße river in Saxony ... 56
6.5.3 Flood forecast for the Lausitzer Neiße river in Brandenburg ... 58

7 Scientific-technical projects for flood simulation and pre-cautionary flood protection ... 59

7.1 Flood simulation projects ... 60
7.1.1 LISFLOOD ... 60
7.1.2 ODRAFLOOD ... 62

7.2 Further projects for flood protection ... 65
7.2.1 Planning basis for pre-cautionary flood protection ... 65
7.2.2 Projects for flood information systems ... 66

8 Summary and résumé ... 69

8.1 Summary of the present state of development of the operational flood forecast in the Odra river basin ... 69

8.2 Approaches for the improvement of the operational flood forecast in the Odra river basin ... 71
8.2.1 Data collection and data supply ... 72
8.2.2 Model structure and components ... 72
8.2.3 Integration of model operators and users of model results ... 73
8.2.4 Use of pre-operational models ... 74
8.2.5 Transboundary co-operation ... 75
8.2.6 Co-ordination of ongoing and planned activities ... 76

8.3 Résumé ... 78

References ... 80

Abbreviation index ... 86

Appendix ... 90

Register of figures

Fig. 1: Odra river basin with its main tributaries 6
Fig. 2: Lower Odra river with the main polder areas 11
Fig. 3: Storage volume of the Czech and Polish reservoirs in the Odra basin 12
Fig. 4: Flood forecast in the Czech Republic (after KUBÁT, 1998) 14
Fig. 5: System of flood forecast and flood warning in the Czech Republic (after KUBÁT, 1998) 15
Fig. 6: Flood forecast and decision system in the Polish part of the Odra river basin (supplemented after SCHMITT, 2000) 18
Fig. 7: Flood alert stages I to IV in the Federal States of Brandenburg and of Saxony (after LUA, 1995; SMU, 1998) 20
Fig. 8: System of flood forecast and flood defence in the German Odra river basin (under the authority of the Federal States) 22
Fig. 9: Organisation scheme of the ICPO, July 2000 (SCHMITT, 2000) 23
Fig. 10: Present systems of flood forecast in the Odra river basin, state: December 2000 36
Fig. 11: Sketch of the Upper Odra river, its main tributaries, and the reservoir system on Czech territory 39
Fig. 12: Principle of the flood warning system based on neural networks (STARY et al., 1998) 42
Fig. 13: Scheme of the model system operated by the IMGW Wrocław for flood forecast in the Upper and Middle Odra river basin (modified after MIERKIEWICZ, 1993) 45
Fig. 14: Weather radar system POLRAD in Poland (existing and planned weather radar stations) (IMGW, 1999) 48
Fig. 15: Visual presentation of the river gauges on the Upper and Middle Odra river and the distribution of precipitation within the catchment using FLOOD WATCH (STROŃSKA et al., 1999) 50
Fig. 16: Sketch of the Lausitzer Neiße/Nysa Łużycka/Lužická Nisa river 55
Fig. 17: LISFLOOD simulation concept (source: http://natural-hazards.aris.sai.jrc.it/floods/risks/) 61
Fig. 18: ODRAFLOOD model system (GKSS & PARTNERS, 1999) 62
Fig. 19: Comparison of observed hydrographs with hydrographs simulated by SEROS for the Odra river gauge Gozdowice for the Flood 1997 (RUHE et al., 1999) 63
Fig. 20: River gauges 92
Fig. 21: Polders 94
Fig. 22: Reservoirs 97

Register of tables

Tab. 1: Characteristics of the Odra river and its main tributaries 5
Tab. 2: First and last snowfall occurrence in different regions of the Odra river basin 8
Tab. 3: Comparison of extreme discharge values with long-term annual averages 8
Tab. 4: Comparison of different flood forecasting systems 26
Tab. 5: Components and factors of an early flood warning system 29
Tab. 6: Main causes for flood formation in the Odra river basin 31
Tab. 7: Highest water levels (HW) and highest water discharges (HQ) of selected ice floods at the river gauges Eisenhüttenstadt and Hohensaaten-Finow 33
Tab. 8: Highest water discharges of selected summer floods on the Odra river 35
Tab. 9: Numerical meteorological models which results are used by the ČHMÚ for the quantitative precipitation forecast 37
Tab. 10: Hydrometric and hydrometeorological stations in the Upper and Middle Odra river basin planned to be automated 48
Tab. 11: Flood forecast by the IMGW Poznań 52
Tab. 12: Selected projects for the flood forecast in the Odra river basin 59
Tab. 13: International projects for flood simulation 60
Tab. 14: Comparison of the projects ODRAFLOOD and ODER-LISFLOOD 64
Tab. 15: International projects on flood protection in the Odra river basin within the field of planning and information systems 68
Tab. 16: Important names in Polish, Czech and German language 90
Tab. 17: Important Odra river gauges in Poland, the Czech Republic, and Germany 91
Tab. 18: Used polders on the Odra river 93
Tab. 19: Polish reservoirs 95
Tab. 20: Czech reservoirs 96
Tab. 21: Survey of the projects of Chapter 7 98

1 Motivation, objectives and proceeding

1.1 Motivation

Floods and related inundations are **natural phenomena** and since ever cause large hazards for the affected population and material values. „Of all natural hazards floods occur globally most frequently and cause the most fatalities and largest economical damages“ (MÜNCHNER RÜCK, 1997, p. 7). Therefore, it was pursued to warn efficiently and in time of such natural hazards since ever. For Central Europe SCHAFFERNAK (1935) reports about first flood forecasts on the river Seine in France by BELGRAND in the year 1856. FÜGNER (1995) illustrates how in the 18th century on the river Elbe upstream of the city of Dresden warnings of ice-break-up triggered floods were announced by riders and cannon rumblings.

Flood events **in the Odra river basin** are **not uncommon** either. With regard to peak discharge, but also to duration and damages, the Summer Flood 1997 can be considered as the largest flood of the 20th century in the Odra basin. In the Czech Republic and in Poland more than 100 fatalities had to be grieved. In all three affected countries together the Czech Republic, Poland, and Germany damages amounted to more than 3.53 billion EURO (IKSO, 1999). In the Upper and Middle Odra river basin the flood had a catastrophic extent. Many dike breaches on the Upper and Middle Odra river , especially on the Polish territory, caused a large relief of the situation on the German-Polish Border Odra river (GRÜNEWALD et al., 1998). It was mainly due to this circumstances that by means of disaster prevention a catastrophe could be prevented here.
The **Flood 1997** *clearly showed* the **deficits** of the existing flood forecasting and warning system on the Odra river. There were deficits concerning the components of the system itself (detecting-forecasting-warning-reacting) as well as of their interaction which in the end influenced the transboundary information transfer (GRÜNEWALD et al., 1998). On the Odra river there was no sufficient preparation for a flood event of that magnitude. Because of many fortunate circumstances, the damages were relatively small in Germany.

After the Flood 1997 **a number of projects and measures** for the improvement of the flood management and the transboundary co-operation - from the modernisation of the dikes and monitoring networks up to the development of varied flood simulation models – were launched. One of these projects is the „Simulation of flood events in the Odra basin with a coupled model system“ (**ODRAFLOOD**) financed by the German Federal Ministry of Science and Technology (BMBF). In this project German and Polish partners (GKSS Geesthacht, IMGW Wrocław, MRI Szczecin, DLR Cologne, BTU Cottbus) are involved. This study is part of this project.
Objective of the project ODRAFLOOD is the development of a coupled system consisting of rainfall-runoff models and wave transformation models for the river Odra and its tributaries, including scenarios of city inundation and dike breaches. In the first place, the model is planned to be used pre-operationally for the analysis of former flood events, for the development of scenarios, optimal controlling strategies for reservoirs, polders and retention basins. Besides this, it is also planned to develop „basics (models and scenarios) for the development of an operational flood forecasting model“ (GKSS & PARTNERS, 1999).

1.2 Objectives

This study aims,

- at *showing* the *general* and *specific* **requirements** on an operational flood forecasting system in the Odra basin, especially considering the aspect of transboundary co-operation
- and *at assessing* the **state of development** of the operational flood forecasts in the Odra river basin (with their specific meteorological and hydrological input data and available hydrological models) by *comparing* it with these requirements.

First of all, this study is a preliminary investigation for the project „ODRAFLOOD“ of the GKSS and their project partners. But the study is also addressed to the various organisations and institutions which plan or already carry out projects and measures regarding flood prevention in the Odra river basin.

An effective reaction to imminent flood hazards requires a comprehensive description of possible courses of the flood and the timely and sufficiently accurate forecasts. Thereby, damages can be remarkably reduced and the affected population can be better protected.
Therefore, the *operational flood forecast* has to be envisaged in connection with the other components of an **early flood warning system**. That means, it is one part of a whole system of monitoring, meteorological forecast, flood forecast, flood information system, decision finding, disaster prevention, and reaction of the affected population (PARKER et al., 1994).
One of the main problems of the flood forecasts is the fact that generally the benefit of the implementation of an improved flood forecasting system is not immediately recognisable. The flood forecast systems, the decision finding systems, the disaster prevention and information systems for the public etc. have to be developed correspondingly (PARKER et al., 1994). The experiences of the decision-makers, of those responsible and the people affected have to be adequately included.

1.3 Proceeding

The components and the complexity of an early flood warning system depends among others on the hydrological conditions, the structure and financial means of the flood forecast and flood information services and the efficient use of the system (FELDMANN, 1994). On international rivers like the Odra river additionally the specifics of the necessary transboundary co-operation have to be taken into account.

After a brief introduction to the Odra river basin, the legal basis and the responsibilities for the flood forecast and flood information services in the Czech Republic, Poland and Germany (with its Federal States Brandenburg and Saxony) will be presented. Subsequently, the general requirements on operational flood forecasting systems of international river catchments and possible causes for the flood formation in the Odra river basin are described.
Central objective of this study is the presentation and assessment of the present state of the flood forecasting system in the Odra river basin. For each country separately, the specification is carried out along the Odra river. The sub-catchment of the Lausitzer Neiße river, where three countries Czech Republic, Poland and Germany (with its two Federal States Brandenburg and Saxony) border on, will be presented exemplary. As far as possible, projects and plans in the different countries are included. Selected international projects concerning flood protection in the Odra river basin are briefly presented. Finally, the state of development of the operational flood forecasting systems in the Odra river basin is assessed and critical

elements identified. In a résumé, proposals for an improvement, especially under the aspect of a gradual development of a transboundary early flood warning system on the Odra river, are derived.

In the study, the geographical names are used corresponding to the actual maps of the respective countries. Only for some towns/cities in Poland and the Czech Republic German terms are used for the better readability in the German speaking regions. To avoid misunderstandings, in some cases the Czech and Polish and also partly the German terms are used parallel (e. g. Lužická Nisa/Nysa Łużycka/Lausitzer Neiße). In Table 16 in the Appendix often used Czech, Polish and German geographical names are listed.

2 Brief description of the Odra river basin

The main hydrographical, climatological, hydrological and water management specifics of the Odra river basin are briefly presented in this chapter. Further information can be obtained from, e.g. IKSO 1999, LUA 1998 and the Odra monograph of BUREAU 1896[1] in several volumes with maps and tables.

2.1 Hydrography

The **Odra** river (in German: Oder), 854 km long, with an annual discharge volume of about 18 billion m³ (annual period 1941-96 without 1945; LUA, 1998), forms the sixth largest freshwater tributary to the Baltic Sea. The Odra river originates at a height of 634 m a.s.l. in the Odra Mountains, the south easterly section of the Sudeten Mountains.
The **catchment of the Odra river** encompasses 118 861 km², of which the largest section is located on Polish territory (*89%)*. Almost the entire western half of the *Republic of Poland* is drained by the Odra river. *6 %* of the Odra river basin are located in the *Czech Republic* and *5 %* in the *Federal Republic of Germany* (approx. 5 600 km²) (Fig. 1).

The **landscape of the Odra river basin** is subdivided from South-West to North-East into mountains, foothills, plateaus and lowlands. Although *most of the Odra river basin is formed by lowlands* with elevations below 200 m a.s.l., the *flood discharge behaviour of the Odra river* is influenced mainly by the *mountainous catchment areas in the South and South-West* and their foothills. The southern boundary is formed by the Moravian Beskidy Mountains with the highest summit Lysá Hora (1 324 m a.s.l.). In the western direction the Moravian gap is located where the water divide between the Odra and the Danube river basin is only at 310 m a.s.l.. The entire South-West boundary with approx. 350 km length is formed by the Sudeten Mountains. Their northern outliers from the Moravian to the Lusatian gap drain to the Odra river. The highest summits are Praděd with 1 490 m a.s.l. in the East and Śnieżka with 1 602 m a.s.l. in the West.

According to the geomorphology and the discharge behaviour the Odra river can be divided into three sections (IKSO, 1999):
Upper Odra: from the springs to the mouth of the Nysa Kłodzka river,
Middle Odra: from the mouth of the Nysa Kłodzka river to the mouth of the Warta river,
Lower Odra: from the mouth of the Warta river to the Odra Lagoon / Zalew Szczeciński.

On the Upper Odra river with only a length of approx. 54 km (*Odra headwaters*) the river shows mountainous character with a steep gradient up to 7.2 ‰. On its way through the

[1] Although even published in the year 1896 it is the most complete description of the Odra river basin. Extracts of the monograph are also published in UHLEMANN (1999).

foothills of the Sudeten Mountains to the city Bohumín (Polish-Czech border) the Odra river has an average gradient of 0.36 ‰.

On the Middle reach the Odra river is flowing with an average gradient of 0.28 ‰, except two north leading narrow openings in push moraines between the Pleistocene ice-marginal valleys at Ścinawa and Nowa Sól, in wide valleys in North-West direction up to the mouth of the Lausitzer Neiße (Polish: Nysa Łużycka, Czech: Lužická Nisa). From this point the flow direction changes to the North and on a length of 161.7 km up to Gryfino the Odra river forms the so called „**Border Odra**", *the border between the Republic of Poland and the Federal Republic of Germany*. North of Frankfurt/Oder the Odra river receives on the right-hand side its largest tributary, the Warta river. The Warta river catchment almost encompasses half of the Odra river basin and supplies in the long-term annual mean approx. 40% of the total Odra river discharge. The gradient declines downstream of the Warta river mouth to 0.05 ‰. Further important tributaries of the Odra river are listed in Table 1.

At Widuchowa the Odra river divides into the Western and Eastern Odra. The Western Odra forms the border between Poland and Germany on a length of 17.1 km, but the Eastern Odra is the original Odra river. Eastern and Western Odra are connected by several small rivers and channels which flow through the area of the polder Międzyodrze. After passing Jezioro Dąbie the Odra river, as one river, flows into the Stettiner Haff / Zalew Szczeciński (Odra Lagoon). The Stettiner Haff is connected with the Baltic Sea (Pommersche Bucht / Zatoka Pomorska (Pommarian Bay)) via three distributaries: Peene, Świna, and Dziwna.

Tab. 1: Characteristics of the Odra river and its main tributaries

river	length [km]	drainage area [km^2]	source area	elevation of the source area [m a.s.l.]
Odra/Oder	**854.3**	**118 861.0**		**634**
Opava (Oppa) (l) **	131.0	1 835.0	Sudeten Mountains	1 400
Ostravice (Ostrawitza) (r) **	65.0	811.0	Beskidy Mountains	730
Olše, Olza (Olsa) (r)	86.2	1 117.6	Beskidy Mountains	850
Kłodnica (Klodnitz) (r)	75.3	1 084.8	Sudeten Mountains	305
Osobłoga (Hotzenplotz) (l)	65.5	993.2	Sudeten Mountains	700
Mała Panew (Malapane) (r)	131.8	2 131.5	Silesian-Cracovian Plateau	**315
Stobrawa (Stober) **	85.0	1 601.9	Foothills of Silesian-Cracovian Plateau	260
Nysa Kłodzka (Glatzer Neiße) (l)	181.7	4 565.7	Sudeten Mountains	975
Oława (Ohle) (l)	91.7	1 002.7	Foothills of the Sudeten Mountains	315
Ślęza (Lohe) (l)	78.6	971.7	Foothills of the Sudeten Mountains	370
Bystrzyca (Weistritz) (l)	95.2	1 767.8	Sudeten Mountains	690
Widawa (Weide) (r)	103.2	1 716.1	Wał Trzebnicki	200
Kaczawa (Katzbach) (l)	83.9	2 261.3	Sudeten Mountains	**540
Barycz (Bartsch) (r)	133.0	5 534.5	Wał Trzebnicki	126
Bóbr (Bober) (l)	271.6	5 876.1	Sudeten Mountains	1 190
Nysa Łużycka, Lausitzer Neiße, Lužická Nisa (l)	251.8	4 297.0	Sudeten Mountains	**777
Warta (Warthe) (r)	808.2	54 528.7	Silesian-Cracovian Plateau	380
Ina (Ihna) (r)	129.1	2 189.4	Pommerian Lake District	**107

Source: IMGW, 1983; ** BUREAU, 1896
(l) – left-hand side tributary
(r) – right-hand side tributary

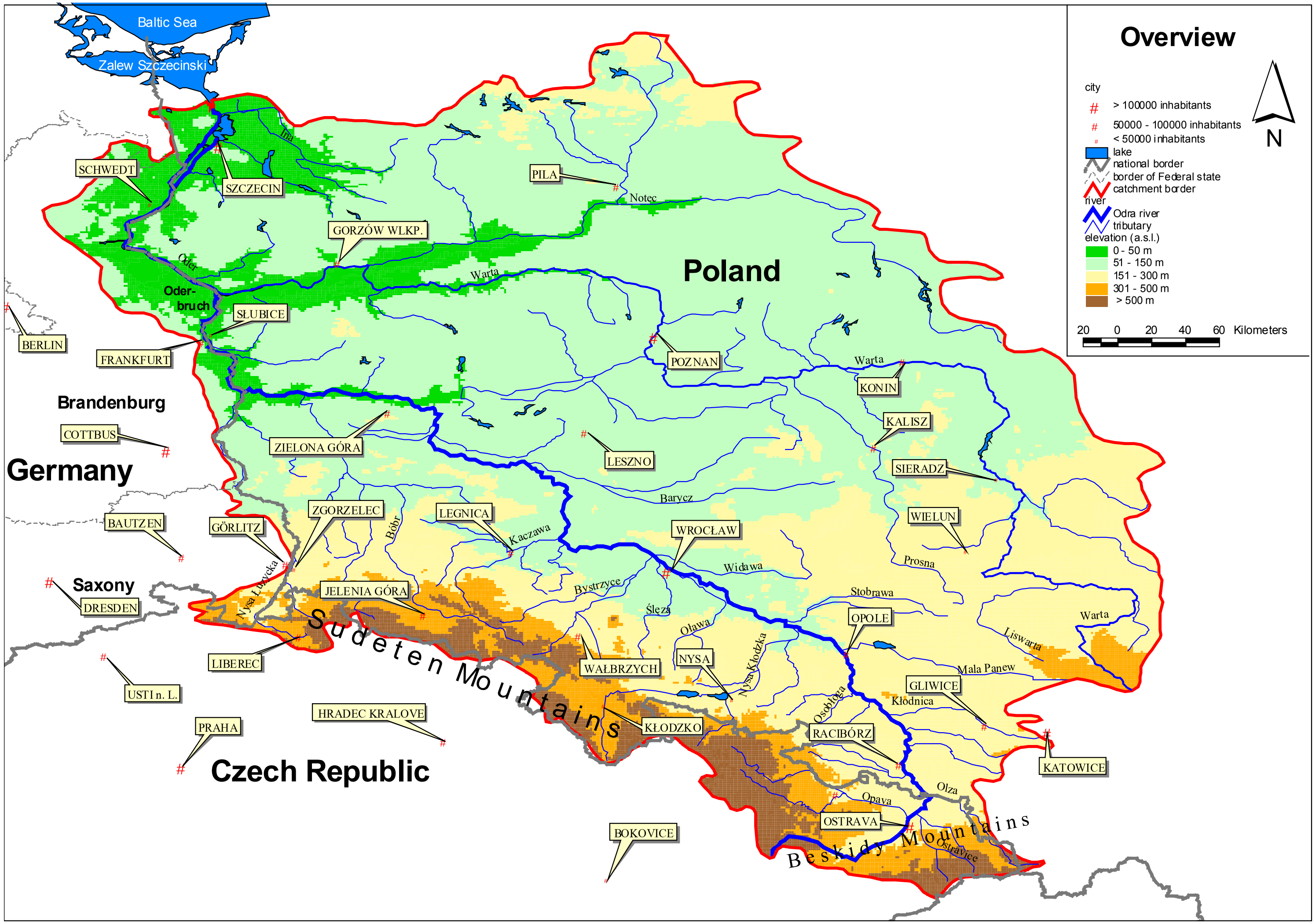


Fig. 1: Odra river basin with its main tributaries

2.2 Climate and precipitation conditions

The Odra river basin is located in the *temperate west wind zone* dominating whole Central Europe. But the **climate** is already characterised by a noticeably *continental influence* from Eastern Europe. It shows *a higher seasonal variability of the weather situation* and hence of the discharge conditions.

The location of the mountain ranges of the Sudeten and Beskidy directly influences the **precipitation conditions** (BUREAU, 1896): Moist air masses transported by the west winds are forced to rise at the western (in the summer mainly south-western, in the winter north-western) slopes of the mountains. The north-easterly foothills are located in the lee of the mountains and receive less precipitation than could be expected due to their elevation. The largest precipitation amounts in the Odra river basin receive the north-western slopes of the South-West to North-East stretched Beskidy Mountains.
At the *mountain ranges* the *annual precipitation* amounts to *1 000 – 1 400 mm*, especially in the headwaters of the Ostravice, Olše/Olza, Opava, Nysa Kłodzka, Bóbr, and Lužická Nisa/Nysa Łużycka/Lausitzer Neiße river. *The largest part of the Odra river basin* receives an *annual precipitation* amount of *600 - 700 mm*. On the lower reaches of the Odra river annual precipitation amounts of less than 500 mm are measured (LUA, 1998).

Within the year the *highest precipitation amounts* (more than a third of the annual precipitation amounts) occur between *June and August*.
In the *summer* cyclones (low pressure) sporadically deviate from the normal paths on the *Vb*[2] track. This track is stretching from Italy to Poland crossing the Baltic States. In combination with north to north western winds this constellation causes extended heavy rainfalls at the northern slopes of the Beskidy Mountains and the northern slopes of the Sudeten Mountains and their foothills. Under such a weather situation the *danger of the occurrence of a summer flood in the Odra river basin is very high.* The situation aggravates if, due to very slow movement of the cyclone, precipitation falls over long periods of time.

The **snow conditions** differ strongly depending on the elevation and the distance to the sea. Table 2 provides an overview about the first and last snowfall occurrence in the different regions of the Odra river basin.
An extended snow coverage in the catchment leads to temporal storage of large amounts of water and can have important influences on the discharge conditions. On average, a snow coverage can be expected in the whole Odra river basin between December and February, at higher elevations between the middle of October and May. The average annual period of snow coverage amounts in the lowlands to 40-60 days, in the foothills to 80-120 days, and in the mountainous regions to 120-200 days (BUREAU, 1896; HAD, 2000).

[2] A typical weather situation (called by the meteorologists as Vb weather situation) which is famous for triggering summer floods in the Odra river basin. The situation is characterised by a massive stream of cold air moving across Central Europe that forms a low pressure area in North Italy – supported by the lee effect of the Alps. This moves in north-north-easterly direction and carries along warm-most ocean air of the Adriatic Sea which is forced to rise when hitting the cold air. The high elevation and the strong turbulences within these air masses as well as the slow movement cause extended and long lasting storms.

Tab. 2: First and last snowfall occurrence in different regions of the Odra river basin

region	first snowfall	last snowfall
mountain tops	middle of August	beginning of June
mountains, foothills	beginning – middle of October	beginning –middle of May
hills, catchment of Warta river	beginning of November	end of April
lowland	beginning of November – beginning of December	middle of March –middle of April
mouth area	middle of November – beginning of December	beginning of April

Source: BUREAU, 1896; HAD, 2000

2.3 Discharge and floods

The Odra river shows a *distinct variability* in **discharge**. This becomes apparent when looking at the percentage of extreme values with regard to the long-term annual discharge values. In Table 3 this is exemplary elucidated using the river gauges Eisenhüttenstadt and Hohensaaten-Finow in comparison to the Rhine river gauges similar in size of catchment area. The percentual discharges based on the average discharge (MQ) at the Odra river gauges are noticeably higher in flood situations and lower in low flow situations compared to those at Rhine river gauges. Besides the ice formation in winter, the mostly in the summer and autumn *occurring low water periods* hinder the navigation on the Odra river. In average, at Racibórz ice is observed 25 days and at Hohensaaten 44.1 days per year (1900-1990; UHLEMANN, 1999), respectively.

Tab. 3: Comparison of extreme discharge values with long-term annual averages

Odra river gauges	NNQ [m³/s] onset date % of MQ	MQ [m³/s]	HHQ [m³/s] onset date % of MQ
Eisenhüttenstadt A = 52 033 km²	73.6 (07.08.1950) 24	304 (1941-1995 without 1945)	2 500 (06.11.1930) 822
Hohensaaten-Finow A = 109 564 km²	111 (11.09.1921) 21	521 (1941-1995 without 1945)	3 480 (03.04.1888) 668

Source of data: DGJ 1995 (Elbegebiet, Teil II)

Rhine river gauges	NNQ [m³/s] onset date % of MQ	MQ [m³/s]	HHQ [m³/s] onset date % of MQ
Speyer A = 53 131 km²	364 (04.01.1954) 29	1 270 (1951-1989)	4 350 (27.05.1983) 343
Kaub A = 103 729 km²	476 (28.12.1921) 29	1 620 (1931-1986)	7 000 (05.01.1883) 432

Source of data: DGJ 1989 (Rheingebiet, Teil I); DGJ 1986 (Rheingebiet, Teil III)

The **Upper and Middle Odra river** discharge is dominated by *snowmelt and rainfall*. At the **Lower Odra river** the *hydrological conditions* are determined by a *complex* interaction of backwater effects from the Stettiner Haff / Zalew Szczeciński and the Baltic Sea, atmospheric factors (wind and atmospheric pressure) and discharge coming from the catchment upstream (BUCHHOLZ, 2000).

Floods on the Odra river are not *unusual* and, in certain regions, occur *almost every year*. *The probability* of a flood of disastrous magnitude affecting the *entire course of the Odra river* is lower. One differentiates between the spring floods related to snowmelt (Chapter 5.1) and floods caused by extended heavy rainfalls mostly in the *summer* („Johanni Flood") (Chapter 5.2). Although *the winter floods are dominating* also *on the lower reaches of the Odra river*, it has to be stated that the Odra river is affected *more often by summer floods* than e.g. the *Elbe river* (FISCHER, 1907; IKSO, 1999). Further *peculiarities* of the Odra river are the so-called *ice floods* (Chapter 5.1) which occur in winter caused by backwater effects due to „ice jam formation" and ice shifting on the Middle and Lower Odra river.

Information about historical flood events on the Odra river is provided by chronicles and other documents. For instance, there is a report of the flood 1310 on the Nysa Kłodzka river. During the inundation of the suburb of the town Glatz (Kłodzko) 2000 people drowned (FAL, 1997). Flood marks on the stone gate in Krosno Odrzańskie verify the floods of July 1595, April 1698 and May 1729 (BUREAU, 1896).
The most devastating floods in the 18^{th} and 19^{th} centuries occurred in July 1736, August 1813 and August 1854. Along the entire course of the Odra river they caused numerous dikes to be awash or to breach resulting in extended inundations (FISCHER, 1907).
In the 20^{th} century the worst floods occurred in July 1903, October 1915, June 1926, November 1930, September 1938, March 1940 and 1947, July 1958, June 1965, August 1985, August/September 1977, January 1982 and July 1997 (BFG, 1997; LUA, 1998). Due to precipitation and discharge conditions in the catchments of the tributaries and also due to the local discharge situation (especially in the winter time in relation with ice jams) different flood events caused maximum water levels and discharge values at the individual river gauges. E.g., the flood of 1903 caused maximum values especially on the Upper and Middle Odra river whereas the maximum water level values on the lower reach of the Odra river date from the flood events in the years 1940 and 1977. In the region of the Border Odra river the winter flood 1947 was extremely severe. Due to ice blocking dikes were awash and the Oderbruch (Odra marshland area) was flooded. The *Summer Flood 1997* is the *greatest flood event on the Odra river in the 20^{th} century*. This encompasses the extension of the area affected as well as the dimension and duration of the flood event and the related damages (GRÜNEWALD et al., 1998).

2.4 Hydraulic engineering and flood defence structures

Besides these „natural" influences travel time and shape of the flood waves are influenced by hydraulic engineering measures. The **development of the course of the Odra river**, especially *for navigation*, started as *early as the 13^{th} century*. The first levees erected as protection against floods date back to this period. It was in the *18^{th} century* that *extensive development of the Odra river and its tributaries* started. There were hydraulic works and changes like straightening of the river course, cut-off of meanders and ox-bows, construction of bypass channels, dikes, polders, groynes, weirs, reservoirs, and retention basins.

Straightening of the water course: Due to cut-offs in the time between 1740 and 1896 the course of the Odra river was shortened by approx. 160 km or around 20 % of the total length (BFG, 1997). In the region of the Oderbruch the course of the Odra river was moved to the elevated eastern side.

Bypass channels: Bypass channels were built to protect cities like Wrocław, Opole and Racibórz.

Dikes: Between the mouth of the Opava (Opawa, Oppa - km 0) river and the Stettiner Haff / Zalew Szczeciński originally there were natural flood plains of 3 700 km². In 1896 a natural flood plain of only 860 km² (approx. 23 %) remained (BFG, 1997). Besides the Oderbruch of about 800 km², retention areas primarily on the Upper and Middle Odra river were lost.
The dikes that can be found nowadays were constructed over several centuries and are based on different design water levels. Due to this fact, there is no uniform flood protection system along the Odra river. The distance between the dikes, the size of the transverse sections and the height of the dike crest were not fixed, designed and realised using an uniform hydrological design basis. Moreover, the geological conditions underneath the dikes are often inappropriate (IMGW, 1975; WKP, 1997; BGR, 1997).
Since the Flood 1997 in Brandenburg the dikes were systematically and fundamentally restored. Since 1997 embankment sections of a total length of more than 50 km were repaired and reinforced (MLUR, 1999). Due to financial shortages only the repair of the numerous dike breaches could be carried out in Poland and the Czech Republic. In the year 1998 the German-Polish Commission on Border Water Bodies decided to design the dikes at the „Border Odra" to a 200-year flood with an additional freeboard of 1 m.

Polders: Polder areas, which can be used for flood retention, are located mainly upstream of the city Wrocław, in the mouth of the Warta river and in the Lower Odra Valley (Tab. 18 and Fig. 21 in Appendix).
The existing polders on the Upper and Middle Odra river encompass an area of more than 120 km^2 and a volume of about 184 mio. m³ (NALBERCZYŃSKI, 1999). The flooding of the polders can not be controlled. No respective devices are implemented. Additional polder areas of more than 95 km^2 (193.6 mio. m³) could be identified. But more likely are plans to create 5 new polders with a total area of more than 40 km^2 and a storage volume of 67.6 mio. m³ (NALBERCZYŃSKI, 1999). The insufficient volume of the polders and the partly poor technical condition of the hydraulic-engineering controlling devices restrict the possibility of their utilisation for water management tasks. For a polder management focussing at the flood protection, respective system and legal solutions are missing (ZALESKI, 1998).
In the area of the mouth of the Warta river on the Polish side there exists no continuous dike line. Therefore, here a large natural flood plain exists (nature reserve (polder) Słonsk with a flooding plain of 51 km^2). During the Flood 1997 this area served as storage for large amounts of Odra flood water.
The most important polder areas for flood protection on the Lower Odra (Fig. 2) on the Polish side are located between the Eastern and Western Odra (Międzyodrze, 60 km^2) (BUCHHOLZ, 1997); on the German side these are the polders Criewen (A), Schwedt (B) and Fiddichow (10) near Schwedt (LUA, 1997 a). In the Federal State of Brandenburg the establishment of further polders of altogether 60 km^2 (e. g., Lunow-Stolper Polder with 16 km^2, Gartzer Bruch with 10 km^2, Neuzeller Niederung with 23 km^2, and Kienitz-Sophientaler Polder with 6.45 km^2) and a storage volume of about 13 mio. m³ is discussed (LUA, 1997 a).

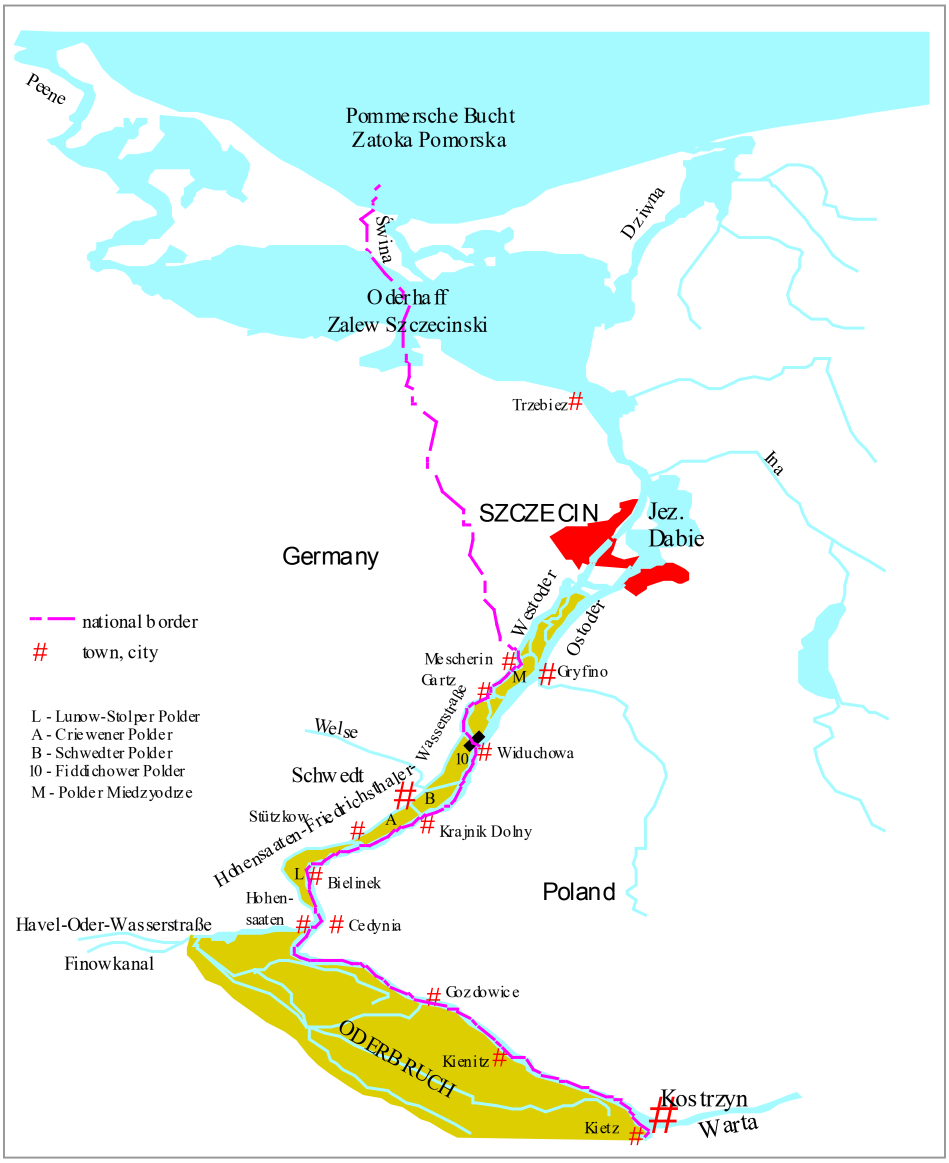


Fig. 2: Lower Odra river with the main polder areas

Groynes: The Oderstrombauverwaltung (Odra Construction Work Administration), which was founded in the year 1874, improved the conditions for navigation in regulating low and mean discharge. That had been done by fixing the Odra river with a groynes system downstream of Koźle in a narrow, slightly curved riverbed under these discharge conditions (LPB, 1996). Nowadays, the existing groynes of the Odra river section downstream of the mouth of the Warta river to river km 683 (in the area of the Criewener Polder) serve more or less as bank consolidation (www.wsa-eberswalde.de).

Weirs: To guarantee the navigability by raising the water level, 24 weirs with locks were constructed on the Odra river section between Koźle and Brzeg (Koźle, Januszkowice, Krępa, Krapkowice, Rogów, Kąty, Groszowice, Opole, Wróblin, Dobrzen, Chróścice, Zawada, Ujście Nysy Kłodzkiej, Zwanowice, Brzeg, Lipki, Oława, Ratowice, Janowice, Bartoszowice, Zacisze, Różanka, Rędzin, Brzeg Dolny). 15 of these weirs are new, currently, two of them are rebuilt and two have to be reconstructed (ZALESKI, 1998). Two new weirs at Malczyce and Lubiąż are planned.

Storage reservoirs and flood retention basins: Storage reservoirs play a crucial role in flood protection since they help to reduce the size and to retard the peak of the flood wave downstream of the reservoir. But the regulations for flood management are in contrast to the needs of the navigation and the energy industry. Therefore, not the entire storage volume can be used in a flood situation.
In the Czech part of the Odra river basin there are 8 reservoirs with a total storage volume of more than 358 mio. m^3 (Fig. 3, in the Appendix Fig. 22 and Tab. 20). The most important ones are in Slezká Harta on the Moravice river and in Sanče on the Ostravice river (IKSO, 1999; POVODÍ ODRY, 1999; www.povodiodry.cz).
The total storage volume of the Polish storage reservoirs in the Odra river basin amounts to about 937 mio. m^3. The largest reservoirs are located in Otmuchów and Nysa (on the Nysa Kłodzka river), in Turawa (on the Mała Panew river) and in Jeziorsko on the Warta river (IKSO, 1999; in the Appendix Fig. 22 and Tab. 19). Further three reservoirs are under construction (Sosnówka, Kozielno and Topola) and two reservoirs are planned (Racibórz and Kamieniec Ząbkowicki) (ZALESKI, 1998).

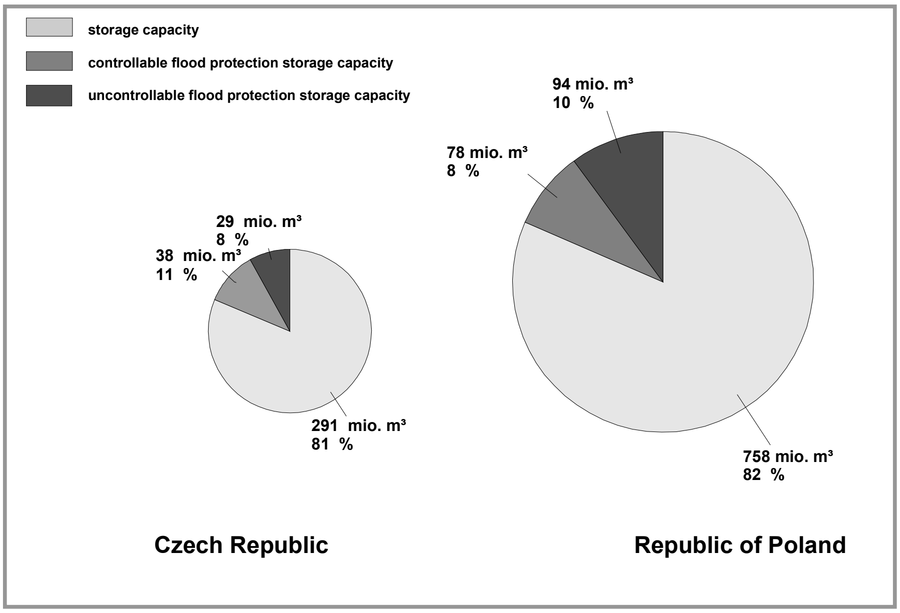


Fig. 3: Storage volume of the Czech and Polish reservoirs in the Odra basin

In the time period between 1905 and 1929 14 flood retention basins were built in the catchments of the Upper and Middle Odra river. Later two of those, Bukówka and Słup (former Żarek), were rebuilt to reservoirs. The total volume of the remaining 12 retention basins amounts to about 53 mio. m^3, 24 mio. m^3 of which can be controlled (IKSO, 1999). The retention basins are especially of local importance because they are located in densely populated river valleys in the headwaters of the tributaries. But they alone cannot provide a sufficient flood protection (ZALESKI, 1998).

It can be concluded for the whole Odra river basin *that the Odra river is no more a natural watercourse*. Throughout the centuries, the Odra river has been subject to manifold alterations and interventions, motivated mainly by economical aspects. For the flood protection on the Upper and Middle Odra river reservoirs are important while on the Lower Odra river polders play an important role. The Odra Flood of July 1997 showed clearly, that according to the state of the art of science and technology many of the hydraulic structures (dikes, navigation waterways, polders, channels etc.) are in poor condition and obsolete (MAŁKIEWICZ &

BARTOSIEWICZ, 1997). In the Polish „Programme for the Odra 2006“ there are, among others, plans for extensive investments in the modernisation and the reinforcement of the existing flood protection system (ZALESKI, 1998). A large potential for a precautionary flood protection lies in reactivating the existing polders, their equipment with controlling devices, and the construction of further storage basins in the headwater of the Odra and its tributaries. Furthermore, it has to be assessed to what extent the existing storage capacities for flood protection can be increased with regard to the other uses.

3 Legal basis and responsibilities

One of the main principles for an effective disaster prevention is the organisation of a functioning flood forecast and information service. Subsequently, the legal basis and the responsibilities of the flood forecast and information services within the three riparian countries in the Odra basin are introduced.

3.1 Czech Republic

In the Czech Republic the following **acts and decrees** are important for the *flood forecast* and *flood information service*:

- Water Act No. 138/1973 Compendium of laws (§ 42 Principles of flood prevention), currently under revision
- Czech National Council Act No. 130/1974 Compendium of laws „On state administration in water management“ verbatim like the Czech National Council Act No. 458/1992 Compendium of laws
- Czech Government Decree No. 100/1999 „On flood protection“ (replaces the Czech Government Decree No. 27/1975)

Currently, there is a new water law in progress which in principally contains most of the regulations of the Czech Government Decree No. 100/1999 on flood protection and is expected to come into force after passing the parliament on the 01.01.2001 (KRAMER et al., 2000).

The Government Decree No. 100/1999 contains, among others, regulations about the drawing up of flood schemes, about investigations on „early flood detection“ and on flood forecast and information services. The drawing up of flood schemes is subject of the Ministry of Environment of the Czech Republic, the district, local and city authorities, but also of the users and owners of estates along the water courses or in flood prone areas. The flood schemes have to be confirmed by the next higher administration unit. The confirmed flood schemes have to be annually revised and, if necessary, to be supplemented and to be adapted, respectively. These changes have also to be confirmed.

The flood schemes contain details about the organisation of the flood forecast and information service. The flood forecast and flood information services are entrusted by law to the **Czech Hydro-Meteorological Institute (ČHMÚ)** in co-operation with the **River Basin Authorities (Povodí)** (§ 19 Paragraph 3 Clause 1 Act on the State Administration in Water Management).

The **ČHMÚ** is represented by a central forecast office in Prague and six regional forecast offices, with the offices in *Ostrava* (Odra river in the Czech Republic, Ostravice river, Moravice river, Opava river, Olše river, Bělá river), *Hradec Králové* (Stěnava river), and *Ústí nad Labem* (Lužická Nisa river and Smědá river) in the Odra basin. The *ČHMÚ* is responsible for the *meteorological* and *hydrological forecasts*. The main task of the meteorological service of the ČHMÚ with respect to flood forecast is the monitoring of the weather situation, issuing advisories and warnings of dangerous weather situations, especially heavy rainfall events, storms, hail etc. as well as quantitative precipitation forecasts (KUBÁT, 2000 a). The hydrological service of the ČHMÚ monitors the actual situation on the river by its own river gauge network. The River Basin Authorities (Povodí) provide additional data of their monitoring network and information about the operation of the water management structures. The River Basin Authority responsible for the main part of the Odra river basin is Povodí Odry with its headquarter in Ostrava. In Figure 4 the main components of the flood forecast in the Czech Republic are presented.

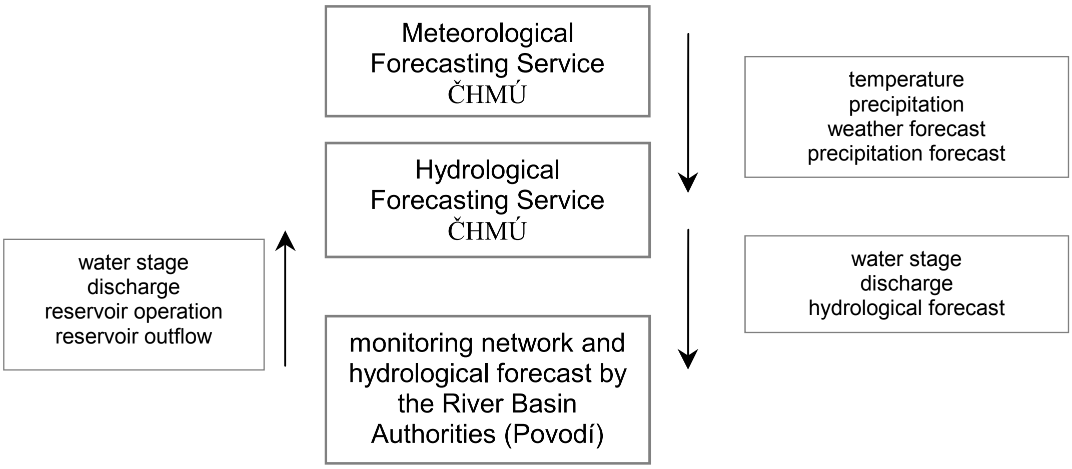


Fig. 4: Flood forecast in the Czech Republic (after KUBÁT, 1998)

On regional and national level flood warnings are disseminated by the central office of the ČHMÚ in Prague to the central flood protection authorities and other important institutions and organisations (e.g. River Basin Authorities, Main Office of Civil Defence, Main Centre of Fire Protection Service) (Fig. 5). On regional level and in larger cities flood warnings can also be issued by the regional flood forecast offices (KUBÁT, 1998). Between the ČHMÚ and the media there is the agreement, that in urgent situations the affected population can be directly informed by the public media (radio, television, internet etc.). Conversely all inhabitants are obliged to immediately announce imminent flood hazard to the responsible authorities.

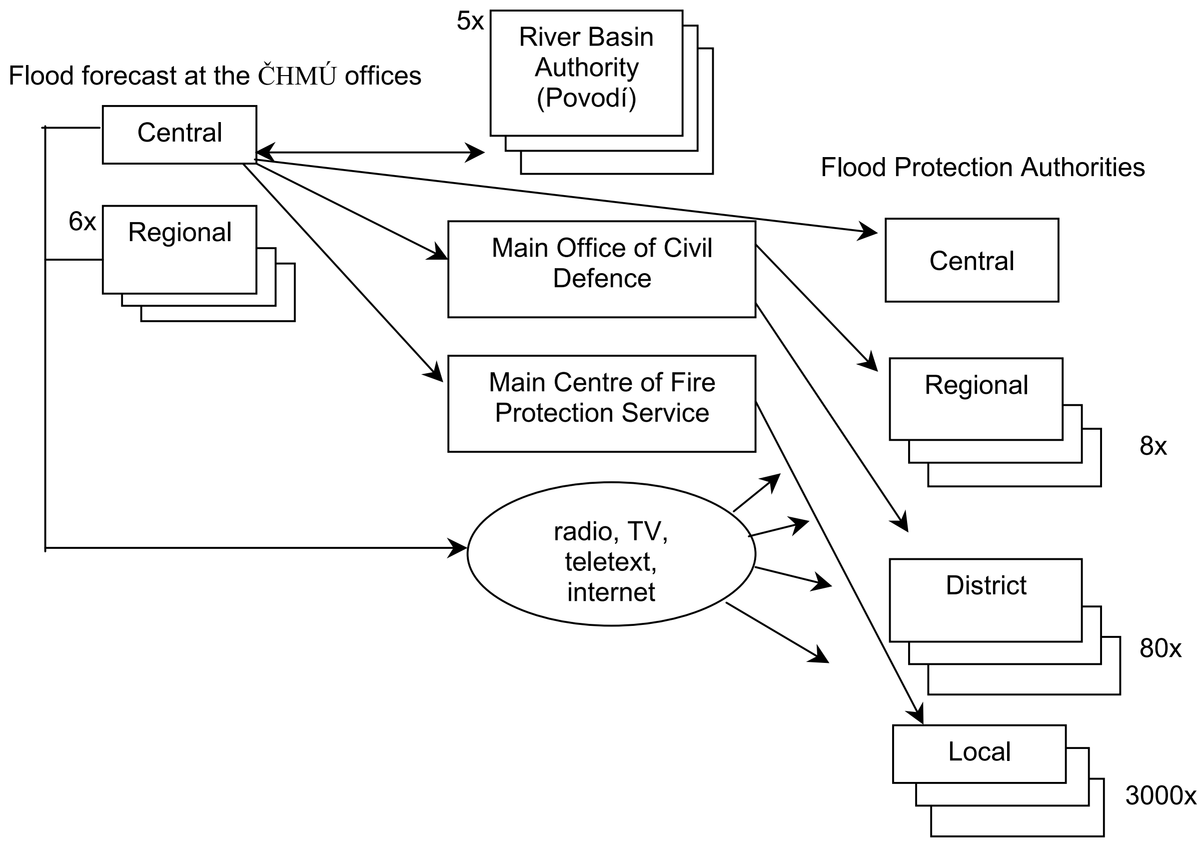


Fig. 5: System of flood forecast and flood warning in the Czech Republic (after KUBÁT, 1998)

In the Czech Republic flood danger is announced by **three alert stages** (KINKOR, 2000; BFG, 1998):

- **alert stage 1** – „*Alert*“: The alert stage starts when a certain water level at selected river gauges is reached and when a dangerous situation is possible because of unusual factors like precipitation situation, snow situation or others. The flood watching and reporting services are started and report about the flood situation daily.
- **alert stage 2** – „*Emergency*“: It is declared when the water level continues to rise and areas outside of the river bed are already inundated. The flood protection bodies have to keep security equipment ready and have to carry out measures to reduce the flooding according to the flood schemes. When a certain water level is reached the corresponding report is issued twice a day.
- **alert stage 3** – „*Danger*“: This stage starts in case of danger that a number of damages might occur and human lives and property are in peril. Flood protection and, if required, rescue operations and evacuations are organised. When reaching certain water levels the reports are issued three times a day.

In flood situations the flood protection activities are organised by the local, district and city Flood Protection Authorities as well as the Central flood protection authority in the Czech Republic (KINKOR, 2000). The alert stage for the community (local) is announced by the local authority and for the district by the district authority, respectively (KRAMER et al., 2000).

3.2 Republic of Poland

In the Republic of Poland the following **acts and decrees** are important for the flood forecast and information service:

- Water Act of 24.10.1974 with later implemented changes (currently under revision), Law Gazette No. 38, Pos. 230
- Decree of Council of Ministers of 30.12.1972, No. 338/72 on the national hydrological-meteorological service
- Decree of Council of Ministers of 11.03.1977 on the protection of environment against floods, Law Gazette No. 10, Pos. 39 with later implemented modifications
- Decree of 29.11.1999 on the organisation structure and tasks of the Regional Boards of the Water Management, Law Gazette No. 101, Pos. 1180

According to Art. 70 of the Polish Water Act the direct flood prevention belongs to the tasks of the flood committees. In flood situations they co-ordinate all public and private activities of flood prevention. The Main Committee for Flood Prevention is led by the Head of the Council of Ministers. In flood situations the Voivodship Flood Committees give the order for formation of Regional, Local, City and Company Flood Committees (Fig. 6).
In Poland the local government reform and the gained experiences during the last flood resulted in changes of the flood prevention structure. Besides flood committees (Main, Voivodship, Local and City Committees), responsible exclusively in flood situation, the continuously working Authorities for Crisis Management were set up and a new continuously working structure of flood prevention was established.

In Poland **warning and alert stage** are distinguished. The **warning** stage starts approx. 10 cm below the water level when flooding starts. In case of warning, higher watchfulness is required. The **alert stage** indicates flood hazard. This stage is announced by taking into account the degree of management in the area and exceeds the water level when flooding starts by several cm (IKSO, 1999).
During the flood prevention the present state of the flood hazard is assessed by the working group „Analysis and Prognosis" of the flood protection committee. Proposals for further measures (e.g. about evacuation) and decisions (e.g. declaration or lifting of the flood warning, water release from reservoirs) are made to the head of the committee.
The *working group „Analysis and Prognosis*" mainly uses the hydrological and meteorological information of the **Institute of Meteorology and Water Management (IMGW)**. The IMGW disseminates flood forecasts and warnings as well as further hydrological-meteorological information parallel to different bodies and prepares information for the media. *The centre of the flood forecasts* in the Odra basin is located at the *IMGW in Wrocław*. In the Odra river basin the following regional IMGW branches are responsible: *IMGW in Katowice* (Odra river basin from the Polish-Czech border up to mouth of Nysa Kłodzka river, excluding the Nysa Kłodzka river, but including the Stobrawa river), *IMGW Wrocław* (Odra river basin from the mouth of the Nysa Kłodzka river to the mouth of the Lausitzer Neiße/Nysa Łużycka river including the catchments of the Nysa Kłodzka river and Nysa Łużycka river), *IMGW in Poznań* (Odra river basin downstream of the mouth of the Lausitzer Neiße/Nysa Łużycka river up to including the profile Gryfino (Lower Odra) and the Warta river basin) and *IMGW Gdynia* (Odra river basin downstream of the profile Gryfino to the mouth of the Odra river and the area drained to the Zalew Szecziński).

The IMGW Wrocław provides the flood information service for the Odra and its tributaries on Polish territory from the Czech-Polish Border up to the profile Słubice at the „Border Odra“. For the flood information service on the Odra river downstream of the profile Słubice to the profile Gryfino (Lower Odra river) and on the Warta river the IMGW Poznań is responsible.
For the flood forecast the IMGW closely co-operates with the **Regional Water Management Authorities (RZGW)**. Catchment related the RZGWs are responsible for the water management and the maintenance of the hydraulic-engineering structures (KRAMER et al., 2000). The RZGW Gliwice is responsible for the Odra catchment between the Czech-Polish border and Kędzierzyn-Koźle, the RZGW Wrocław for the catchment between Kędzierzyn-Koźle and the mouth of the Lausitzer Neiße/Nysa Łużycka river and the RZGW Szczecin from the mouth of the Lausitzer Neiße to the Odra river mouth into the Baltic Sea. For the catchment of the Warta river the RZGW Poznań is responsible (Polish Law Gazette Dz.U.99.101.1180 of 17.12.1999). In flood situations the Voivod as Head of the Voivodship Flood Committee decides about the operation of the reservoirs and retention basins.

An overview about the flood forecast and decision system in Poland is given in Figure 6.

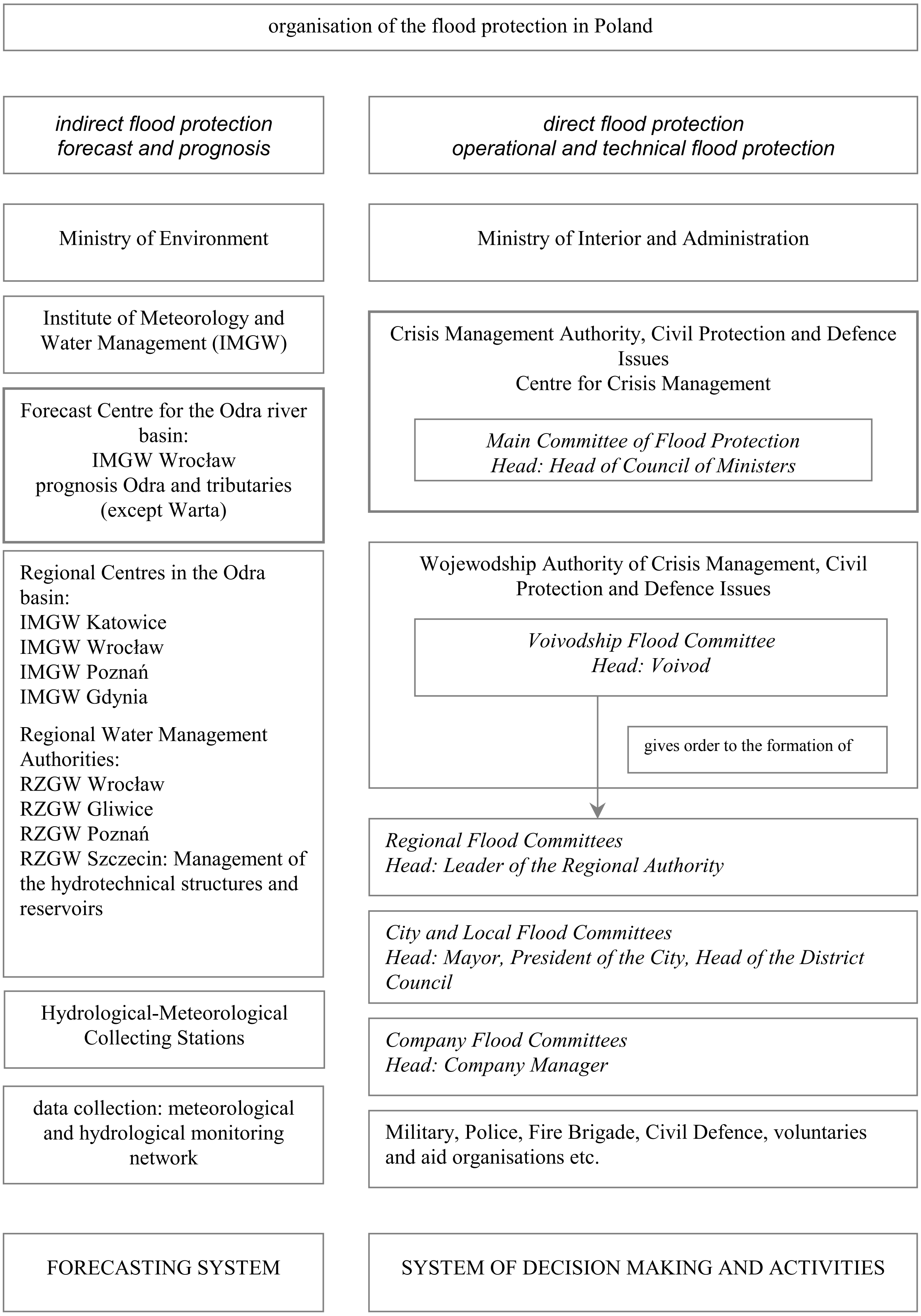


Fig. 6: Flood forecast and decision system in the Polish part of the Odra river basin (supplemented after SCHMITT, 2000)

3.3 Federal Republic of Germany

According to the Constitution of the Federal Republic of Germany flood protection is **task of the Federal States** (Bundesländer). For the Odra river basin these are the Federal States of *Brandenburg* and *Saxony* (Lausitzer Neiße river). Flood protection is undertaken according to the different federal water regulations by the states, districts, municipal cities (kreisfreie Städte) or local communities. Based on the structures that existed before 1990 the presently responsible authorities in the two Federal States are similar to a certain degree. In the case of national waterways the water level measurement and the flood announcement service are provided by the Wasser- und Schifffahrtsverwaltung (Federal Waterway and Navigation Administration) of the Federal Government in co-operation with the respective responsible Federal State.

The following **legislation documents** are important for the flood forecast and flood information service:

Federal State of Brandenburg:

- Brandenburgian Water Act (BbgWG) of 13.07.1994, in the version of the last changes by the act of 22.12.1997
- Decree of 09.09.1997 on the implementation of a warning and alarming service for the protection against water related hazards and for the dissemination of flood information (Flood Information Service Decree of the Federal State of Brandenburg)

Free State of Saxony:

- Saxon Water Act of 23.02.1993 respectively its revision of 21.07.1998
- Decree on the Flood Information Service in the Free State of Saxony (HWNDV) of 14.10.1993 and the Flood Report Regulation (HWMO) of 20.11.1993 and 08.12.1997, respectively

For the organisation of the flood information service and the setting up and maintenance of the flood report river gauges in the German Odra river basin are responsible:

- *Federal Waterway and Navigation Authority East* (WSD Ost): flood prone water bodies that are federal waterways (but the flood forecast is provided by the respective Federal State Agencies)
- *Environmental Agency Brandenburg* (LUA): flood prone water bodies in Brandenburg which are no federal waterways
- *Saxon Agency for Environment and Geology* (LfUG) and the *Environmental State Agencies* (StUFA): flood prone water bodies in the Free State of Saxony which are no federal waterways

The flood information service includes the monitoring and reporting of meteorological variables, water levels, discharges and ice phenomena. These observations are analysed for actual flood reports and disseminated in form of actual water stages and flood forecasts according to fixed information schemes to the agencies, institutions, companies and the public. Information about the beginning, the development and the spatial extent of the flood and of ice hazards, respectively, is provided and the alert stages are triggered off, so that corresponding defence measures can be started in time. Both Federal States have a system of **four alert stages** to start flood defence measures in time (Fig. 7).

<table>
<tr><td></td><td>alert stage I
water level information duty</td><td>alert stage II
control duty</td><td>alert stage III
watch duty</td><td>alert stage IV
disaster defence against flooding</td></tr>
<tr><td rowspan="2">pre-requisites</td><td colspan="4">water levels exceed alert levels at flood watching river gauges, further increase of water levels has to be expected</td></tr>
<tr><td></td><td>respectively obstruction of discharge by ice development that can cause a rise in water levels</td><td>respectively obstruction of discharge by ice, trees, shrubs and other drifting materials, which can cause a rise in water levels</td><td>respectively independently of the alert water levels there is urgent danger of the safety of flood defence structures</td></tr>
<tr><td>Situation</td><td>water bodies start to overflow</td><td>flooding of grassland and forested areas in the flood plains;
flooding of embanked water bodies reaches dike foot</td><td>flooding of some estates, streets or basements;
high water content of polder areas and drainwater;
water levels reach approx. half height of the dikes</td><td>flooding of larger areas including streets and sites in settled areas</td></tr>
<tr><td rowspan="4">Measures/ actions</td><td colspan="4">information about the water levels in fixed time intervals to a certain group of recipients, additional river gauge readings in the flood areas;
information of the agencies about the flood development;
controlling of the functioning of the flood protection structures;
controlling of evacuation of livestock, equipment and material out of flood threatened areas</td></tr>
<tr><td></td><td colspan="3">daily controlling of the embankments and the water management structures;
preparation of a continuously working monitoring service at the embankments;
pre-cautionary arrangements with companies on providing working forces, material and transport capacities;
preparation of transport of flood defence material to the threatened sites</td></tr>
<tr><td colspan="2"></td><td colspan="2">continuous monitoring of the dikes;
transport of flood defence materials to known endangered sites and to prepared temporary stores;
pre-cautionary actions to reduce dangers (e. g. measures to secure construction sites)</td></tr>
<tr><td colspan="3"></td><td>active defence against occurred hazards;
preparation of evacuations</td></tr>
</table>

Fig. 7: Flood alert stages I to IV in the Federal States of Brandenburg and of Saxony (after LUA, 1995; SMU, 1998)

In Brandenburg the alert stages I and II are released and cancelled by the Environmental Agency (LUA), the alert stage III and IV by the responsible district heads and mayors of the municipal cities on the recommendation of the Environmental Agency (LUA, 1995). In Saxony the alert stages I to IV are released for respective river reaches by the lower administration agency in charge (SMU, 1998).

In both Federal States the flood information service starts as soon as either the alert stage I at one flood watching river gauge is exceeded and a further rise of the water level has to be expected or because of the weather situation a flood warning was disseminated. The flood information service is terminated when the alert stage II is not reached and a further increase in the water level is not be expected.

In **Brandenburg** flood warnings and flood forecasts for the threatened river reaches are prepared by the LUA. The LUA disseminates these information to the affected district agencies, districts and municipal cities, which distribute the information within the area they are responsible for. In accordance with the LUA the districts and the municipal cities with the respective administrations for disaster protection are responsible for the flood defence. The head of the flood defence is the district administrator and the mayor, respectively. Is the alert stage IV released by the State of Brandenburg, the Ministry of the Interior, as the upper disaster protection administration, takes over the co-ordination.

In the Free State of **Saxony** the LfUG is the central flood office. It manages and co-ordinates the flood information service in the free state of Saxony, works out the flood reports as well as the regional flood reports for the Ministry of Environment and Agriculture and arranges the implementation and the development of flood forecast models. Heads of the flood defence are the districts and municipal cities as the lower disaster protection administration and the Ministry of Interior as the upper disaster protection administration.

According to the Saxon Water Act, in disaster situations the local Saxon communities are responsible to implement a water defence service, if experience shows that they are prone to flooding. They have to keep working forces and technical material (stock of flood material) ready. In agreement with the responsible Environmental State Agency the responsible water authority orders the beginning, the end, the extent and the content of the defence measures to the municipality. Both institutions as well as the Landestalsperrenverwaltung (Saxon Reservoir Authority) assist the municipalities at the defence of water threats. If disaster alert or pre-disaster alert takes place the disaster protection administration orders the forces, which are qualified to fight against the disaster and to reduce its effects, and leads their joint operation.

An overview on the flood protection system in the German Odra river basin is presented in Figure 8. It is subject of the sovereignty of the Federal States, but it is similar in structure in Brandenburg and Saxony.

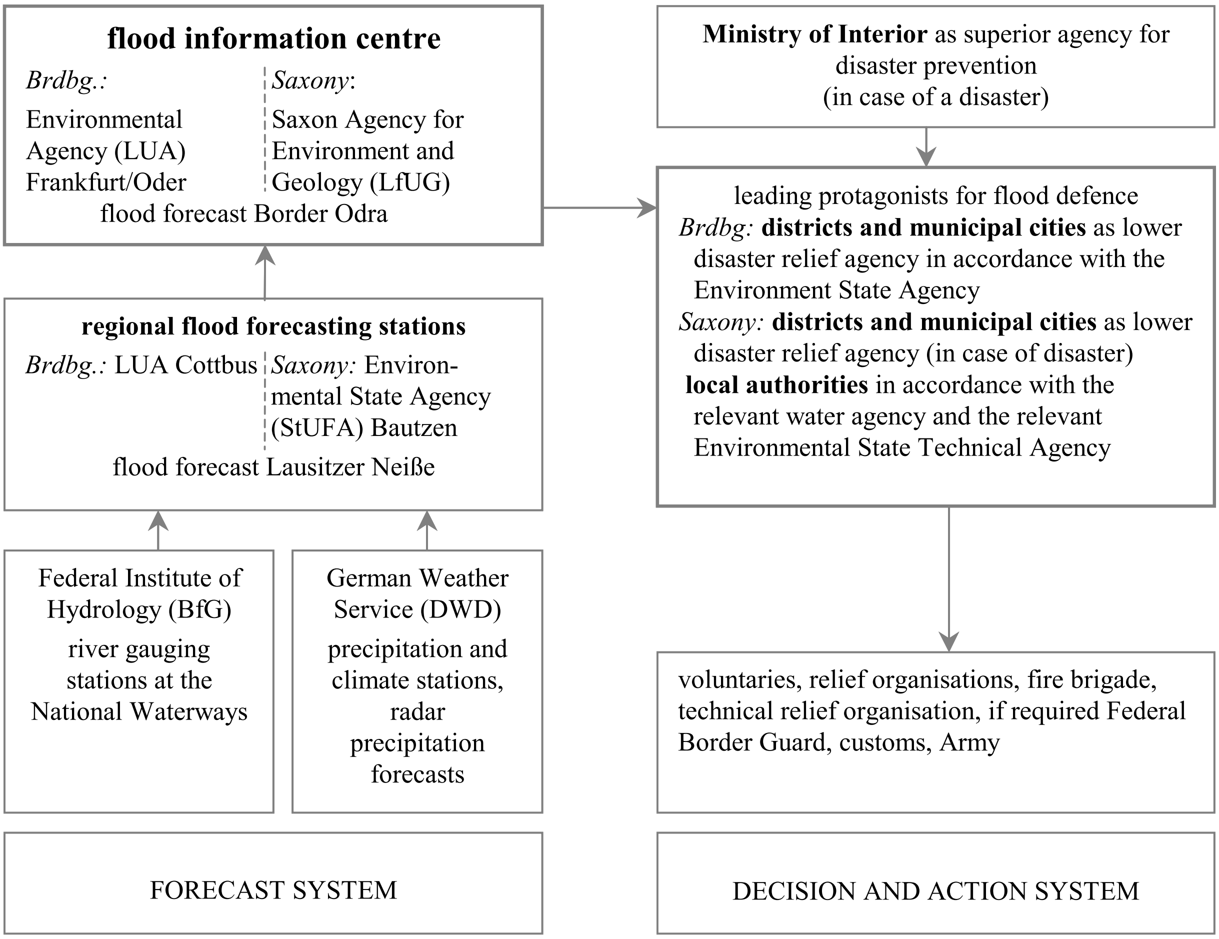


Fig. 8: System of flood forecast and flood defence in the German Odra river basin (under the authority of the Federal States)

3.4 International co-operation

Transboundary rivers require international agreements for water management and flood protection. *In the Odra river basin* the following **treaties** are essential:

- Treaty between the Federal Republic of Germany and the Republic of Poland about co-operation on the field of water management on the border water bodies of 19.05.1992
- Treaty between the Federal Republic of Germany and the Czech Republic about co-operation in the field of water management on the border water bodies of 12.12.1995
- Treaty between the Republic of Poland and the Government of the former Republic of Czechoslovakia about co-operation in the field of water management on border water bodies of 21.05.1958, Prague
- Treaty between the Republic of Poland, the Federal Republic of Germany and the Czech Republic as well as the European Union about the International Commission for Protection of the Odra against Pollution (ICPO) of 11.04.1996

Within the frame of the first three treaties the *German-Polish*, *German-Czech* and *Polish-Czech* **Commissions on Border Water Bodies** were set up. Their tasks are, among others, the flood protection, the co-ordination of co-operation of the hydro-meteorological services, the exchange of monitoring results and the daily information exchange in flood situation including hydrological forecasts. Therefore, the Commissions on Border Water Bodies are an important platform for the *bilateral information exchange*.

The **International Commission for the Protection of the Odra river (ICPO)** was founded 1996 due to the need that effective water protection on international water bodies has to be catchment related. The ICPO had only a preliminary status until the treaty came into force on the 28.04.1999. After the Summer Flood 1997 (04.08.1997) the responsible ministers agreed to extend the duties of the ICPO on the field of flood prevention and flood protection. The current structure of the ICPO is presented in Figure 9.

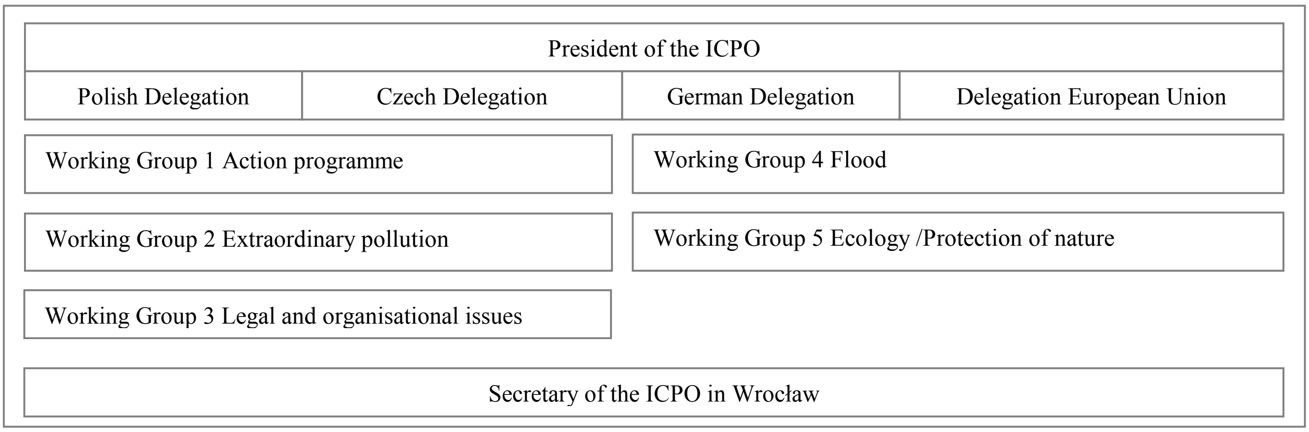


Fig. 9: Organisation scheme of the ICPO, July 2000 (SCHMITT, 2000)

The *main task of the ICPO* is the development of *transboundary programmes and common strategies* to *prepare political decisions*. This is done in working groups and for special issues also in expert groups. For instance, one of them is the expert group „flood information services and flood forecast" of the ICPO workgroup „*Flood*".
The secretary of the commission started its official work in February 2000. It is responsible for the organisation and co-ordination of the work of the commission and its working groups. Furthermore, it wants to become the major information centre for the Odra river and its basin.

The working groups of the Commissions on Border Water Bodies differ from those of the ICPO in the fact that they work bilaterally and only along the borders, mostly on very special issues. The *ICPO* on the other hand is looking on the entire Odra river basin and *unifies all riparian countries* within its bodies (SCHMITT, 2000).

4 Flood forecast and early flood warning systems

In the following the fundamental requirements on an operational flood forecast, which constitutes an important component of the early flood warning system, are formulated. The actual state of development is presented exemplary for several river basins.

4.1 Fundamental requirements on flood forecast

Early flood forecasts enable the authorities to take precautionary measures of disaster prevention like construction of mobile protection walls, road closings, and evacuation of the population. During the event measures can be planned more efficiently and less expensively and put into action. Reliable flood warning keeps large financial and psychological burdens from the communities, the citizen and the companies (HOMAGK & MOSER, 1998).

Besides the *use of the system* and the available *financial means*, the required components and complexity of a flood forecasting system are mainly determined by the *hydrological conditions* (FELDMANN, 1994). Concerning the influence of the hydrological conditions SCHAFFERNAK (1935, p. 365) stated: „In principle, the methods of the short-term forecast are different, e.g. for a river course with a small catchment and therefore short travel time or a large river with a hydrographically and morphologically heterogeneous catchment.“

In the **headwaters** of a river, mostly situated in mountainous areas, the discharge occurs rapidly and severely after rainfall or sudden thaw weather situations. The forecast lead times are short, and the *runoff generation process*, possibly even the *precipitation formation process* has to be included into the simulation. The threatening by flood is especially large. During the *runoff concentration process* the discharge is often limited on narrow valleys and causes severe damages on the narrow flood plains. Due to the very short warning lead times the people living there are severely threatened.

On the **lower reaches of the river**, mostly situated in the lowlands, the effects of individual local rainfall events are often attenuated. Spatially extended precipitation events of long duration are here of special importance, especially if they are connected with sudden snowmelt and saturated soils. The inundations related to the *wave transformations process* within the riverbed are spatially extended and threaten buildings and material values in the first place. Due to the longer lead times for warnings and evacuations the threat of human lives is less severe with an efficient disaster prevention (PLATE, 1997).

On the lower reaches there are often larger settlements, which are protected by dikes to a certain degree. Here, it is important to forecast those water levels, where overwashing of dikes occurs, and to assess the stability of dikes regarding the duration of the flood situation. Hydrodynamic models are necessary to simulate the wave transformation within the riverbed, dike breach and city inundation scenarios. Data of hydrometric measurement networks, transverse sections of the riverbed and digital elevation models based on uniform problem related topographical maps have to be provided. The flood wave transformation models should be coupled with rainfall-runoff models of the headwaters.

Flood forecast has to be regarded as a *component* of a complex *flood forecast and warning system*. The warnings have to be received by the affected people in a sufficient *lead time* and in sufficient *accuracy*. However, with longer lead times the *uncertainties* of the flood forecast increase. Already SCHAFFERNAK (1935, p. 381) stated that the accuracy of the short-term forecast depends on the used method and the length of the forecast lead time. In the first half of the 20th century „the water level on the Elbe river in Germany was forecasted for the next

6 days with a accuracy of about 20 cm, on the Elbe river in the Republic of Czechoslovakia for 1 to 2 days with an average accuracy of 5 cm and on the Danube river in Austria for 1 day. Here in most cases the deviation amounted in average to 3 cm."

The water level and discharge forecasts are based on various *hydrometric* and *hydro-meteorologic data* and *products*. The main hydrological and meteorological input data are water level, precipitation, temperature and snow cover parameters. If possible, these data should be collected by a dense automated measurement network. To secure the transfer of data also in flood situations the measurement stations should be equipped with alternative ways for long distance data transfer. Water levels and discharges, respectively, are forecasted by using the measured water levels and discharges, respectively, plus the measured or forecasted precipitation amounts.

Typical components of a **flood forecasting system** are:

- hydrological rainfall-runoff model
- routing model
- up-dating-procedure.

Generalised *flood forecasting software packages*, which are operationally used at present, are e.g. MIKE 11 (DHI - Danish Hydraulic Institute) and HBV (SMHI – Swedish Meteorological and Hydrological Institute) (REFSGAARD & HAVNØ, 1997). The hydrological models within these program packages are of conceptional and lumped type. The flood routing modules range from models based on the complete Saint-Venant equations down to simple linear hydrological routing procedures. Using up-dating-procedures manual corrections and the determination of error ranges is possible. Generally, the software is well developed and tested. More important improving steps of such systems are the improvement of *providing of input data* and of *quantitative precipitation forecast* and not the improvement of the model structure (REFSGAARD & HAVNØ, 1997).

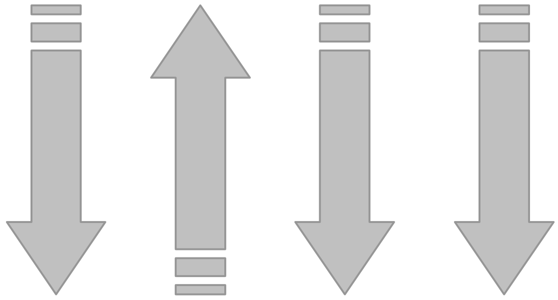
Also HOMAGK & MOSER (1998) emphasise the necessity to *reinforce the use of hydrometeorological data and products*. By using measured and forecasted meteorological variables, e.g. quantitative precipitation forecasts provided by numerical weather forecast models, forecast lead times can be increased.

Quantitative precipitation forecasts for large scale weather situations can be produced quite well whereas the forecasts of small-scale weather phenomena like convective precipitation events is still insufficient with this method. These convective precipitation events often trigger flash floods, where the runoff occurs within several hours. The spatial detection of precipitation in real time can be improved by using weather radar data.

The *extension of the forecast lead time* is especially important for the fast reacting headwater, but with it the accuracy declines. Regarding these types of flood forecasting systems and their various complexities are presented in Table 4.

Tab. 4: Comparison of different flood forecasting systems

	flood forecasting system	forecast lead time	reliability	expense	complexity of forecast procedures
A	real-time measurement of water level and discharge respectively and routing / correlation to key locations				
B	A plus precipitation in correlation to key locations				
C	real time measurement of precipitation, discharge, temperature etc. + rainfall-runoff model				
D	C plus weather forecasts (precipitation, temperature, etc.)				



Source: FELDMANN, 1994, slightly modified

The *spatial assessment detection of precipitation,* e. g. with weather radar, and the quantitative precipitation forecast with numerical weather simulation models is still associated with large uncertainties. Therefore, the main pre-requisite for an improved forecast with long lead times is the improvement of the accuracy in precipitation forecast (REFSGAARD & HAVNØ, 1997). SCHAFFERNAK (1935, p. 365) formulated that the future development in the water level forecasts depends strongly on the progress in the field of the meteorological weather forecast. And that – as long as meteorologists are only able to make short-term forecasts and are not able to forecast the course of the expected precipitation – „the water level forecast still will have to be based mainly on hydrographical observations.“

Hydraulic-engineering structures (e. g. reservoirs, polders) have to be included in the modelling. Due to corresponding control operations the flood danger for the area directly downstream of these structures can be remarkably reduced. Furthermore, an overlapping can be prevented. However, for a successful operation reliable hydrological forecasts are necessary.

A *necessary pre-requisite* of an effective flood forecasting system „is a *suitable organisation of the information service*. This includes a fast transfer of hydrographical and meteorological observations and measurements as well as the reliable dissemination of the forecast“ (SCHAFFERNAK, 1935: p. 366).

Within large catchments, often several institutions are responsible for the collection of hydrometrical and hydrometeorological information and for the flood forecast. Because of this a *reliable* and *effective data exchange* is of great importance. On transboundary catchments the monitoring network is maintained by the different riparian states. Therefore, mutual agreements about the data exchange are necessary. This requires a corresponding infrastructure.

The Task Force „Flood prevention and flood protection“ of the Convention on the Protection and Use of *Transboundary Watercourses* and International Lakes recommends a *compatible* meteorological and hydrological *information system* for the entire catchment *including* a *data base* with, if possible, fully automated data communication system. Additionally, an automated information system about the operation of reservoirs and other hydraulic-engineering structures should be implemented and maintained (UN/ECE, 2000).

4.2 State of development of operational flood forecast and early flood warning systems

After the first hydrographical approaches for flood forecasts (cf. SCHAFFERNAK, 1935), the national and international development of the meteorological and hydrological services, the extension of the corresponding monitoring networks, the rapid progress in the field of data communication and processing etc. resulted in the implementation of more or less systematical and more or less efficient instruments for flood forecast in all larger river catchments. They range from simple river gauge relation for peak water levels up to effective flood forecasting systems, e.g. on the Rhine river (BARTH & HOMAGK, 1992) and on the Elbe river (System „ELBA", FRÖHLICH, 1998). An overview on the state of development in the different Federal States in Germany is presented in LAWA (1993). Furthermore, in different Federal States there are developments for improved flood forecast and protection concepts in progress (e. g. „Integrierende Konzeption Neckar-Einzugsgebiet IkoNE" (www.IKoNE-online.de)). As with all so-called „natural hazards" and related damages, the problem „flood" normally does not come into public awareness until the moment of flood occurrence.
The great flood events on the Rhine river in the years 1993/94 and 1995 induced the Ministers of Environment of the EC-countries and Switzerland to pass the „*Declaration of Arles*" (04.02.1995). According to this, the International Commission for the Protection of the Rhine river (IKSR) was instructed to draw up a flood *Action programme for the* **Rhine** river. In the mean time, this programme is drawn up based on an extensive inventory (IKSR, 1997). Within this programme it is planned to invest 12 mio. ECU in the years 1998 to 2005 for the *improvement of the transboundary flood forecast* (IKSR, 1998).
In the last years, similar activities on other European rivers, e.g. Meuse, Moselle and Saar as well as the Elbe river, made different progress. On the 8th of April 1998 the flood action programme for the **Meuse** river basin was passed. A flood action programme exists for the catchments of the **Moselle** and **Saar** river (IKSMS, 1999). For the **Elbe** river there is a strategy for flood protection (IKSE, 1998). The ICPO (2000) also presented a first common strategy about flood protection for the **Odra** river as basis for a flood protection action programme.

In the year 1993 in the Mississippi and Missouri river system nine of the US-States, which encompass approx. 15 % of the territory of the **United States,** were affected by disastrous flooding. Large areas were flooded for more than 200 days (INGRAM, 1997). As reaction on this flood the National Weather Service (NWS) implemented the „*NWS Advanced Hydrologic Prediction System (AHPS)*". Most efforts were put into the modernisation of remote sensing, the automation of data communication and in an improvement of the hydrological-hydrometeorological modelling tools. This improved system can be used since spring 1997 (INGRAM, 1997).
From **England** and **Wales** PRITCHARD (1996) and HAGGETT (1998) report about the implementation of a new flood warning system and the state of the stepwise translation of an *integrated approach in flood forecast and flood warning* into action. For an accurate, reliable and timely warning, all components of the forecast and early flood warning system have to work efficiently together. Regarding the integrated approach large efforts were put into the improvement of the *flood information and decision systems* in Great Britain over the last years. Factors, which influence the effectiveness of the flood warning system, depend on the legal pre-requisites, the institutional understanding, the technological possibilities, the existing expertise, and the availability of data (HAGGETT, 1998). For the development of such an integrated system, it is important that the *roles and responsibilities of the institutions and*

organisations are clearly defined. The „*political avowal for flood warning*“, the corresponding decisions and a „*positive culture and climate within the organisations*“ are further important factors.

One institution should be obliged to control the whole process of flood forecast and warning (HAGGETT, 1998). In England and Wales 22 centres for integrated flood warning are operating under the responsibility of the Environmental Agency. In the year 2000, the Environmental Agency organised a large „*Flood Awareness Campaign*“ (www.environment-agency.gov.uk). Flood risk maps were distributed to local authorities and are also available in the internet. The implementation of a national phone centre for the *direct information of the citizens* about the flood situation (FLOODLINE) is regarded as special success. The severe floods in autumn 2000 were a first critical test for the new system, well worth to be analysed.

In Table 5 the components and factors are listed, which are necessary and have to be connected as a **chain** from **detection to reaction** for an effective *early flood warning system* constituting of an integrated flood forecast, flood information and flood defence system. In most cases the components of the early flood warning system are treated individually. However, the entire system is more than individual components attached to each other. The individual component should be state-of-the-art technology, but of all-decisive importance is their co-operation. Often there is only investment into the development of flood forecasting systems without regarding the dissemination of warning and forecast or their execution (HANDMER et al., 1999; SAMUELS, 1998; PARKER et al., 1994).

The efficiency and the usefulness of the flood forecast and flood warning have to be seen in connection with the decision makers and the affected population. Besides the scientific-technical aspects regarding flood forecasts it is also important how the affected protagonists use these forecasts and how they influence the decision making processes.

Tab. 5: Components and factors of an early flood warning system

	activities	principal agencies, institutions and organisations	key factors
DETECTION	collection of meteorological data and weather forecasts collection of hydrometric and hydrological data	meteorological agency central or state water management agency with regional/local units	automated and telemetric data collection and transmission dense networks of data collection station weather radar
FORECASTING	receiving and interpreting of data flood modelling flood forecasting issuing of warnings	flood forecasting agency central or state water management agency with regional/local units	operational flood forecasting system with R-R-model and flood wave transformation model efficient inter-agency and transboundary communication system
WARNING	receiving of flood forecasts and warnings interpretation and decision finding dissemination of warnings providing of information co-operation of involved parties and media	regional and local decision makers flood committee and disaster prevention civil protection (rescue service, police, fire brigade, etc.) media	unambiguous responsibilities 24 – hour staffed offices fast and efficient communication long forecast lead time few false warnings targeted warnings efficient inter-agency and transboundary co-operation
RESPONSE	co-ordination of response activities/measures and participants informing the public	flood committee and disaster prevention local government units civil protection	good information system for the public with learning feedback
REACTION	reduce vulnerability to damage by pre-cautionary measures, flood defence and evacuations	river user companies, industry within flood prone areas population at risk	response to information and warnings availability of assistance awareness of the situation prior flood experience

Source: modified after PARKER et al., 1994

In addition *transboundary* river catchments pose special requirements. An extensive analysis is given in the proceedings conference volume of the UN-ECE Seminar „Sustainable flood protection“ (UN/ECE, 2000) which took place on the 7.-8. October 1999 in Berlin. Within the frame of the „Convention on the Protection and Use of Transboundary Watercourses and International Lakes“ internationally agreed recommendations for flood prevention actions are given in the „Guidelines on sustainable flood prevention“ (UN/ECE, 2000 a). Among others, the guidelines provide recommendations concerning the *development of transboundary early flood forecast and warning systems* and *interstate information exchange*.

Within the frame of the „International Decade for Natural Disaster Reduction (IDNDR)“, which ended in the year 1999, *early flood warning systems were identified as the most important tools for damage reduction* (UN Resolution 49/22 B of 21. June 1995). At the end of the IDNDR Decade, Germany proposed, among others, the implementation of an international co-ordination centre for early warning in Germany (seat in Bonn). Undoubtedly, during the last years Germany was one of the pacemakers by initiatives for the improvement of early warnings, e.g. with the organisation of the „Early-Warning-Conference“ in Potsdam (PLATTE, 2000). In consequence of this activity, the German Research Network Natural Disasters (DFNK) was founded. Its tasks is the linking of the necessary integrative and interdisciplinary disaster research and disaster prevention. The aims are to concentrate the experiences of institutions and research groups working in various fields of disasters, to standardise information and warning systems, to generalise the best experiences, systems, and working methods respectively, and to put these into practice in the disaster management. Moreover, the DFNK shall enhance the awareness for the importance of the disaster prevention in politics and public (http://dfnk.gfz-potsdam.de). The first period of the DFNK is oriented towards a region on the Rhine river with focus on the region of Cologne (flood, earth quakes, storm). First considerations concerning the second phase (fire, droughts) and the regional extension to Berlin-Brandenburg (HÜTTL, 2000) exist.

5 Causes for floods in the Odra river basin

The requirements on flood forecasting systems or on early flood warning systems strongly depend on the conditions for flood formation in the river catchment. These serve as a basis for the subsequent presentation and assessment of the flood forecasting system in the Odra river basin.

The different floods occurring in the Odra river basin can be roughly characterised according to Table 6.

In the **winter half-year** higher discharges in the Upper and Middle Odra river basin are triggered mainly by snowmelt (spring floods). Dangerous situations occur, when snowmelt coincides with rainfall or ice jam and ice shifts, respectively, especially on the Lower Odra reach.

In the **summer half-year** cyclonic rainfalls related with general weather situations can cause extreme floods in the entire Odra river basin. On the Lower Odra river the situation can be intensified by wind induced backwater effects from the Stettiner Haff.

Also convective rainstorms play a significant role in the summer on the Upper Odra river and its tributaries which drain mountainous areas.

Tab. 6: Main causes for flood formation in the Odra river basin

Upper Odra river basin and the headwaters of the left-hand side tributaries	snowmelt	convective rainstorms cyclonic rainstorms
Middle Odra river basin and Warta river basin	snowmelt	cyclonic rainstorms
Lower Odra river basin	ice floods	cyclonic rainstorms backwater effects from Stettiner Haff
	winter half-year	summer half-year

5.1 Winter half-year

Winter and spring floods

In spring increased discharge, particularly in February and March, is observed on the Odra river due to the melting of extensive snow coverage. Because the snow in the lowlands and valleys normally melts prior to that at the higher elevations long-lasting flood periods can develop (BUREAU, 1896). Inundations due to snowmelt events preferably occur on the right-hand side tributaries of the Odra river (BUREAU, 1896; CZAMARA & WOJARNIK, 1999).

Snowmelt alone generally does *not induce extreme floods* on the Odra river and its tributaries. However, *discharge volume*, *peak flow* and *flood duration* can be *intensified by simultaneous occurrence of rainfall events*.

Ice floods

Compared to European river basins further westwards the Odra river basin more often is influenced by cold continental air masses. Hence the Odra river is more often affected by river ice formation. On the section at the Odra river mouth the ice formation occurs similarly to that of stagnant waters, i.e. starting from the banks and proceeding towards the middle (JAHRBUCH DER SCHIFFAHRT 1964, 1965). In freezing periods of long duration on the Upper and Lower Odra river sections besides marginal ice[3] also ground-[4] and floating ice[5] forms, which can be drifting as drift ice[6] until it is piled up in front of obstacles.

On the *Upper and Middle reaches of the Odra river* weirs, especially at Wrocław, Oława and Brzeg, and narrow bridges (Krosno, Cigacice, Głogów, Opole) induce piling up of drift ice[6] (UHLEMANN, 1999).

On the *Lower Odra river* the strong reduction in water level slope (from 28 cm/km at Eisenhüttenstadt to less than 1.5 cm/km downstream of Schwedt), the backwater effects of the Stettiner Haff / Zalew Szczeciński and of the Baltic Sea as well as the bottlenecks of the cross sections downstream of the weir Widuchowa are adverse factors for the ice discharge capacity

[3] ice that has formed at the water surface in contact with the banks or obstacles or has been piled up
[4] ice that has formed on the bottom of the riverbed below the water surface, as long as it remains there
[5] ice that floats within the water body
[6] drifting as ice floes at the water surface

(FREYDANK, 1986). The drift ice is stopped by the ice cover[7] of the Stettiner Haff / Zalew Szczeciński or of the lake Jezioro Dąbie.

The piled up ice floats merge by freezing and form upstream a so-called ice jam[8]. The rough undersurface of the ice jam reduces the flow velocity and at constant discharge results in backwater effects (JAHRBUCH DER SCHIFFAHRT 1964, 1965). The rise in water level amounts to 0.8 m – 1.5 m depending on the discharge on the Border Odra river section (LUA, 1994). How fast the ice jam is proceeding upstream depends on the amount of drift ice and on the discharge. The flow velocity determines how strong the ice floats are pressed together. (FREYDANK, 1986).
At the end of the frost period first ice-free channels form downstream of inflows and at the end of the groynes. This initiates the natural break-up of the ice jam. The ice breaks into floats which drifts downstream as „ice drift“. Hazardous for dikes and structures is the formation of the so-called ice shifting[9]. Therefore, the discharge of ice drift has to be ensured by timely ice breaking operations starting from Stettiner Haff / Zalew Szczeciński and from lake Jezioro Dąbie (LUA, 1994).

According to BUREAU (1896) at the river gauge Schwedt the *time period* when the Lower Odra river section is *affected by ice* starts between 16. and 23. November and ends around the 21. February - 18. March. In the last 100 years approx. every 2 years the ice jam formation proceeds up to the mouth of the Lužická Nisa/Nysa Łużycka/Lausitzer Neiße river. Especially due to the pollution and the heating of the river water by sewage and cooling water the duration and intensity of the ice formation have changed. Since the beginning of the 70ies shorter ice jam periods are observed (LUA, 1994).

Ice and **spring floods** can **coincide** and due to ice shifting cause *special hazard to the dikes*, when:

- the water level of the Odra river is already high and further rises due to backwater effects by ice jam formation occur (rise in water level of 0.80 to 1.50 m is possible),
- there is a large storage of snow within the area of the low mountain ranges of the Odra river basin and due to rise in temperature sudden thaw weather with precipitation are occurring in this area,
- on the Lower Odra river there are still frost conditions, and an ice breaking operation starting from the mouth of the Odra river is limited (LUA, 1994; TRÖMEL, 1997).

A disastrous coincidence of ice flood and snowmelt occurred in March 1947 (TRÖMEL, 1997, p. 5): „In the night of the 22. March 1947 Odra flood water overspilled the main dike near Reitwein on a long stretch. The floodwater inexorably ate into the dikes and dragged wide gaps into the dike at two sites. Subsequently, the severest flooding disaster, which happened to the Oderbruch in this century, occurred“.

Water levels and discharges at the river gauges Eisenhüttenstadt and Hohensaaten-Finow of selected ice flood events in the recent past are listed in Table 7.

[7] stiff ice cover formed at the water surface exceeding the area of marginal ice
[8] state after drift ice in the flowing water is frozen to each other and comes to a standstill
[9] ice floats that are shifted together and are strongly narrowing the discharge cross section of flowing water

Tab. 7: Highest water levels (HW) and highest water discharges (HQ) of selected ice floods at the river gauges Eisenhüttenstadt and Hohensaaten-Finow

flood event	river gauge Eisenhüttenstadt/Oder		river gauge Hohensaaten-Finow/Oder	
	HW [cm]	HQ [m³/s]	HW [cm]	HQ [m³/s]
March 1940	611 on the 22.03.	1830	778 on the 21.03. 9.30 p.m.	2 120 on the 19./21.03.
March 1947	638 on the 23.03. 8.00 a.m.	2 040 on the 23.03. 8.00 a.m.	598 on the 31.03. 12.00 a.m.	1 790 on the 31.03. 12.00 a.m.
December 1981	485 on the 17.12. 6.00 a.m.	764 am 16.12. 6.00 a.m.	662 on the 27.12. 6.00am-6.00 p.m.	1 210 on the 17.12. 6.00 a.m.
January 1982	596 on the 24.01. 6.00-7.00 a.m.	972 am 14.01. 12.00 p.m.	746 on the 18.01. 2.00 pm-8.00 p.m.	1 515 on the 15.01. 12.00 p.m.-4.00 a.m.

Source: LUA (1994)

Because the water level is additionally influenced by ice jams the discharge peak often does not coincide with the highest water level (LUA, 1994).

5.2 Summer half-year

The natural discharge behaviour of the Odra river in summer flood situations is formed by the development of precipitation and runoff conditions on the tributaries of the Odra river and their sub-catchments, especially those originating in mountainous regions.

According to BUREAU (1896) the precipitation-runoff behaviour for the **Upper and Middle Odra river** can be described like this:
Extreme rainfall events with high intensities and high (local) precipitation totals *in the mountainous regions*, on the Upper Odra river, its tributaries, and the left-hand side tributaries of the Middle Odra river section cause a sudden rise in water levels (flash floods). *Preceding long-lasting rainfalls* often caused *soil saturation* and therefore an aggravation of the runoff situation of the extreme summer floods. This was the main cause for the floods in 1736, 1854, 1903, and 1997. Due to the *concentric river network* on the Upper Odra river and similar stream lengths of the Odra river and its tributaries there is the danger of an *overlapping* of the flood waves at the confluence. Besides the rainfall intensity and the total rainfall amount the flood wave also strongly depends on the *spatial precipitation distribution*:
If *precipitation* occurs simultaneously in the *Sudeten* and *Beskidy Mountains* the flood waves of the Ostravice river and the Olše/Olza river are extended by the flood waves of the Headwater Odra river and the Opava river, which arrive one day later. The flood wave of the Osobłoga river generally arrives earlier than the wave coming from the headwaters of the Odra river and is often more severe than the headwater flood wave itself. The flood wave of the Nysa Kłodzka river is retarded by the branched river network. Consequently, it often coincides with the flood wave of the Osobłoga river.
If the *precipitation in the Beskidy Mountains* occurs one day earlier than in the Sudeten Mountains, the flood waves of the Headwater Odra river, of the Osobłoga river, and of the Nysa Kłodzka river overlap and are forming a steep flood wave. When extreme precipitation occurs in the catchments of the left-hand side tributaries (especially of the Bóbr river and Lužická Nisa/Nysa Łużycka/Lausitzer Neiße river) an overlapping of flood waves and backwater effects occur on the Middle Odra river.
The headwaters of the Bóbr river with its tributary Kwisa and of the Lužická Nisa/Nysa Łużycka/Lausitzer Neiße river are of distinct mountainous character. The flood wave of the

Bóbr river travels approx. four days from the mountains to the mouth into the Odra river. The flood wave of the Lužická Nisa/Nysa Łużycka/Lausitzer Neiße river needs approx. three days from Görlitz to the mouth into the Odra river. The tributaries Kłodnica, Mała Panew, Stobrawa, Oława, and Ślęża rarely are affected by floods. Also the flood waves of the Bystrzyca, Kaczawa and Widawa river generally do not result in an important rise of water level in the Odra river. Generally, they arrive several days in advance of the Odra flood wave their respective mouths into the Odra river. But the flood wave of the Barycz river often coincides with the Odra river flood wave.
The Warta river, the largest tributary of the Odra river, generally carries no larger flood wave to the Odra river. This was also the case in the Flood 1997. Main reasons are the lowland character of the Warta river catchment and the large retention areas of the reservoir Jeziorsko and the natural polder area along the Warta river section Konin-Pyzdry (KOWALCZAK, 1998). The area of the Warta river mouth with the spatially extended polder Słonsk also serves as retention area for the flood wave of the Odra river. During the Flood 1997 large water amounts were flowing from the Odra river into this polder area. This resulted in a dropping of the water levels in the Odra river itself (TADEUSZEWSKI, 2000). However, the flood wave in the Odra river can be prolonged by the discharge of the Warta river.

The drainage area of the **Lower Odra river** is predominantly located in the lowlands, where summer rainfalls generally do not induce distinct flood waves. The flood waves coming from the Odra river upstream enter this river section in an attenuated form and are here further attenuated. Especially the area of the polder Międzeodrze serves as retention area and reduces the water levels.
On this river section influenced by the Baltic Sea there are other discharge conditions compared to those on the Upper and Middle Odra river. This river reach is characterised by a low slope and the backwater effect by the Stettiner Haff and the Baltic Sea, respectively. The water levels and discharges are determined by a complex interaction of backwater effects by the water level of the Stettiner Haff and the Baltic Sea, of atmospheric factors (wind and atmospheric pressure) as well as of the runoff coming from the upstream Odra river basin. Hazards due to high water level are considered to be less critical for this Odra river section. During the Flood 1997 on this reach of the Odra river the highest water levels (HHW) were not exceeded in contrast to the Upper and Middle Odra river. High flow velocities were more problematic. Especially at bottle-necks like the Bielinek site, narrowed by dikes on both sides of the river, locally high flow velocities of up to 2.5 m/s could be observed. During the Flood 1997 local erosion phenomena of the river bottom of up to 9-10 m occurred which threatened the stability of flood protection structures. In case of high discharge the influence of wind is of less importance than in case of low water conditions. However, backwater effects induced by north-western and north-eastern winds can aggravate the runoff situation. The coincidence of flood waves and long-lasting winds from northern directions is of less probability (BUCHHOLZ, 1997).
On average depending on the precipitation distribution in the individual sub-catchments and the general initial conditions, the *travel times of the flood waves* starting from the river gauge Miedonia on the Upper Odra river down to the Border Odra river section amount to 7 - 10 days. On the Border Odra river the travel time for the section from Eisenhüttenstadt to Schwedt amounts approx. to 1.4 days in flood situations (LUA, 1994).

Table 8 compiles the highest water discharges of important summer floods which affected the entire course of the Odra river.

Tab. 8: Highest water discharges of selected summer floods on the Odra river

river gauge	highest water discharges [m³/s]				
	August 1854	July 1903	August 1977	August 1985	July 1997
Chałupki		-	738	1 050	2 160
Racibórz-Miedonia (Ratibor)		*2 000	960	1 337	3 100
Koźle (Kosel)	***2 850	-	886	1 287	3 290
Opole (Oppeln)		-	1 014	1 306	3 500
Brzeg Most (Brieg-Brücke)		-	1 300	1 350	3 530
Malczyce (Maltsch)		*2 200	1 470	1 510	3 100
Głogów (Glogau)	***2 313	*1 975	1 430	1 260	3 040
Połęcko (Pollenzig)		**2 110	1 680	1 290	3 200
Eisenhüttenstadt		**2 110	**1 615	****1 370	**2 600
Słubice		**2 120	-	-	3 320
Hohensaaten-Finow		**2 120	**1 795	****1 435	*****2 700 to 3 000

Source: RADCZUK, 1997; * FISCHER, 1907; ** BFG, 1997; *** BUREAU, 1896, estimated discharges; **** LUA, 1997; *****LUA , 1998

Altogether, it can be stated, that to date *summer floods represented the most severe events* affecting *large reaches* of the river *simultaneously*. The runoff situation on the Upper Odra river is characterised by a frequent overlapping of flood waves of the left-hand side tributaries and an extensive hydraulic-engineering infrastructure (reservoirs, weirs, etc.). Winter /spring floods and ice floods alone generally do not result in extreme floods affecting large areas. However, their coincidence can result in locally extreme situations. Basically, the situation on the Lower Odra river differs from the situation on the Upper and Middle Odra river section due to the very low slope and the backwater effects by the Stettiner Haff / Zalew Szczeciński.

6 About the state of the operational flood forecast in the Odra river basin

Presently, **flood forecast** and **flood information services** in the Odra river basin *are mostly arranged according to the state boundaries* and less to the sub-catchments or hydrological conditions. Due to this fact the flood forecasting systems for the respective parts of the Odra river basin are presented in this chapter according to the administrative boundaries of countries and Federal States. In Figure 10 an overview about the present systems of flood forecast in the Odra river basin is given.

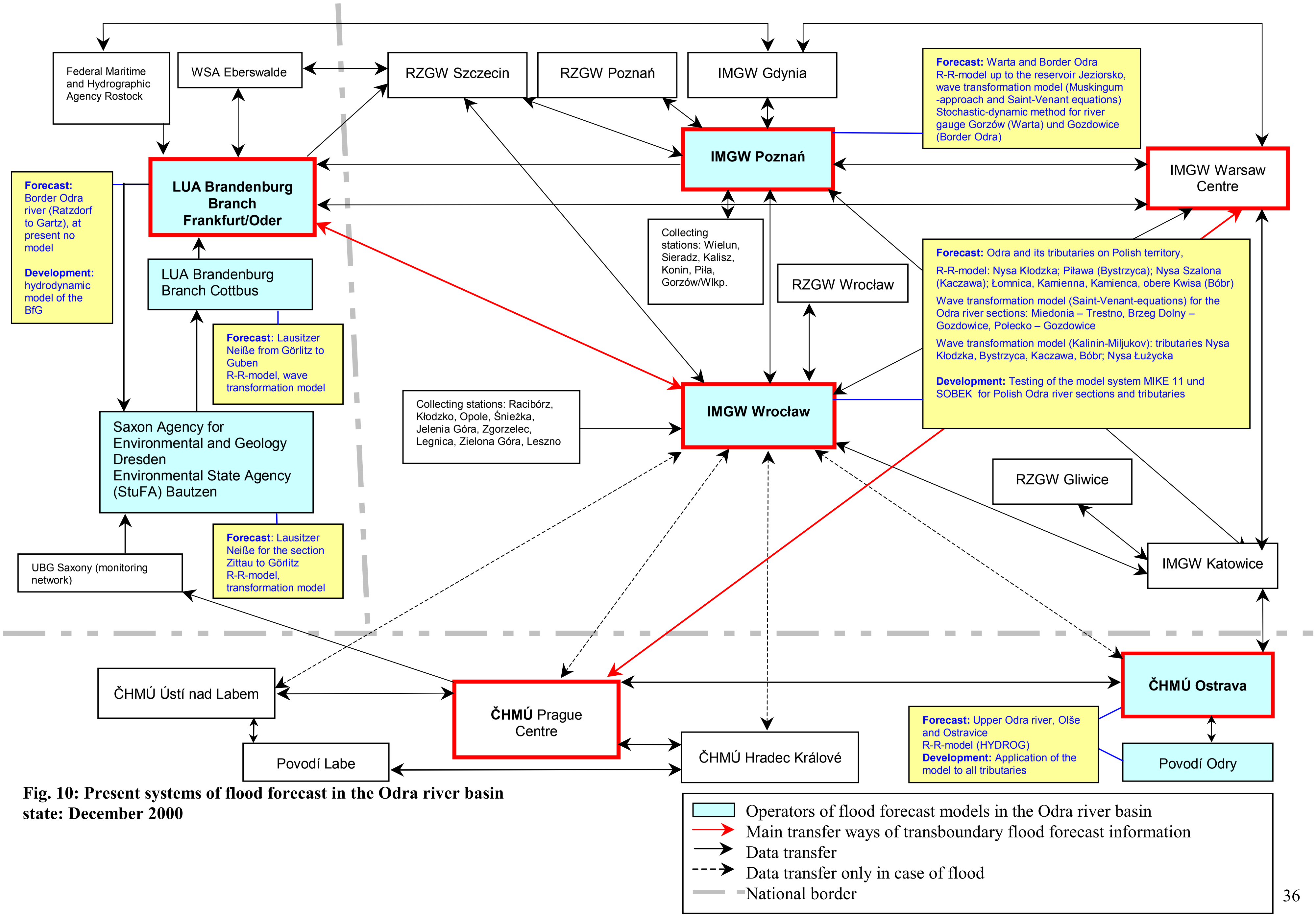


Fig. 10: Present systems of flood forecast in the Odra river basin state: December 2000

6.1 Flood forecast for the Upper Odra – Czech Republic

The headwaters of the Odra river in Northern Moravia and Silesia represent the *main parts of the Odra river basin in the Czech Republic*. Small parts of the sub-catchments of the Stěnava, Smědá (Polish: Witka) and Lužická Nisa (Nysa Łużycka/Lausitzer Neiße) are located in Northern Bohemia.

The **Czech Hydrometeorological Service (ČHMÚ)** is in charge of flood forecast and flood warning. Within the ČHMÚ the formally separated meteorological and hydrological services work together closely. The *central office of the ČHMÚ* is located in *Prague-Komořany*. The regional offices of the ČHMÚ, responsible for the Odra river basin, are situated in Ostrava (Odra river on Czech territory, Ostravice river, Moravice river, Opava river, Olše river, Bělá river), in Hradec Králové (Stěnava) and in Ústí nad Labem (Lužická Nisa river and its tributary Smědá). The ČHMÚ partly uses the well developed monitoring systems of the respective river basin authorities Povodí Odry and Povodí Labe.

6.1.1 Meteorological forecast service by the ČHMÚ

The main task of the meteorological service of the ČHMÚ in the scope of flood forecast is to provide information and warnings about dangerous weather situations, e.g. heavy rainfall, storms, hails and others. The meteorological services of the centre in Prague and of the regional offices in Ústí nad Labem and Mošnov (airport of Ostrava) work non-stop (KUBÁT, 1998).
The ČHMÚ uses the results of four **numerical meteorological models** which are operated in Germany, Great Britain, France and in the Czech Republic (Tab. 9) for the **quantitative precipitation forecast** provided twice a day. Since July 1998 the local model ALADIN is run on a main frame in the forecast centre of Prague-Komořany (ŠÁLEK, 1998 a).

Tab. 9: Numerical meteorological models which results are used by the ČHMÚ for the quantitative precipitation forecast

model	country	grid step [km]	time step [h]	forecast lead time [h]
EUROPA Model	Germany (Offenbach)	50	6, 12, 24	78
Deutschland Model	Germany (Offenbach)	15	6	48
British LAM Model	Great Britain (Bracknell)	50	3, 6	36
ALADIN Model	France Czech Republic (since 1998)	15	3, 6, 12, 24	48

Source: KUBÁT, 2000

The quantitative precipitation forecast by meteorological models still bears some shortcomings. The simultaneous application of different models is worthwhile in the assessment and evaluation of the results (KUBÁT, 2000).

Currently, the 3-day quantitative precipitation forecast calculated by the model ALADIN for nine regions of the Czech Republic is only used internally. The regional offices further specify the results for the area they are in charge for. It is planned to publish the quantitative

precipitation forecasts as a grid based data set (KUBÁT, 1999). In flood situations the forecast calculated by the model ALADIN are made available to public domain on the webpage of the ČHMÚ (www.chmi.cz/meteo/ov/aladin/res/index.html).
Presently, numerical meteorological models are suitable rather for the forecast of large cyclonic rainfall than for local heavy rainfall. **Meteorological radar** and **satellite systems** are used to detect local rainfall events, to improve the forecast quality, and to issue warnings (KUBÁT, 2000 a). They provide information about the weather situation in real-time.
Meteorological radar stations reflect the current precipitation situation in real-time. Information about local rainstorms are of special importance, because they are often not detectable by ground monitoring stations. In the Czech Republic two meteorological radar stations (Brdy-Prague and Skalky near Boskovice) are operated. Information about these stations are available on the webpage www.chmi.cz/meteo/rad/erad_sit.html. Together with radar stations of neighbouring countries the territory of the Czech Republic is almost completely covered. A co-operation with the Polish meteorological radar stations (Orzesze near Katowice and Pastewnik south of Wrocław) is planned to produce a radar image of the mountainous region of the Odra river basin available to both countries (HOŠEK, 1998).
The radar data have a temporal resolution of 10 minutes. The spatial extension and the dynamics of the precipitation are well reflected by the radar images. Problems exist in the derivation of quantitative precipitation data. These often differ strongly from those measured by the ground monitoring network (KUBÁT, 2000). Currently the system RAMAP is developed to process radar precipitation data. The system shall generate average areal precipitation values and control, if thresholds are exceeded (KUBÁT, 1999). It is in preliminary operation at the central office of the ČHMÚ to monitor hazardous precipitation events (KIMLOVÁ, 1999).
The ČHMÚ also uses **NOAA** and **METEOSAT satellite data**. The polar orbiting NOAA satellite provides information about this region four times a day (ŠÁLEK, 1998). The information of the geostationary METEOSAT satellite are accessible every 30 minutes and published on the webpage www.chmi.cz/meteo/sat/sat_eng.html. The METEOSAT-data allow the observation of the development of clouds almost in real-time (ŠÁLEK, 1998).
The precipitation data of the **ground survey stations of the ČHMÚ**, which are available for real-time warnings, are limited by the number of automated measurement stations. Real-time data are mainly provided by the synoptic stations of the ČHMÚ. The automation of further stations is in progress. Agreements with the river basin authorities (which operate their own monitoring networks) about data exchange are being made.

6.1.2 Hydrological forecast service by the ČHMÚ

In the Czech Republic the central flood forecast office for the Upper Odra river is the regional office Ostrava of the ČHMÚ. There is a close co-operation with the ČHMÚ central office in Prague and the regional meteorological forecast service in Mošnov/Ostrava as well as with the river basin authority Povodí Odry. The *special situation* of **Povodí Odry** is based on a strongly increased water demand caused by the regional development in population and in industry. High investments in the water management infrastructure for water storage, flood protection, and recreation were established.

The existing eight reservoirs (Fig. 11) are operated and managed by Povodí Odry. For the monitoring of this complex water management system Povodí Odry operates an own partly automated measurement network which will be further developed (POVODÍ ODRY, 2000).

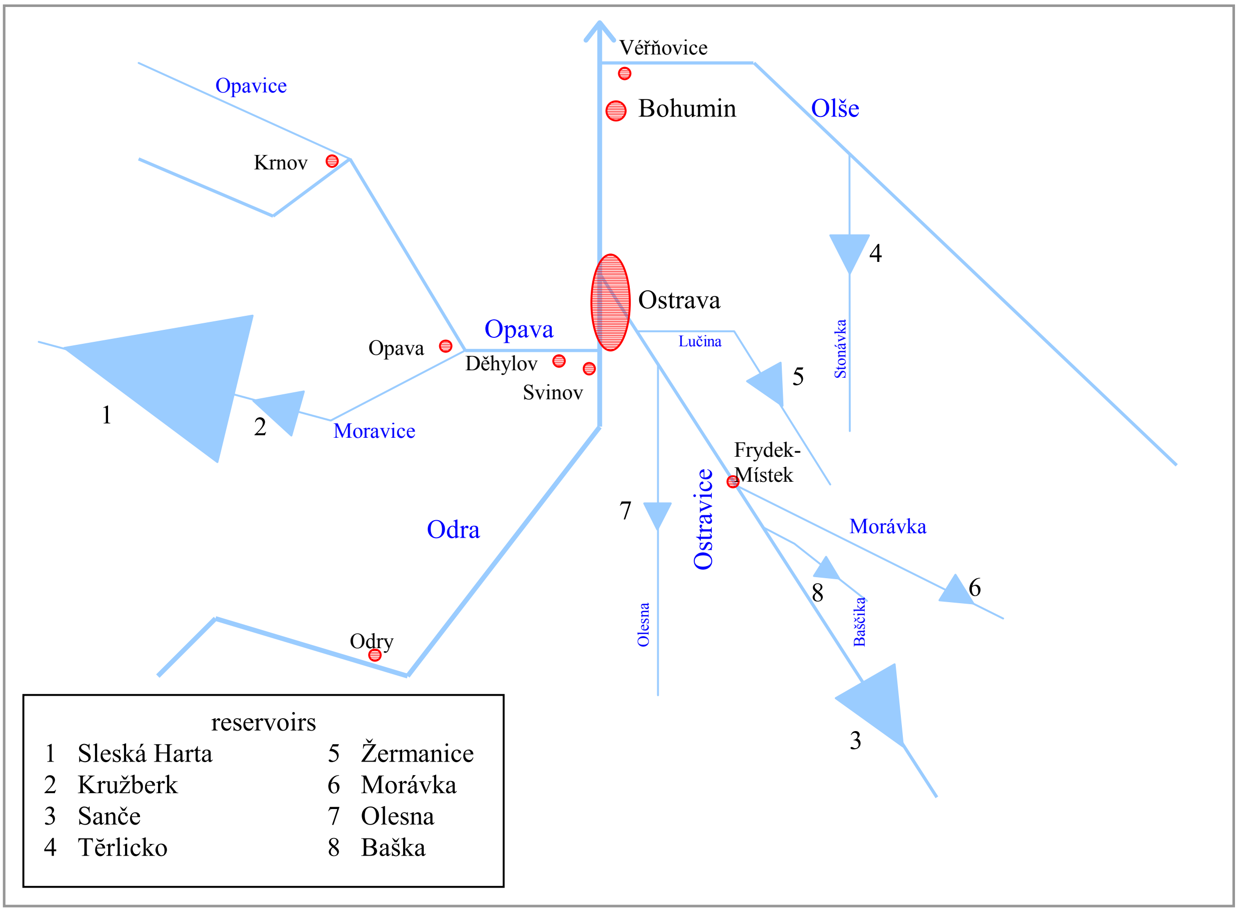


Fig. 11: **Sketch of the Upper Odra river, its main tributaries, and the reservoir system on Czech territory**

Thus, besides the **data** and **information** of the own monitoring network those of *Povodí Odry* are additionally available to the ČHMÚ Ostrava for the flood forecast.

Altogether Povodí Odry provides continuously recorded data of 48 (in future 56) automated precipitation stations and of 43 (in future 46) automated river gauging stations. Furthermore, information about water level and outflow of 6 reservoirs (hourly recorded data) are transmitted.

The *ČHMÚ* measurement network provides information of 3 (in future 4) professional meteorological stations (hourly recorded data), of 8 automated climate stations (data recorded every 3 hours), of 2 (in future 3) automated precipitation stations (data recorded once a day, in flood situations more often) and of 15 automated river gauges (data recorded once a day, in flood situations more often).

The data of the ČHMÚ are transmitted by permanent communication lines (in case of emergency by mobile phones) and those of the river authority Povodí Odry by radio network. Most of the announcement profiles are equipped with two alternative ways for data transmission. The exchange of data and information between the ČHMÚ Ostrava and Povodí Odry is automated and carried out by the FTP Server of the ČHMÚ.

Additionally, **meteorological data** and **forecasts** of the meteorological services of the ČHMÚ are available.

The meteorological central office in Prague provides:

- daily weather situation and forecast for the Czech Republic for the next 2 to 6 days
- daily quantitative precipitation forecast for the next 48 h for 6 regions of the Upper Odra basin
- daily quantitative precipitation forecast for 2 mountainous regions for the next 72 h
- daily information on heavy and long lasting rainfall up to 72 h in advance
- daily warnings on the occurrence of hazardous and threshold-exceeding precipitation events for the next 24 h
- composite radar information of the meteorological radar stations Skalky near Boskovice and Brdy-Prague (in future supplemented by information of the Polish radar stations Orzesze near Katowice and Pastewnik near Wrocław), updated every 10 minutes (Intranet ČHMÚ)
- actual meteorological satellite images (Intranet ČHMÚ)

The *regional office in Mošnov/Ostrava* provides the regional weather forecast for the next 12 h (two times a day) and for the next 2 to 3 days (once a day) (HOŠEK, 2000).

From *the Polish side* the IMGW offices in Katowice and in Wrocław provide daily data of 4 meteorological stations, 5 precipitation stations and 7 river gauge stations as well as forecasts and warnings. The hydrometeorological data are mainly from the Olše river catchment where the upper part of the catchment is situated on Polish territory (HOŠEK, 2000).

The **flood forecast** by the ČHMÚ is prepared only for some selected river gauges and is mainly based on river gauge relation to upstream stations (KUBÁT, 1998). In the Odra river basin a 6-hour forecast is prepared for the river gauge Bohumín. After the Flood 1997 an increased application of rainfall-runoff models was demanded (ŘIČICOVÁ, 1999).
The ČHMÚ Ostrava decided to use the **model system HYDROG** developed by Povodí Odry. Povodí Odry has already implemented this model for the management of the reservoir systems in two sub-catchments of the Odra river (Ostravice river, Olše river). Since 1997 Povodí Odry also uses the quantitative precipitation forecasts yielded by the numerical meteorological model ALADIN of the ČHMÚ in Prague (see Chapter 6.1.1). The model version HYDROG-S currently tested by the ČHMÚ only contains the rainfall-runoff-model without the module for the operative reservoir management. The ČHMÚ plans to extend the model HYDROG to the entire Upper Odra river catchment up to the Czech-Polish border including the catchment of the Bělá river (tributary of the Nysa Kłodzka river).
In the model HYDROG the catchment is subdivided in river sections, sub-areas along these sections and reservoirs. The runoff is simulated by a combination of hydraulic and hydrological methods. The surface runoff and the flow within the river system is modelled using a kinematic wave approximation, and the subsurface runoff of the sub-areas by using a conceptual model (STARY et al., 1998). Besides the rainfall-runoff module HYDROG also contains a module for the operative reservoir management (HOŠEK, 2000).

The forecast model HYDROG is operated by Povodí Odry for the following sub-catchments:

- Ostravice river to the mouth into the Odra river
- Olše river to the mouth into the Odra river

Povodí Odry and ČHMÚ Ostrava are testing the model for the following sub-catchments:

- Bělá river to the border profile (HYDROG, Povodí Odry)
- Odra river to the announcement profile Odra (HYDROG-S, ČHMÚ Ostrava)
- Opava river to the announcement profile Opava (HYDROG-S, ČHMÚ Ostrava)

In the *regional operational data base* of the **flood centre of ČHMÚ Ostrava**, which is still under construction, the operational hydrometeorological data are collected. After verification and processing these data are automatically transferred to the central office ČHMÚ in Prague, to Povodí Odry, and also to the flood protection authorities and to foreign partners in fixed times.

Once a day a data exchange by the telecommunication services of the ČHMÚ centre in Prague with the IMGW centre in Warsaw takes place. In case of floods there is a direct exchange between the regional offices of the ČHMÚ (Ústí nad Labem, Hradec Králové, and Ostrava) and those of the IMGW (Wrocław, Katowice) (HOŠEK, 2000).

6.1.3 Planned activities

In the year 2001 48h-forecasts (today 6 h) will be prepared for the river gauge Bohumín (Odra river), for the Odra profile downstream of the mouth of the Olše river and for the border profile Mikulovice on the Bělá river.
Currently, a *snowmelt module* for the model HYDROG is under development. The model HYDROG will also be supplemented by a simulation module for controlled flooding and dike overflows (POVODÍ ODRY, 2000).

Two application possibilities of *neural networks* for the optimisation of control processes and algorithms are considered:
The first one concerns the forecast of the *precipitation distribution* by the meteorological model ALADIN. The model provides precipitation intensities for six regions. The forecasted precipitation is assumed to be homogeneous for the respective area. Since the catchment of the Upper Odra river, situated in a mountainous region, this assumption is questionable. By using neural networks the forecasted precipitation amount will be transformed into intensities for the individual precipitation stations.
The second approach aims at *developing a warning system*. The neural network is trained with a series of various combinations of input data (different states of the system and different precipitation forecasts) and the corresponding results calculated with the HYDROG model (peak discharges at selected profiles). Less time is needed for the analysis of the data. This enables the person responsible for the reservoir management to act earlier and to start precautionary flood protection actions in time (Fig. 12) (STARY et al., 1998).

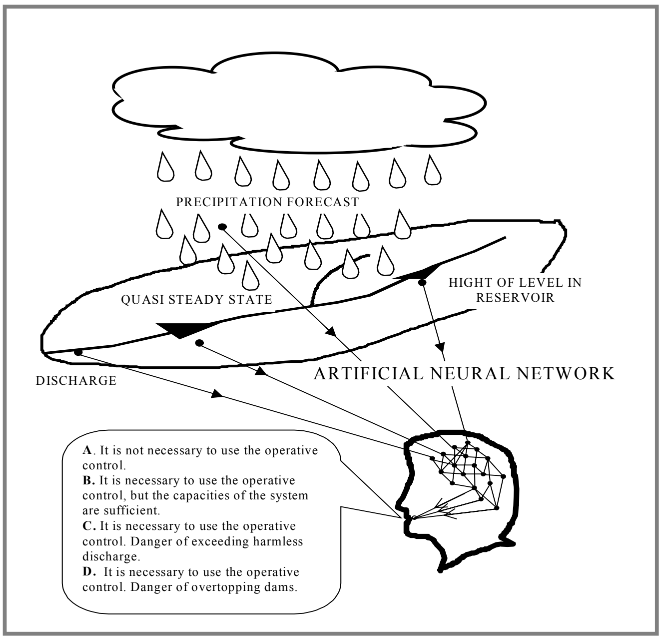


Fig. 12: Principle of the flood warning system based on neural networks (STARY et al., 1998)

6.2 Flood forecast for the Upper and Middle Odra river - Poland

With 89 % Poland holds the largest part of the Odra river basin. The **Institute of Meteorology and Water Management (IMGW)** is in charge of the flood forecast and information service. The IMGW has its central office in Warsaw and *four regional offices* for the respective parts of the Odra river basin. These are:

- *IMGW Katowice*, in charge of the catchment of the Upper Odra river from the Polish-Czech border to the mouth of the Nysa Kłodzka river (except the catchment of the Nysa Kłodzka river) including the catchment of the Stobrawa river, as well as for the catchment of the Upper Warta river to the mouth of the Liswarta river. Within the scope of the hydrological information service the IMGW Katowice works together with the IMGW Wrocław.
- *IMGW Wrocław,* in charge of the catchment of the Upper and Middle Odra between the mouth of the Nysa Kłodzka river (excluding the Stobrawa river) and the mouth of the Nysa Łużycka river including the catchment of the Nysa Łużycka river. The IMGW Wrocław secures the hydrological information service for the Odra river basin between the Polish-Czech border to the profile Słubice (Border Odra).
- *IMGW Poznań*, in charge of the Odra river basin between the mouth of the Lausitzer Neiße/Nysa Nysa Łużycka and the profile Gryfino (including the profile Gryfino), as well as the catchment of the Warta river downstream of the mouth of the Liswarta river. The IMGW Poznań ensures the hydrological information service for the Odra river basin between the profile Słubice and the profile Gryfino.
- *IMGW Gdynia*, in charge of the Lower Odra downstream of the profile Gryfino to the mouth into the Baltic Sea, as well as for the Polish rivers draining into the Baltic Sea.

(MALINOWSKA-MAŁEK, pers. communication)

Similar to the ČHMÚ in the Czech Republic the meteorological and hydrological services within the IMGW are co-operating closely. The forecasts and warnings prepared by the central forecast office are sent together with the data, which are exchanged by the global telecommunication system of the WMO, to central users and the regional forecast offices. The regional meteorological and hydrological forecast offices process data, prepare and disseminate regional and local forecasts and warnings. In the regional offices the two sections „Hydrology“ and „Meteorology“ are working closely together. The meteorological forecasts (only regional), hydrological forecasts and all hydrological and meteorological warnings and reports prepared by the regional offices are sent to the central forecast office in Warsaw. The transfer of the observed and measured data, of the reports, warnings and forecasts between the IMGW and the regional offices is carried out by the Polish *IMGW network „MetPak“*(using the protocols X.25 and TCP/IP). This network is connected to the internet (TCP/IP) and the network of the global weather service of the WMO (X.25). Thereby, data can be exchanged internationally and the internet can be used as additional or main medium for the dissemination of prepared information. It is aimed at using similar program systems at the central and regional offices for the collection and the processing of the data, and for the transfer of the prepared information (IMGW, 2000).

For *hydrological forecasts and warnings* in the Polish part of the Odra river basin the *IMGW Wrocław* and *Poznań* are responsible (KUNDZEWICZ et al., 1999).

6.2.1 Meteorological forecast service by the IMGW Wrocław

The meteorological forecast prepared by the forecast centres is mainly based on experience. The forecast is supported by the **results of numerical meteorological forecast models** which are made available by the global telecommunication system of the WMO (IMGW, 1999). The IMGW uses the results of the European forecast centres in Offenbach (EUROPA-Model and Deutschland Model) and Bracknell (British LAM-Model). In Poland the model ALADIN is operated by the IMGW Kraków and the model UMPL (Unified Model of Poland) by the University in Warsaw (IMGW, 1999). The insufficient capacity of the IMGW information transfer system partly limits the use of the forecast results and of radar and satellite data by the forecast centres (IMGW, 1999).

Only the IMGW office in Kraków is able to use high-resolution data of the geostationary and polar **satellites**. Other offices can only use low-resolution data (WEFAX data transmission) (IMGW, 1999). Within the frame of the SMOK programme (Chapter 6.2.3.1) the meteorological forecast system is planned to be modernised and extended.

The IMGW receives information by the **Polish radar network POLRAD** presently comprising three meteorological radar stations: the station Legionowo near Warsaw and the stations Orzecze (near Katowice) and Pastewnik (south of Wrocław) which cover areas of the Upper and Middle Odra river basin (Fig. 14 in Chapter 6.2.3.1.; IMGW, 1999).

The meteorological forecast office at the IMGW Wrocław prepares meteorological forecasts for the Upper and Middle Odra river basin up to the profile Słubice. They are based on the information provided by the IMGW network „MetPak“. These are short- and middle-term prognoses, spatial distribution of selected meteorological variables for Europe which are issued by the European forecast centres in Offenbach (Germany) and Bracknell (Great Britain), results of the numeric meteorological model ALADIN of the IMGW Kraków and METEOSAT satellite images and radar images (IMGW, 2000).

For the hydrological forecast quantitative precipitation forecasts for the next 72 h including precipitation type and onset time as well as forecasts of further meteorological variables (air temperature, mean wind velocity, air moisture and total radiation) are produced.

6.2.2 Hydrological forecast service by the IMGW Wrocław

The hydrological information system is run according to the flood information system of the Odra and Warta river basin (Polish: System Osłony Powodziowej Dorzecza Odry i Warty SOPDOiW). The hydrological forecast system consists of the *System of Operational Hydrology* (Polish: System Hydrologii Operacyjnej SHO) and the *System of Hydrological Forecast* (Polish: System Prognoz Hydrologicznych SPH)

The **system of operational hydrology** obtains the data of the IMGW observation network delivered by:

- 8 collecting stations (Racibórz, Opole, Kłodzko, Jelenia Góra, Zgorzelec, Zielona Góra, Legnica, Leszno), which call up the data of the meteorological and hydrological observations, process the data and send them to the IMGW in Wrocław. The IMGW Wrocław also receives data from the 6 collecting stations of the IMGW Poznań
- the regional offices IMGW Katowice and IMGW Poznań (Chapter 6.3)

(IMGW, 2000).

Routinely, the data of the IMGW **hydrometeorological network** are called up once a day at 6 GMT, in flood situations in 3-hour intervals (0, 3, 6, 9, 12, 15, 18, 21 GMT) (DUBICKI & MALINOWSKA-MAŁEK, 2000). However, the majority of the measurement stations is not automated. They are operated by part-time observers. This can become problematic during flood events of long duration (IMGW, 1999). An extensive automation of the hydrometeorological measurement stations is planned within the frame of the SMOK-programme (Chapter 6.2.3.1).
Data about hydraulic-engineering structures and ice conditions are delivered by the RZGW Wrocław and the RZGW Szczecin.

Within the **international information exchange** the IMGW Wrocław receives daily data from the ČHMÚ regional offices Hradec Králové, Ústí nad Labem and Ostrava *from the Czech side*:

- precipitation information of 4 professional meteorological stations, 19 climate stations and in future 11 precipitation stations
- information on water level and discharge at 15 river gauges
- information on outflow from 5 reservoirs
- 6 h water level forecast for the river gauge Bohumín

(HOŠEK, 2000).

Moreover, there is a daily data transfer between the IMGW centre in Warsaw and the ČHMÚ centre in Prague. In case of flood, the frequency of data exchange is increased. In such situations the IMGW Wrocław has direct access to the FTP server of the ČHMÚ centre in Prague and is in direct contact with the regional ČHMÚ offices. At present, the development of a regional data base at the ČHMÚ Ostrava is in progress, so that in future information about the conditions on the Upper Odra river will be available in 3 hour intervals in flood situations (MALINOWSKA-MAŁEK & DUBICKI, 2000).
Information about the situation on the *German part* of the Odra river basin is provided by the LUA Brandenburg with data of the flood announcement river gauges on the Odra river

(Ratzdorf, Eisenhüttenstadt, Frankfurt/Oder, Kietz, Kienitz, Hohensaaten-Finow, Hohensaaten Ostschleuse OP[10], Hohensaaten Westschleuse OP, Hohensaaten Westschleuse UP[11], Stützkow, Schwedt Oderbrücke, Schwedt Schleuse OP, Schwedt Schleuse UP, Gartz, and Mescherin) and on the Lausitzer Neiße river (Zittau 1, Görlitz, Klein Bademeusel, and Guben).
Altogether there are approx. 60 users (administrations, agencies, also foreign institutions like the LUA Brandenburg) connected to the flood forecasting system of the IMGW Wrocław. The information is provided via phone, fax, e-mail and webpages of the IMGW (www.imgw.pl).

The development of the **System of Hydrological Forecast** operated by the IMGW Wrocław was started at the end of the 80ies. The system is of modular structure and adapted to the hydrological conditions and the available data.
The forecast system is orientated to the **left-hand side tributaries** of the Odra river. These strongly influence the flood discharge in the Odra river and are also themselves frequently affected by floods. Figure 13 presents a scheme of the used model system consisting of a rainfall-runoff model for the mountainous headwater section down to a reservoir situated in the middle reach, and a wave transformation model for the river reach downstream of the reservoir down to the mouth into the Odra river.

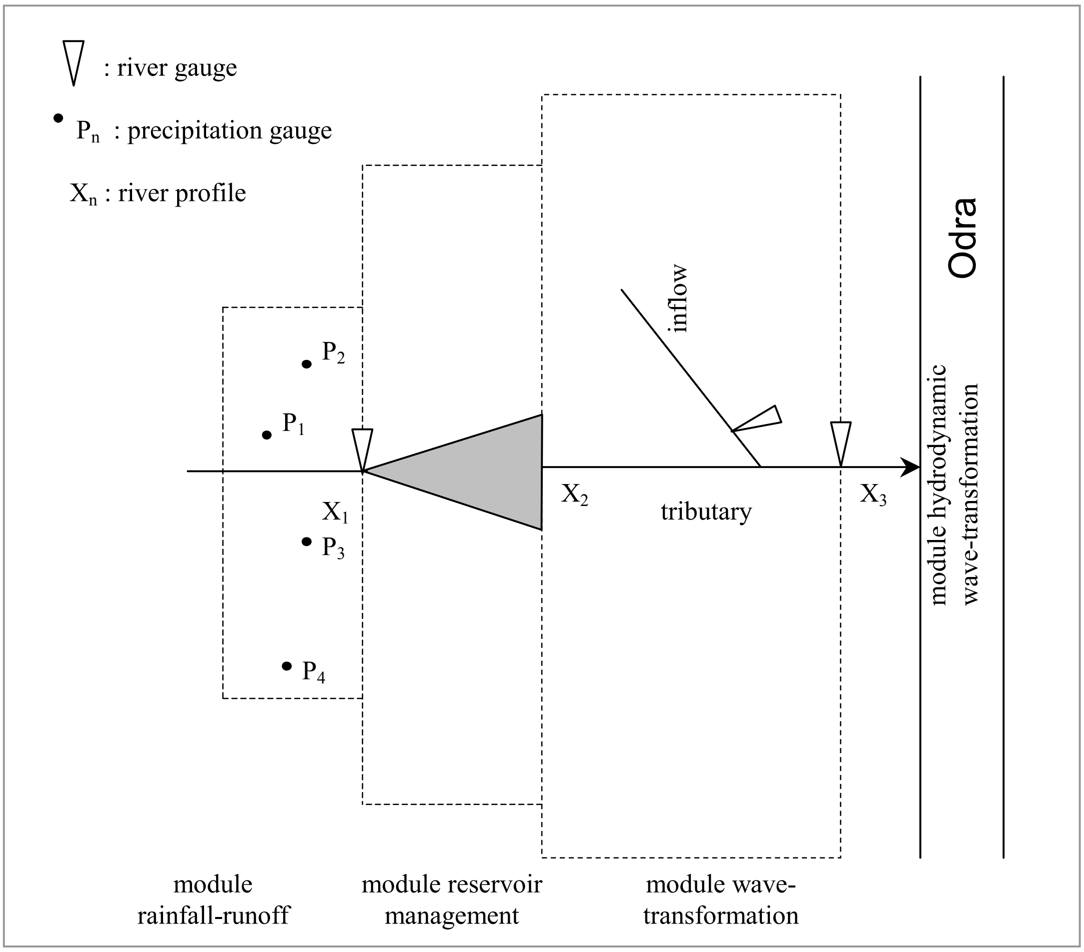


Fig. 13: Scheme of the model system operated by the IMGW Wrocław for flood forecast in the Upper and Middle Odra river basin (modified after MIERKIEWICZ, 1993).

[10] Upstream river gauge
[11] Downstream river gauge

The river basin upstream of the reservoir is simulated by a lumped type of **rainfall-runoff model**. The effective precipitation is calculated using the saturated-area method. The runoff concentration process is based on the „Geomorphological Instantaneous Unit Hydrograph" (GIUH) approach (DUBICKI & MALINOWSKA-MAŁEK, 2000).

The **rainfall-runoff model** is operated for the following eight sub-catchments:

- Nysa Kłodzka river up to the reservoir Otmuchow
- Piława river (tributary of Bystrzyca river) up to the profile Mościsko
- Nysa Szalona river (tributary of Kaczawa river) up to the reservoir Słup
- Kaczawa river up to the profile Rzymówka
- Łomnica river (tributary of Bóbr river) up to profile Łomnica
- Kamienna river (tributary of Bóbr river) up to profile Jelenia Góra
- Kamienca river (tributary of Bóbr river) up to the profile Barcinek
- Upper Kwisa river (tributary of Bóbr river) up to the reservoir Złotniki

Input data are observed discharge and precipitation values of the preceding 24 hours (as 3- or 12 hourly totals) at selected stations and river gauges and quantitative precipitation forecasts for the next 72 hours including precipitation type and onset time. Furthermore, daily meteorological variables (air temperature, mean wind velocity, air moisture and radiation) of the preceding 24 hours and the prognosis for the next 72 h are taken into account. The rainfall-runoff model yields the hourly discharge for the next 72 h for the sub-catchments (DUBICKI & MALINOWSKA-MAŁEK, 2000). Snowmelt processes cannot be simulated by the model (GKSS & PARTNERS, 1999).

For the **reservoirs** control routines for normal situations and for flood situations are used (MIERKIEWICZ, 1993).

Downstream of the reservoir, the **wave transformation within the riverbed** is simulated by the *Kalinin-Miljukov approach* for the following river sections:

- Nysa Kłodzka river: downstream of the reservoir Nysa to the mouth into the Odra river
- Bystrzyca: downstream of the reservoir Lubachów to the reservoir Mietków and downstream of the reservoir Mietków to the mouth into the Odra river
- Kaczawa river: downstream of the profile Rzymówka to the mouth into the Odra river and for the Nysa Szalona river downstream of the reservoir Słup
- Bóbr river: downstream of the reservoir Buków to the reservoir Pilchowice and downstream of the reservoir Pilchowice to the mouth into the Odra river as well as for the Kwisa river downstream of the reservoir Leśna
- Nysa Łużycka river: downstream of the profile Zgorzelec to the mouth into the Odra river

Input data are the inflows into the river reach and the release from the reservoirs, respectively, for the preceding 24 h and their forecast for the next 72 h. *Results* are the hourly *forecasts of the discharge for the next 72* h for the river reaches (DUBICKI & MALINOWSKA-MAŁEK, 2000).

Discharge at river gauges, for which presently no rainfall-runoff and wave transformation models are in operation, is predicted using simple river gauge relations (DUBICKI & MALINOWSKA-MAŁEK, 2000).

For the course of the **Odra river** a one-dimensional **hydrodynamic model** based on the Saint-Venant equations is used for the following Odra river sections:

- between Miedonia and Trestno (Wrocław)
- between Brzeg Dolny and Gozdowice
- between Połecko and Gozdowice

(DUBICKI & MALINOWSKA-MAŁEK, 2000).

Input data are the measured discharges or water levels within the preceding 24 h and the forecast for the next 72 h for the principal river gauge of the Odra river and the main tributaries: Ruda, Kłodnica, Osobłoga, Mała Panew, Stobrawa, Nysa Kłodzka, Kaczawa, Barycz, Bóbr, Nysa Łużycka, and Warta. The *output is* the *hourly forecast of discharges and water levels for the next 72 hours* for the above mentioned Odra river sections (DUBICKI & MALINOWSKA-MAŁEK, 2000).

6.2.3 Planned activities

After the Flood 1997 numerous measures and projects were planned and launched. Besides the World Bank financed *SMOK-programme,* two hydrodynamically oriented model systems, which were implemented at the IMGW Wrocław for the Upper and Middle Odra river in co-operation with Denmark (*MIKE 11*) and with the Netherlands (*SOBEK*) count to the most important projects in Poland.

6.2.3.1 SMOK (System Monitoringu i Osłony Kraju) –programme

After the Flood 1997 the World Bank launched an extensive loan programme for Poland for the reparation of flood damages and for the improvement of the flood management (www.pcu.org.pl). The SMOK programme of the IMGW Warsaw is financed within the programme section „Flood management and risk minimisation" of the World Bank loan (www.pcu.org.pl/komponenty/komponent-b2.html). It comprises the improvement of the hydrological and meteorological forecast and warning systems of the Odra river and Vistula river.

To improve the **meteorological forecast** the development of a mesoscale non-hydrostatic numerical meteorological model for Poland with a grid resolution of 2.5 x 2.5 km is planned. The existing co-operations with the University Warsaw and the meteorological forecast services of Great Britain and France will be used. Quantitative precipitation forecasts for the next 48 h shall be calculated four times a day (IMGW, 1999).

The meteorological *weather radar system of Poland (POLRAD)* (Fig. 14) is being extended. In Summer 2000 the weather radar station Pastewnik south of Wrocław started its operation. Together with the Czech radar stations the mountainous region of the Odra river basin will be covered completely.

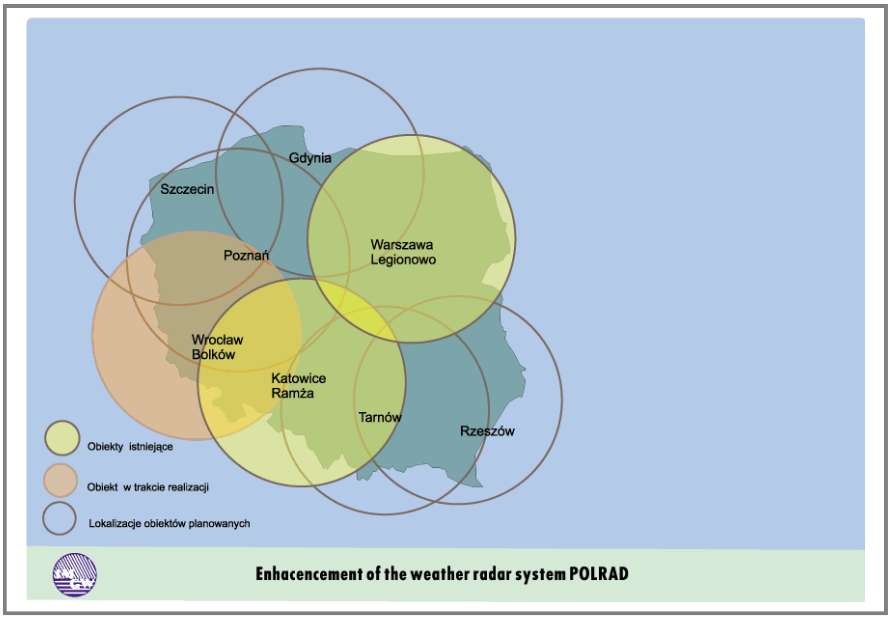


Fig. 14: Weather radar system POLRAD in Poland (existing and planned weather radar stations) (IMGW, 1999)

Main objectives of the SMOK programme are the reconstruction of the 1997 destroyed hydrometric measurement stations, the automation of the hydrometeorological measurement network and the improvement of the IMGW telecommunication network. This is planned mainly for the Upper and Middle Odra river basin (Tab. 10) and the Upper Vistula river basin.

Tab. 10: Hydrometric and hydrometeorological stations in the Upper and Middle Odra river basin planned to be automated

	catchment	number of measurement stations			
		river gauge	precipitation and climate stations	synoptic stations	total
1.	Odra downstream of the Czech-Polish border	19	-	1	20
2.	Odra downstream of the mouth of the Nysa Kłodzka river	20	10	3	33
3.	Nysa Kłodzka river	16	15	1	32
4.	Oława, Ślęza and Bystrzycza rivers	18	10	1	29
5.	Kaczawa river	11	5	1	17
6.	Bóbr and Kwisa rivers	25	22	2	49
7.	Nysa Łużycka river	10	5	-	15
8.	Widawa and Barycz rivers	11	5	1	17

Source: DUBICKI, 1999

The monitoring stations shall record in short time intervals (e.g. 10 minutes interval), and two independent telecommunication channels for data transfer shall be installed. The collecting stations will collect the data in 1- or 3-hourly time intervals and transfer the information automatically to the regional IMGW offices (IMGW, 1999).

6.2.3.2 MIKE 11 (Software of the Danish Hydraulic Institute (DHI))

The objective of the Danish-Polish co-operation project financed by the Danish Ministry for Environmental Protection was the transfer of Danish flood management technology to Poland. Therefore the operational flood forecast and flood management model MIKE 11 was implemented for the Upper and Middle Odra river at the IMGW Wrocław and for the Upper Vistula river at the IMGW Kraków (STROŃSKA et al., 1999).

The model system consists of the following components:

- The deterministic, conceptual, hydrological lumped model (NAM) for simulation the runoff from sub-catchments.
- The hydrodynamic model (HD) for simulation of the discharge in the riverbed and on the floodplains.
- The MIKE 11 GIS Interface. By linking the simulation results of the hydrodynamic module with the topography, maps of flooded areas can be produced.
- The MIKE 11 FF flood forecasting module, which allows the calculation of flood situations in real-time. It consists of a real-time management system with direct access to the data base and user-designed data entry menu for the calculation of the areal precipitation using the data from point measurements. The areal precipitation is transformed by the rainfall-runoff model (NAM) into the sub-catchment runoff. The flood wave transformation is simulated by the hydrodynamic module. An automated up-dating procedure uses all information available on discharge and water level.

MIKE 11 is implemented for the Odra river section between Chałupki (km 20.7) and Połęcko (km 530.3) and takes the following 14 tributaries of the Odra river into account (IMGW, 2000 b):

- Olza to the river gauge Cieszyn
- Ruda to the river gauge Ruda
- Kłodnica to the river gauge Lenartowice
- Osobłoga to the river gauge Racławice
- Mała Panew to the reservoir Turawa
- Stobrawa to Karlowice
- Nysa Kłodzka to the river gauge Bardo and Nysa Kłodzka to the river gauge Skorogoszcz (hydrodynamic module)
- Oława to the river gauge Oława
- Ślęza to the river gauge Borów
- Bystrzyca to the river gauge Jarnołtów
- Widawa to the river gauge Krzyżanowice
- Kaczawa to the river gauge Piątnica
- Barycz to the river gauge Osetno
- Bóbr and Czerna (tributary of the Bóbr river) to the river gauge Jelenia Góra

Input data are areal precipitation, temperature and discharge of the preceding 4 days and the forecast of precipitation and temperature for the following 72 h. The model calculates the flood forecast for the next 72 h for the named river sections and the inflow into the reservoirs.

The model results for the tributaries serve as input to the hydrodynamic model of the Odra river.
For the development of a quasi 2-D-model for the Odra river cross-sections at every 1000 m distance, information about the floodplain extent during the Flood 1997 as well as information about hydrotechnical structures and polders along the Odra river are available (STROŃSKA et al., 1999).
The FLOOD WATCH Interface is a decision support system for the operational use and combines time series of data calculated with MIKE 11 with the GIS Interface. By using FLOOD WATCH real-time data can be presented in form of tables, graphs or maps (Fig. 15).

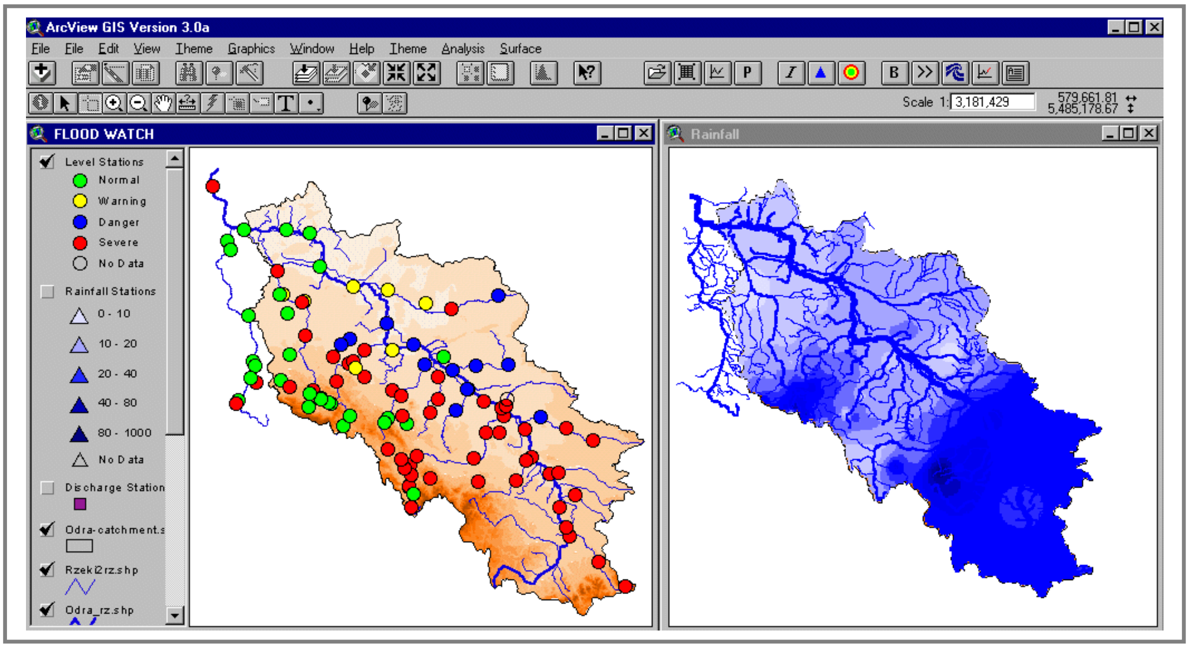


Fig. 15: Visual presentation of the river gauges on the Upper and Middle Odra river and the distribution of precipitation within the catchment using FLOOD WATCH (STROŃSKA et al., 1999)

MIKE 11 is still in testing stage and used parallel to the existing operational flood forecasting model system at the IMGW Wrocław.
Because of a close co-ordination between MIKE 11 and the SMOK-programme, MIKE 11 can be further developed with the data of the improving monitoring network (STROŃSKA et al., 1999).

6.2.3.3 SOBEK

The aim of the project MATRA, a Dutch-Polish co-operation (April 1998 - October 1999; funded by the Netherlands Ministry of Foreign Affairs) was the exchange of knowledge within the field of water management between the two countries. The implementation of the one-dimensional, hydrodynamic simulation model SOBEK (developed by WL | Delft Hydraulics and RIZA) at the IMGW Wrocław was part of this programme.
Since several years the program system SOBEK has been used for the flood analysis in the Netherlands. It represents the base of the flood forecasting model FLORIJN on the Rhine river for the section Andernach-Lobith (SCHÄDLER & PARMET, 1999).
At the IMGW Wrocław SOBEK is implemented for the 125 km Odra river section between Malczyce and Nowa Sól with the main tributaries Kaczawa and Barycz. For the calibration and validation of the model the floods in August 1985 and in June 1986 have been used (IMGW, 2000 a). Due to the time consuming data processing the IMGW Wrocław does not plan to use it for the operational flood forecast, but pre-operationally for simulations of scenarios.

6.3 Flood forecast for the Lower Odra river and Warta river – Poland

The IMGW Poznań is in charge for the **Warta river and the Lower Odra river as part of the flood forecast and information service Odra-Warta**. Its meteorological and hydrological service is structured similar to the one of the IMGW in Wrocław. The area around the Zalew Szczeciński belongs to the responsibility of the IMGW Gdynia.

6.3.1 Hydrological forecast service by the IMGW Poznań

The IMGW Poznań obtains data from the collecting stations Wieluń, Sieradz, Kalisz, Konin, Gorzów Wlkp., and Piła. The IMGW Poznań exchanges information and data with the IMGW Wrocław, IMGW Gdynia, and the RZGW Poznań (about the hydrological situation on the Warta river and the forecast for the reservoir Jeziorsko), the RZGW Szczecin, and also with the LUA Brandenburg (KOWALCZAK, 2000).
For the flood forecast the IMGW Poznań uses rainfall-runoff-models, the Muskingum-routing method and partly also a hydrodynamical wave transformation model as well as empirical methods (KOWALCZAK, 2000).
For the Warta river catchment upstream of the reservoir Jeziorsko a simple rainfall-runoff model – based on the isochrone method – is used to calculate a maximum 5-day forecast. A rainfall-runoff model similar to the one implemented at the IMGW Wrocław is in testing stage for this area (KOWALCZAK, 2000). Additionally, the inflow to the reservoir Jeziorsko is calculated by using river gauge relationships for the next 72 hours. Downstream of the reservoir Jeziorsko, the Muskingum method is used for the forecast for the next 72 hours for the section between the reservoir and Gorzów Wlkp. A development of a hydrodynamic model for this river section is in preparation (KOWALCZAK, 2000).
A one-dimensional hydrodynamic model based on the Saint-Venant equations is implemented for the river section between Śrem and Poznań. A stochastic-dynamic model (similar structured as the Muskingum approach) is used for the forecast at Gorzów Wlkp. by using the data from the river gauges Skwierzyna and Drezdenko. The same model is applied for forecasts at the river gauge Gozdowice on the Lower Odra by using the data from the river gauges Słubice and Gorzów Wlkp.

Tab. 11: Flood forecast by the IMGW Poznań

river gauge	*river*	*forecast*
Gozdowice	Odra	water level
Gorzów Wlkp.	Warta	water level
Poznań	Warta	water level
reservoir Jeziorsko	Warta	inflow to the reservoir
Piwonice	Prosna	water level
Bogusław	Prosna	water level

Source: (KOWALCZAK, 2000)

Because of the flooding of the IMGW information service in Wrocław during the Flood 1997 the IMGW Poznań temporarily took over the function as information service for the Odra river basin (KOWALCZAK, 1998).

6.3.2 Situation on the Lower Odra river

The complex system on the **Lower Odra** with channels, weirs, backwater effects from the Zalew Szczeciński / Stettiner Haff, the influence of wind and the ice formation in winter makes modelling a challenging task. The IMGW Poznań prepares forecasts with a stochastic-dynamic model for the river gauge Gozdowice. The forecast for the river gauge Słubice is prepared by the IMGW Wrocław (KOWALCZAK, 2000).
BUCHHOLZ criticises, that there is no problem adequate flood forecasting system for the Lower Odra river. This should be composed out a monitoring network with automated data transmission and special hydrodynamic models, which can be applied for the specific hydrologic conditions (Chapter 5.2) (BUCHHOLZ, 1997).
The *Maritime Research Institute* (**MRI**) in Szczecin has developed the basis for such a forecast system. In the early 80'ies the MRI Szczecin installed a monitoring network on the Lower Odra to investigate the influencing factors on water level and discharge (www.im.man.szczecin.pl). It developed a *one-dimensional hydrodynamic model* for the river section between the river gauges Gozdowice and Trzebież (at the Odra river mouth into the Zalew Szczeciński / Stettiner Haff). The modules of this model consider local specifics, such as:

- a basis module including the direct wind impact and the influence of spatial-temporal variations in atmospheric pressure
- module of Odra river bottom position changes in the Gozdowice – Widuchowa section including wind influence upon bottom stresses
- module of Międzyodrze polders' uncontrolled retention
- module of water division into Eastern and Western Odra river by the weir Widuchowa
- module of wind backwater effects under steady non-uniform motion

Presently, the simulations of the MRI are not integrated into the national operational flood forecast system in Poland. Within the scope of the ODRAFLOOD-project (Chapter 7.1.2) the MRI model shall be extended to the mouth of the Warta river. In a further stage the extension shall be proceeded to the mouth of the Nysa Łużycka/Lausitzer Neiße river to cover the reach of the Border Odra completely.

6.4 Flood forecast on the Border Odra - Germany (Brandenburg)

The „*Border Odra*“ is the 167 km long section of the Middle and Lower Odra river, which forms the border between Poland and Germany. On the Border Odra section flood forecast and information is obliged to the IMGW Poznań on the Polish side and the **Environmental Agency Brandenburg (LUA)** on the German side, respectively.

6.4.1 Meteorological Forecast Service by the DWD

In contrast to Poland and the Czech Republic in Germany the responsibilities for the meteorological and the hydrological forecast and information service are under different authorities. The German Weather Service (DWD) is in charge for the meteorological services and the Federal States are responsible for the hydrological services, respectively.
Due to the small catchment area and the long travel times of the flood waves the meteorological data and products of the DWD are of minor importance for the flood forecasts on the Border Odra. Therefore they are described in Chapter 6.5.1 in context with the Lausitzer Neiße river catchment more in detail.

6.4.2 Hydrological forecast service in Brandenburg by the LUA Brandenburg

The branch of the **LUA Brandenburg in Frankfurt/Oder** is in charge for the flood forecast on the Border Odra. Since 01.07.1998 it is responsible for the international information exchange within the Odra river basin as the German flood information centre.
The relevant data for the forecasts are provided to the LUA Frankfurt/Oder by the **Federal Water- and Navigation Administration (WSA) Eberswalde**, by the office of the LUA in Cottbus, by the Federal Maritime and Hydrographic Agency (BSH) Rostock, and by the IMGW for the Polish territory.
The WSA Eberswalde is in charge for the *operation of the river gauges* along the Border Odra National Waterway. The water level measurement is conducted every 15 minutes. The river gauges are equipped (within the WSA) with telecommunication and an announcement service for public use (www.wsa-eberswalde.de). Currently, the Federal Waterway and Navigation Authority (WSD) is working on the improvement of the availability via a FTP-Server. In future, selected river gauge data (especially for the navigation) should be made available also on the internet pages www.elwis.bafg.de (Mrs. Daeglow of the WSD Ost, pers. comm.). The responsibility of the WSA Eberswalde ends with the exceeding of fixed water levels, where the navigation is halted (maximum navigation water levels (HSW)).
The data transmission to the LUA Brandenburg takes place once per day, in flood situations more often (e.g. during the Flood 1997 hourly). The water levels of the river gauges Ratzdorf, Eisenhüttenstadt, Frankfurt/Oder, Kietz, Kienitz, Hohensaaten-Finow, Hohensaaten Ostschleuse OP, Hohensaaten Westschleuse OP, Hohensaaten Westschleuse UP, Stützkow, Schwedt Oderbrücke, Schwedt Schleuse OP, Schwedt Schleuse UP, Gartz and Mescherin and, in corresponding weather situations, ice reports (air and water temperature, ice parameters) are provided. The data transmission takes place via e-mail, in case of emergency via fax.
The WSA Eberswalde is also in close contact with the RZGW Szczecin concerning *ice-breaking operations on the Lower Odra river*. Ice-breaking actions using ice breakers are jointly undertaken with the Republic of Poland under command of the RZGW Szczecin. Within the daily information service the above mentioned water levels and ice reports are forwarded to the RZGW Szczecin via e-mail and in case of necessity via fax.
The *LUA office in Cottbus* provides daily (in flood situation if required also more frequently) water levels and discharges on the Lausitzer Neiße river of the river gauges river Zittau 1,

Görlitz, Klein Bademeusel and Guben 2 and in flood situations forecasts for the next 24 to 48 h (Chapter 6.5.3).
The *Federal Maritime and Hydrographic Agency (BSH) Rostock* daily provides the water level of the gauge Ueckermünde on the Stettiner Haff to the LUA Frankfurt/Oder. This information is important concerning the backwater effects in the Odra river by the Stettiner Haff.
Data are transferred daily by the *IMGW* to the LUA Frankfurt/Oder, in flood situations in time intervals of 6 h, only in extreme situations hourly. For the following Odra river gauges the water levels are provided: Racibórz-Miedonia, Ujście Nysy, Brzeg Most, Trestno, Rędzin, Brzeg Dolny, Malczyce, Ścinawa, Głogów, Nowa Sól, Cigacice, Krosno Odrzańskie, Połęcko, Słubice, Gozdowice, Bielinek, Widuchowa, Gryfino.
For the following river gauges of the Odra river tributaries the data are provided: Skorogoszcz (Nysa Kłodzka), Jarnaltów (Bystrzyca), Piątnica (Kaczawa), Żagan (Bóbr), Gubin (Nysa Łużycka), Ręczyn (Witka) and Slawsk-Konin, Poznań, Gorzów/Wlkp. (Warta) .
For the river gauges Głogów, Połęcko and Słubice on the Odra river and for the river gauge Gorzów/Wlkp. on the Warta river the LUA receives the Polish prognoses (water levels, discharges) for the next 2 days. In the past the data were provided on a mailbox of the IMGW Wrocław, nowadays the transmission is via e-mail. Since April 2000 the outflows of the Polish reservoirs are available at the internet. All data are put into a data base, which is accessible via intranet of the LUA. For a general publication of the data via internet bilateral agreements about the further use of data with Poland would be needed.

During the Flood 1997 an *operational flood forecasting model* for the Border Odra did *not exist*, although the former Wasserwirtschaftsdirektion (Water Management Authority) Oder-Havel Potsdam already developed such a model in 1988 (OPPERMANN et al., 1991). Presently, the forecasts for the Border Odra river section are made by using simple river gauge relations as presented by SCHAFFERNAK (1935).

6.4.3 Planned activities

The LUA Brandenburg commissioned the *Federal Institute of Hydrology* (**BfG**) to develop a *hydrodynamic model for the Border Odra for the operational water level and discharge forecast.* The model is planned to be used also for the water level forecast for navigation and will be developed jointly by both institutions to be in continuous operation. It is based on an one-dimensional hydrodynamic approach based on the Saint-Venant equations. The same model approach is used by the BfG within its model operated on the Rhine river. The model will be developed for the Odra river section between Brzeg Dolny and Szczecin including the river reach of the Nysa Łużycka/Lužická Nisa/Lausitzer Neiße downstream of Guben and that of the Warta river downstream of Gorzów Wlkp. The aim is to produce reliable water level forecasts with lead times of 48 and 72 hours, respectively, on the Border Odra river between the river gauges Ratzdorf and Gartz. Input data are the Polish forecasts of the IMGW (maximum lead time: 4 days) for the river gauges Głogów, Połecko, Słubice and Gorzów Wlkp. The model will be available in the middle of 2002 for the users of the LUA Brandenburg and of the Federal Waterway and Navigation Administration (STEINEBACH, 2000).

6.5 Flood forecast for the Lausitzer Neiße river – Germany (Saxony, Brandenburg)

Although the Lausitzer Neiße/Nysa Łużycka/Lužická Nisa river is only a tributary of the Odra river, the flood forecast is made by several institutions because of the border situation. The upper part of the catchment is situated in the Czech Republic, the German-Polish border runs along the Lausitzer Neiße/Nysa Łużycka/Lužická Nisa river, and the German sub-catchment is divided by the state boundary Brandenburg-Saxony: This makes *three* (taking the Federal States also into consideration, *four*) *riparian states* participate (Fig. 16). Here the problems of flood forecast on a transboundary river are clearly visible. Subsequently, the flood forecasts in **Saxony** and **Brandenburg** are presented in this chapter, the respective services in the Czech Republic and in Poland are explained in Chapter 6.1 and Chapter 6.2.

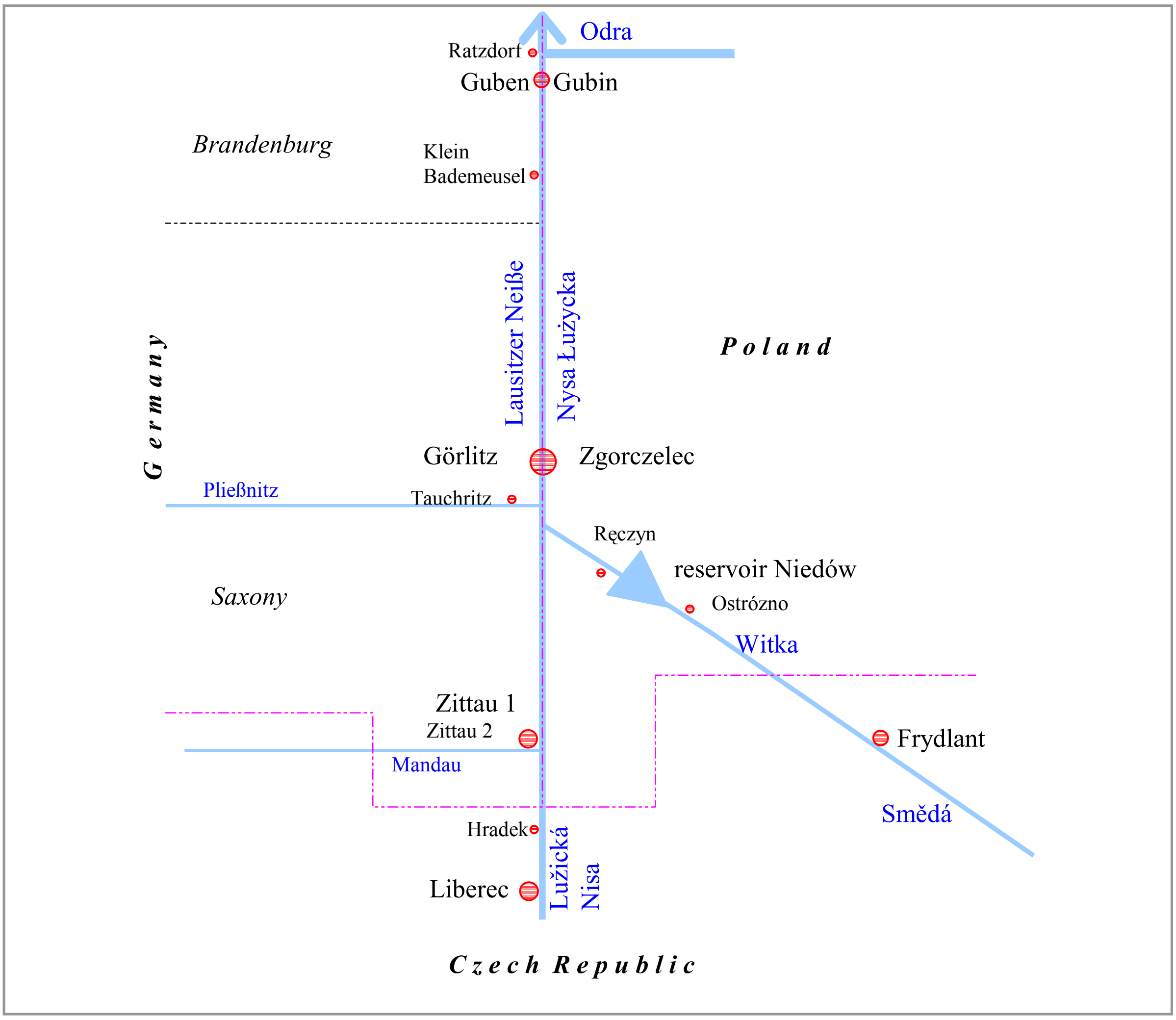


Fig. 16: Sketch of the Lausitzer Neiße/Nysa Łużycka/Lužická Nisa river

6.5.1 Meteorological forecast for the Lausitzer Neiße river by the DWD

The German Weather Service (DWD) operates the regional **numerical weather simulation models** Europa-Model and Deutschland-Model to produce **quantitative precipitation forecasts** (Tab. 9 in Chapter 6.1.1). These are operated since 1991 and 1993, respectively. Concerning the spatial-temporal distribution, cyclonic precipitation can be sufficiently well predicted (FRÜHWALD, 1999). For the improvement of the forecast of convective precipitation the Lokal-Model is in operation by the DWD since 1999 (www.dwd.de/services/gflf/neu_modelle.html). This model has a higher spatial resolution of 7 x 7 km. The resolution is planned to be further discreticised to 2.8 x 2.8 km in the next year (FRÜHWALD, 1999). The use of weather radar and other remote sensing data for the determination of the initial state is planned for the Lokal-Model-version in 2002 (www.dwd.de/services/gflf/neue_modelle.html). The Lokal-Model will be able to forecast high-reaching convection (e.g. thunderstorms) and also heavy rainfall events in summer.

The **hydrometeorological model systems** BONIEOP and SNOW-D serve the improvement of flood forecasts. The model system BONIEOP operationally provides areal precipitation amounts based on a dense automated precipitation measurement network with, at least, hourly data transfer (GÜNTHER, 1999). Presently, the Federal states of Saxony and Brandenburg do not have such a measurement network. With the SNOW-D model system raster based data of the water equivalent are calculated in 6 h intervals for the next 48 hours. The water released by snow cover and actual precipitation events are taking into account. The Spree-Neiße-region belongs to the areas the SNOW-D model was developed for (GÜNTHER, 1998).
Data of the **weather satellites** METEOSAT and NOAA are transferred to the DWD. The METEOSAT data are available to the DWD every 30 minutes (www.dwd.de/general/meteosat.html).
The German territory is fully covered by the **weather radar network of the DWD**. It is operated automatically and centrally managed. Radar images are provided every 15 minutes of the individual radar stations, which are combined to one computer image. Additionally, composite images are produced for those European regions which are involved into the radar data exchange. Within the frame of an international project a radar co-operation for the main part of Central Europe is planned. The weather radar stations in Dresden and Berlin cover parts of the Odra river catchments and of its tributary Lausitzer Neiße/Nysa Łużycka/Lužická Nisa (www.dwd.de/general/metadtdwd.html). The radar station in Dresden is operating since the 21st March of 2000.

The responsible institutions for the flood forecast have to make agreements for the use of data with the DWD.

6.5.2 Flood forecast for the Lausitzer Neiße river in Saxony

The Lausitzer Neiße/Nysa Łużycka/Lužická Nisa river forms the border between Germany and Poland. The Czech Republic is situated upstream of Poland on the Smědá (Polish: Witka) and Lužická Nisa rivers and also upstream of Germany with the Lužická Nisa river and the Mandau river. The regional ČHMÚ office in Ústí nad Labem provides precipitation and river gauge data, but no flood forecast is produced for the border river gauges. On the Polish side the IMGW Wrocław is responsible for the flood forecast and is applying the Kalinin-Miljukov routing approach for the section of the Nysa Łużycka/Lausitzer Neiße river between Görlitz and down to the river mouth into the Odra river (Chapter 6.2.2).

In **Saxony** the hydrological measurement network is operated by the *Umweltbetriebsgesellschaft* (UBG) (Technical State Agency for Environment) with the headquarter in Radebeul. The UBG is the collection centre for the data used in the flood forecast. The UBG is obliged to construct and operate flood announcement river gauges, to produce flood information reports, and to receive and disseminate flood information. The German Weather Service (DWD) provides daily information about precipitation, weather warnings and forecasts and SNOW-results to the UBG (LfUG, 2000). The UBG receives information about water levels and discharges at Czech river gauges and about precipitation from the ČHMÚ in Prague daily.
These information are sent to the Saxon Agency of Environment and Geology (LfUG) by the UBG. The LfUG forwards these information to the regional flood forecast centres in the Environmental State Agencies (StUFA). The flood forecast for the Saxon part of the Lausitzer Neiße river is carried out by the StUFA Bautzen.

This **flood forecast is based on**:

- From the ČHMÚ Prague via UBG once per day water levels and discharges at the river gauges Liberec and Hradek (Lužická Nisa), and Frydlant (Smědá) and precipitation amounts of the stations Liberec and Frydlant (precipitation amount of the previous day).
- Information about weather prognoses, depths of snow covers and 4-hourly updated radar images on the webpages of the ČHMÚ Prague (www.chmi.cz) for the Czech Republic (free access).
- From the DWD via UBG – areal precipitation for the Spree river basin which are considered to be representative for the Lausitzer Neiße catchment (precipitation amount of the previous day) and 10 %, 50 % and 90 %- quantile-values of precipitation (exceedance probabilities) for the present day for the time intervals: 6 – 12 a.m., 12 a.m. – 6 p.m., and 6 p.m. – 6 a.m. and information about the snow coverage (SNOW-D-calculations). Furthermore are available: daily precipitation amounts of the previous day and precipitation amounts for the time intervals of 6 p.m. - 6 a.m. and 0 a.m. – 6 a.m. of the station Görlitz. Additional information about precipitation can be obtained from the threshold reports of the stations Jonsdorf, Walddorf, and Kemnitz.
- Precipitation of the stations Bautzen and Quitzdorf (amounts of the previous day) located in the neighbouring Spree river basin can be used for the evaluation.
- Actual water levels can be called up per telecommunication from the river gauges Zittau 1 and Görlitz on the Lausitzer Neiße river and from the river gauges Zittau 2 (Mandau river) and Tauchritz (Pließnitz river).
- Once a day the IMGW Wrocław issues data about the water level at the river gauge Ręczyn (Witka, corresponds to the release of the reservoir Niedów) via the LUA Brandenburg. German-Polish agreements project extensions of data transfer (3 times daily in case of floods; water level and discharge at the reservoir inflow river gauge Ostrózno).

In 1999 a new flood forecasting model for the Saxon part of the Lausitzer Neiße river was developed (THIELE & BÜTTNER, 1999). It is used in case of flood.

The **flood forecasting model** is a conceptual hydrological model and consists of following components (THIELE & BÜTTNER, 1999):

- rainfall-runoff model for the runoff prediction of the runoff generation area to the river gauge Zittau,
- wave transformation model between the river gauges Zittau 1 and Görlitz,
- discharge model for the sub-catchment between the river gauges Zittau 1 and Görlitz.

Input data for the R-R-model are the observed discharges at the river gauge Zittau 1 and the actual and forecasted precipitation and snowmelt release amounts of the station Görlitz. Additional information for the determination of the average areal precipitation for the station Zittau from the precipitation station Liberec and the Czech radar image can be used. The average areal precipitation is put into the model manually, the discharges at the river gauge Zittau 1 are received by telecommunication.

The R-R-model is run in an hourly time step. To date, the runoff components direct runoff with fast and slow parts, hypodermic runoff and groundwater runoff are determined with measured values using the „input signal detection approach" (input signal analysis). The runoff components are simulated by linear storage cascades. Based on these runoff components the forecasted precipitation depth as input shall be directly transformed to discharge (THIELE & BÜTTNER, 1999).

In the water course model between the river gauges Zittau 1 and Görlitz the wave transformation is simulated separately for the river bed and the flood plain using the linear storage cascade approach. Input data are hourly discharges of the river gauges Zittau 1 and Görlitz.

Another factor, which has to be considered, is the predicted release from the Polish reservoir Niedów (Witka), the actual value usually is not available.

The total program algorithm is calculated three times for the predicted precipitation quantiles of 90 %, 50 %, and 10 % (THIELE & BÜTTNER, 1999).

With this flood forecast program water levels and discharges at the river gauges Zittau 1 and Görlitz can be forecasted in hourly time steps up to 5 days. Therefore, corresponding long-term precipitation prognoses are required. At present, 24 h forecasts are produced, an extension to 48 h is planned.

6.5.3 Flood forecast for the Lausitzer Neiße river in Brandenburg

In Brandenburg the hydrological measurement network is operated by the LUA Brandenburg. The flood forecast for the Brandenburgian part of the Lausitzer Neiße river is prepared at the LUA branch in Cottbus.

The following **information** are available:

- From the LfUG Dresden and the StUFA Bautzen – actual water levels and discharges at the river gauges Zittau 1 and Görlitz as well as the 24 h-forecast for these river gauges.
- From the DWD – areal precipitation for the Spree river catchment (assumed to be representative for the Lausitzer Neiße catchment) of the previous day (daily total) as well as quantile values of the precipitation, which are exceeded with probabilities of 10 % 50 % and 90 % for the actual day in the time interval steps 6 a.m. – 12 a.m., 12 a.m. – 6 p.m., and 6 p.m. – 6 a.m. as well as information about snow cover (SNOW D-calculations). The data are transferred once a day via fax. In the LUA there is also the possibility to get information about the daily and 6 h-totals of the previous day of several precipitation stations via Intranet.
- The actual water levels at the river gauges Zittau 1, Görlitz, Klein Bademeusel and Guben 2 on the Lausitzer Neiße river – via phone query.

The **flood forecasting model** consists of a rainfall-runoff model for the runoff prediction of the catchment encompassed by the river gauge Görlitz with the runoff generation determination based on coaxial diagrams (e. g. DYCK, 1980) and a flood wave transformation model for the wave attenuation between the river gauge Görlitz and the river gauge Guben 2. This model is only operated in flood situations. The calculations are made in 6h-intervals.

The actual water levels and discharges for the river gauges Zittau 1, Görlitz, Klein Bademeusel and Guben 2 are sent to the LUA Frankfurt/Oder daily, the predicted values only if required.

For the year 2001 the development of a new flood forecasting model for the Brandenburgian part of the Lausitzer Neiße river is planned. This shall be directly linked to the Saxon model particularly considering the hydrodynamics. For this a survey of section profiles has already been conducted.

7 Scientific-technical projects for flood simulation and precautionary flood protection

After the Flood 1997 many investigations, projects and measures in the Odra river basin were launched by the affected countries and in international co-operations. The projects for the improvement of the flood forecast with individual countries and river sections, respectively, were already presented and are now only listed in Table 12. In this chapter further important transboundary projects will be described.

Tab. 12: Selected projects for the flood forecast in the Odra river basin

projects on flood modelling and forecast for sub-catchments and river sections, respectively				
project	**schedule**	**sponsor**	**institutions**	**remark**
MATRA (SOBEK) Polish-Dutch bilateral co-operation	01.06.1997 – 30.06.1999	Dutch Ministry of Foreign Affairs	*co-ordinator:* Company Arcadis Heidemij Advies *involved:* institutions of the field water management in Poland and the Netherlands, among others, IMGW Wrocław	among others transfer of one-dimensional hydrodynamic simulation model SOBEK
Improvement of the flood forecasting system in the Upper Odra river basin	since 1997/98	Czech Republic	ČHMÚ Ostrava; Povodí Odry	improvement of the monitoring network and implementation of the R-R-model HYDROG
Hydrological and meteorological monitoring, forecasting and protection system (Polish Abbreviation SMOK)	01.01.1998 – 31.12.2000	Loan of the World Bank	IMGW	improvement of the monitoring network improvement of the meteorological and hydrological forecast systems
MIKE 11 Polish – Danish project	May 1998 – November 2000	DEPA (Danish Environment Protection Agency)	*co-ordinator:* DHI (Danish Hydraulic Institute) *involved:* IMGW Wrocław; RZGW Wrocław; IMGW Warsaw	transfer of Danish flood management technology (Software MIKE 11)
Hydrodynamic model of the BfG	01.07.1999 – 30.06.2002	LUA Brandenburg	BfG (Federal Institute of Hydrology)	development of a hydrodynamic model for the Border Odra

State: December 2000

7.1 Flood simulation projects

Two projects, which are operating transboundary and for large areas of the Odra river basin, are **ODER-LISFLOOD** and **ODRAFLOOD** (Tab. 13). They will be briefly introduced and compared to each other in Table 14.

Tab. 13: International projects for flood simulation

international projects for flood simulation				
project	**schedule**	**sponsor**	**institutions**	**remark**
ODER-LISFLOOD: part of the project Natural Hazards of the EC-JRC	01.01.1999 – 31.12.2000 (extended to 2002)	EC-JRC project to support the IKSO	*co-ordinator:* SAI of the Joint Research Centre of the EC in Ispra, Italy *consultatively integrated:* IMGW Wrocław; RZGW Wrocław; ČHMU Prague; LUA Brandenburg; Saxon Agency for Environment and Geology and different research institutions and companies of the Odra riparian states	R-R-model for the Odra river basin without Warta river and Lower Odra river
ODRAFLOOD	01.01.2000 – 31.12.2002	BMBF project upholder DLR	*co-ordinator:* GKSS (Research Centre Geesthacht); *direct project partners:* IMGW Wrocław; MRI Szczecin; DLR; BTU Cottbus	simulation of flood events in the Odra river basin including the Warta river basin with a coupled model system

7.1.1 LISFLOOD

ODER-LISFLOOD is part of the project „Natural Hazards“ at the Space Application Institute (SAI, Ispra - Italy) of the Joint Research Centre of the EC (JRC). One objective of the project LISFLOOD is the investigation of the influence of land use, soil properties, precipitation, reservoirs and retention areas on actual and historic flood events. It is a *pre-operational model*. The model is being tested for two transboundary European river basins, the Meuse river and the Odra river (for the Upper and Middle Odra river basin upstream of Słubice, the Warta river basin is not included). Within this project, among others, flooding maps to assess the flood damages are generated from ERS SAR satellite data and compared with aerial views of the floods 1994/1995 on the Meuse river and of the Flood 1997 on the Odra river.

The LISFLOOD model system consists of a catchment water balance model (LISFLOOD-WB), run with a daily time step, a catchment flood simulation model (LISFLOOD-FS), run with hourly time step, and a floodplain simulation model (LISFLOOD-FP), run with a time step of several seconds (Fig. 17). The grid size of the entire model is 1 km x 1 km, selected sub-catchments are simulated with a spatial resolution of 100-300 m. For LISFLOOD–FP a spatial resolution of 5 to 50 m is used.

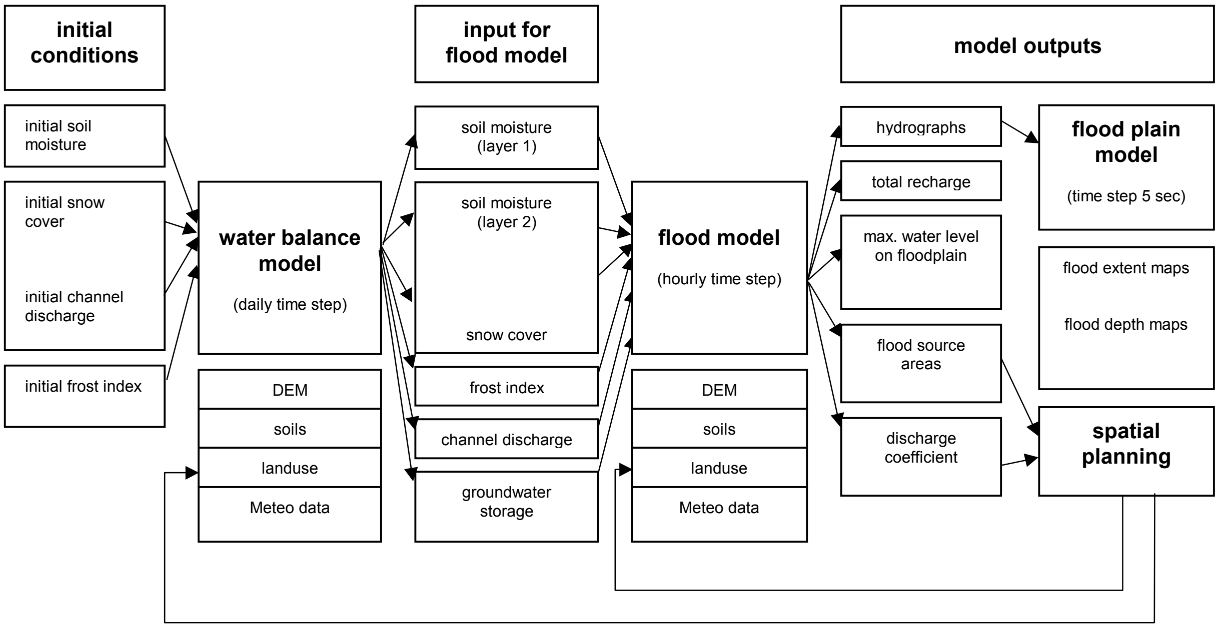


Fig. 17: LISFLOOD simulation concept (source: http://natural-hazards.aris.sai.jrc.it/floods/risks/)

For the Odra river basin three historic flood events were simulated: Summer 1977, Summer 1985, and Summer 1997.

LISFLOOD closely co-operates with the potential operators in Germany, Poland, the Czech Republic, and with the ICPO (regular meetings). Experts of the three riparian states were invited to Ispra for test simulations. They gave advice for a further operator-oriented development of the model. A further testing phase is planned for 2001. There was the agreement on simulating scenarios which were already proposed and accepted by the states. The model is available for operation in the Odra river riparian states. A co-operation with the project ODERREGIO (Chapter 7.2.1) is arranged and implemented. A co-ordination with the project FLODIS-ODER (Chapter 7.2.2) is considered.

Since February 2000 the SAI takes part at the project „European Flood Forecasting System (EFFS)“ (funded by the EC) together with numerous institutions of the Netherlands, Denmark, Germany, Italy, Great Britain, and Sweden. The project is co-ordinated by Delft-Hydraulics in the Netherlands (http://effs.wldelft.nl). Aim of the EFFS project is the development of a prototype of an operational European flood forecasting system for lead times of 4-10 days. The system shall be developed in such a way that it can provide daily information about the probability of flood for large river basins like the Rhine or the Odra river as well as for small catchments threatened by flash floods. First tests were made for the Meuse river basin.

project	schedule	sponsor	institutions	remark
European Flood Forecasting System (EFFS)	since February 2000	Fifth Framework Programme of the EC	*co-ordinator*: Wl | Delft-Hydraulics, Netherlands *project partners*: JRC Ispra and institutions in Italy, Great Britain, Denmark, Sweden, Germany	development of an European Flood Forecasting system for large and small catchments

7.1.2 ODRAFLOOD

The project is a German-Polish co-operation with the German partners GKSS Geesthacht (project co-ordinator), DLR Cologne, and the BTU Cottbus (with this study), and with the Polish partners IMGW Wrocław and MRI Szczecin. The Czech side indirectly is integrated via the contacts of the IMGW Wrocław. A user panel, where also the ICPO shall participate, attends the project.

The objective of the project is the fitting together of existing and tested models in a coupled model system for the simulation of flood events in the Odra river basin including the Warta river basin. The model is also planned for *pre-operational use* but should also provide scenarios and modules for the operational use in the flood forecast. The model system is modular structured (Fig. 18).

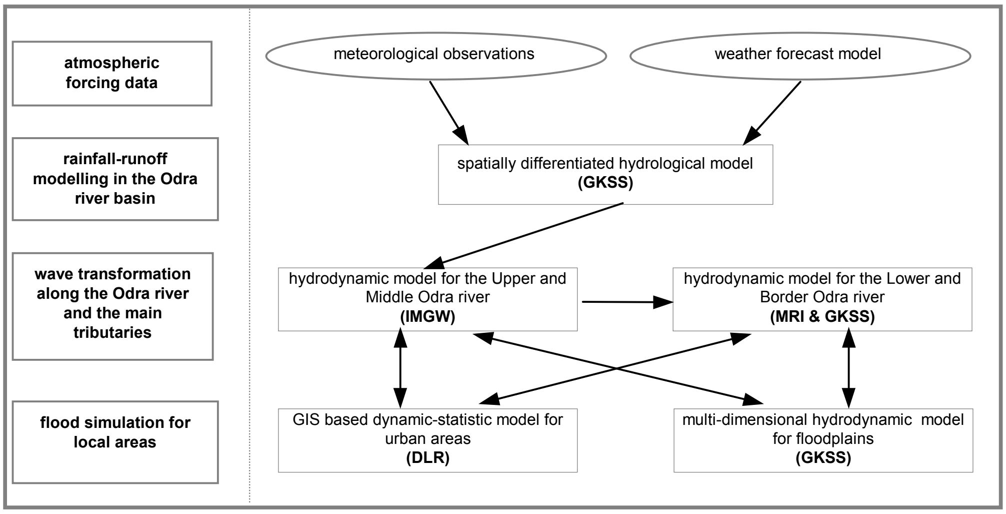


Fig. 18: ODRAFLOOD model system (Source: GKSS & PARTNERS, 1999)

On the Upper and Middle Odra river GKSS and IMGW Wrocław are jointly operating. GKSS operates the spatially differentiated hydrological model SEROS (rainfall-runoff model). It consists of the multi-layer land surface scheme SEWAB, which can be coupled directly to weather forecast models due to its description of energy and water balance, and a routing procedure for the runoff concentration and the wave transformation process in the riverbed. Within the frame of the BALTEX programme simulations with SEROS for the entire Odra river basin including the Flood 1997 were already conducted. The results for the river gauge Gozdowice are presented in Figure 19. Adjustment of the routing parameters improved the simulation results when compared with the measured flood wave on the Border Odra river section which obviously was also noticeably attenuated by dike breaches on Polish territory. This was established without using a hydrodynamic based river model with correspondingly changed cross-section and vertical section data.

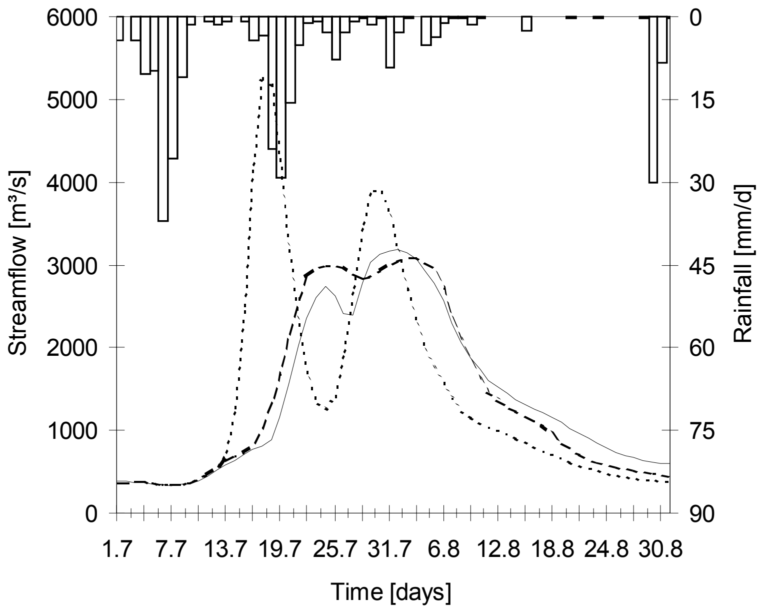


Fig. 19: Comparison of observed hydrographs with hydrographs simulated by SEROS for the Odra river gauge Gozdowice for the Flood 1997 (solid curve = observed; dotted curve = simulated with routing parameters from calibration period 1992-1993; dashed curve = simulated with an improved routing model, discharge related parameters, additional linear reservoirs) **(RUHE et al., 1999)**

The rainfall-runoff model SEROS simulates the inflow to the reservoirs and to the reaches of the Odra river and of its tributaries, respectively. Later on it will be decided, if SEROS will be coupled to the model system for the Odra river, implemented at the IMGW Wrocław or if the SEROS routing model will be applied. Together with the IMGW Wrocław different scenarios will be simulated.

On the Lower Odra river the one-dimensional hydrodynamic model of the MRI Szczecin is used. This will represent the complex river system on the Lower Odra river and the backwater effects of the Stettiner Haff / Zalew Szczeciński. The MRI will spatially enlarge the model from Gozdowice upstream to the mouth of the Lausitzer Neiße/Nysa Łużycka/Lužická Nisa river. The hydrodynamic model TRIM operated by the GKSS will be coupled to the MRI-model for simulating local flooding scenarios (e.g. dike breaches) as well as the effects on the flood wave in the river bed upstream and downstream. Furthermore, an interface to the inundation model of urban areas ARCHE of the DLR, which was tested at the Rhine river, shall be implemented. Within the project ARCHE will be applied to the cities Frankfurt/Oder-Słubice and Wrocław. Scenario simulations will be applied for analysis of the efficiency of flood protection structures in these cities. At a later point social-economic risks shall be assessed using ARCHE providing that the required data are available from the cities.

Tab. 14: Comparison of the projects ODRAFLOOD and ODER-LISFLOOD

	ODRAFLOOD (GKSS and partners)	**ODER – LISFLOOD (EU–JRC) / Natural Hazards**
(not mentioned model elements are treated similarly by both model systems)		
general information		
Schedule	2000-2002	1999-2002
catchment	Odra catchment upstream of Szczecin including the Warta river catchment	Odra catchment upstream of Słubice (without Warta river catchment)
grid size	7x7 km (may contain various land use types)	1x1 km (plus sub-grid land use)
time step	30 min	1 h
co-operation with users	co-operation by user panel, IMGW and MRI are project partners	main water authorities in CZ, PL and Germany
user interface	to be developed	ArcView extension or stand alone model
links to ICPO	information exchange, planned ICPO representative in user panel	direct link by EC contribution to ICPO
data basis		
land use data	1992 CORINE	1992 CORINE, 1975, 1945 aerial views, historic maps (1776 Schmettau, 1850 Military maps)
soil data	FAO soil map 1:5 000 000; Polish soil map 1:250 000 (in preparation)	European soil data base 1:1 000 000; on scale of 1: 250 000 available in February 2001
soil parameters	Clapp / Hornberger transfer functions	HYPRES transfer functions
modelling		
evapotranspiration	coupled water & energy balance module	Penman – Monteith / Priestley / Taylor
snowmelt	GKSS model (energy balance)	degree day method
soil freezing	heat diffusion	degree day method
soil layers	6	2
hydrodynamics	complete Saint-Venant equations for the Odra river downstream of the mouth of the Lausitzer Neiße/Nysa Łużycka/Lužická Nisa river; upstream of this mouth and tributaries diffusion wave	kinematic and dynamic wave transformation
reservoirs	included	included
retention areas	included	included
flood inundation	3D TRIM model including upstream backwater effects	2D LISFLOOD-FP model
inundation of urban areas	ARCHE model (DLR), testing areas: Frankfurt/Oder and Wrocław	2D LISFLOOD-FP model
scenarios	included; to be decided	as agreed in the ODER-LISFLOOD project
test periods	1985-present	1976/77, 1984/85, 1996/97

Source: Co-ordination meeting on the 14.11.2000 in Ispra. Participants: SAI Ispra, GKSS Geesthacht and BTU Cottbus

In another BMBF sponsored joint project concerning flood modelling on the Odra river the University of Kassel, the Potsdam-Institute for Climate Impact Research (PIK) and the GKSS comparatively assessed the models WaterGAP, ARC/EGMO and GESIMA/SEWAB/ TOPMODEL in the Odra river basin and in the sub-catchment of the Upper Odra river, respectively. The models developed for *different scales* were investigated with respect to their scale behaviour and their accuracy in simulating runoff generation and water availability, especially concerning the flood runoff generation. The project conducted by the PIK has a linking function, because it is appliance to the catchment of the Upper Odra river up to the river gauge Chałupki (comparison GKSS - PIK, Flood 1997) as well as to the catchment of the Odra river and Elbe rivers (comparison PIK – University of Kassel, water availability and flood frequency).
In order to consider the heterogeneity of the complex landsurface structure in the Upper Odra river basin the landsurface scheme SEWAB was extended by the topographical index from the model TOPMODEL. By this, the runoff generation in the mountainous area of the river basin could be simulated comparatively as well as with the original SEWAB version but with less calibration efforts. In the second phase of the project SEWAB was coupled to the non-hydrostatic atmospheric model GESIMA, so that the runoff generation in the investigated area can be directly calculated with the precipitation data which are simultaneously simulated by the atmospheric model.

project	schedule	sponsor	institutions	remark
Water availability/ Flood modelling	01.01.1999 – 31.12.2000	BMBF	University of Kassel; PIK (Potsdam-Institute for Climate Impact Research); GKSS (Research Centre Geesthacht)	climate change impacts on water availability and flooding pattern in Europe; comparison of WaterGap – ARC/EGMO – SEWAB/GESIMA in the Elbe and Odra river basins

7.2 Further projects for flood protection

The most important transboundary projects, not directly dealing with flood modelling, are the projects **ODERREGIO**, **Oder-Auen-Atlas**, **FLODIS-ODER,** and **OSIRIS** which can be assigned to the fields of pre-cautionary flood protection and of flood information systems.

7.2.1 Planning basis for pre-cautionary flood protection

Plannings for pre-cautionary protection require - especially on international waters like the Odra river - a uniform data basis for the entire catchment. The main activities on the Odra river dealing with this topic are the project Oder-Auen-Atlas of the WWF-Aueninstitut and the trilateral project ODERREGIO sponsored by the EC.

Immediately after the Flood 1997 the WWF-Aueninstitut started with the work for the **Oder-Auen-Atlas**. Aim of the GIS-based map book produced in close co-operation with Polish and Czech experts was the compilation of an inventory of the Odra river valley under ecological and nature conservation aspects. The atlas is developed as a transboundary uniform planning basis for an ecological oriented flood protection and an sustainable development of the Odra valley. The Oder-Auen-Atlas (scale: 1 : 50 000 expected to be published at the end of 2000 and distributed to all communities, planning agencies and ministries in Poland, Germany and the Czech Republic) will play an important role in the discussion about a possible declaration of flood plain areas. The atlas is based on topographic maps on a scale of 1: 25 000 and comprises the area of the morphologic flood plain of the Odra river. Supplementary to biotopes and bio-indicators, which are defined according to transboundary agreed uniform schemes, the atlas also contains information about the hydraulic engineering infrastructure (dikes, weirs), about nature reserves, about existing and planned polders, and about the flooded area during the Flood 1997.

Since December 1999 methods and the main operations for pre-cautionary flood protection related to spatial planning are developed for the Odra river basin (at present without the Warta river) within the project **ODERREGIO** in the scope of the INTERREG II C programme. These are transnationally agreed in a working group that attends the project. An uniform planning basis on a scale of 1 : 750 000 for the spatial and state planning is developed. Due to the conceptual character plannings and results of other projects are used and made compatible to each other. Besides polders and other hydraulic engineering measures, focus areas for flood protection and flood pre-caution considering settlement and land use are presented. From these recommendations for actions shall be derived. As particularly threatened areas (so-called „hot-spots") Ostrava, Kędzierszyn Kożle, Opole, Wrocław, Głogów, Słubice/Frankfurt (Oder) Schwedt and Szczecin as well as the Odra river tributaries Bóbr and Nysa Kłodzka were identified. The project is carried out on behalf of the United Land-Planning Section Berlin/Brandenburg in close co-operation with the agencies responsible for spatial planning, and water management in Germany (Brandenburg, Saxony), Poland and the Czech Republic by the company Infrastruktur & Umwelt Potsdam/Darmstadt, by Ruiz Rodriguez+Zeisler Wiesbaden, and by the Technical University Darmstadt. The current phase of the project ODERRREGIO will be finished in June 2001. It is planned to be continued in a following phase. Tasks are, among others, the inclusion of the Warta river, a further ascertainment of measures and the co-ordination of further activities.

Pre-operational flood forecasting systems like LISFLOOD and ODRAFLOOD can be used to simulate scenarios of the effects of planning on the course of flood events. The modelling of changes of the hydraulic engineering infrastructure, of river regulations and of controlled and uncontrolled polder flooding is of special interest for the planning on the Odra river. However, this bears greatest requirements on pre-operational models regarding e. g. the representation of the related hydrodynamic processes.

7.2.2 Projects for flood information systems

Flood forecasts are only useful, if they are embedded into a decision and warning system. FLODIS-ODER and OSIRIS are projects within the field of such flood information systems.

The project **FLODIS-ODER** started 1999 by WASY GmbH and partners is financed primarily by the Allianz Foundation for Nature Protection and supported by other institutions / companies. The Water Bodies and Dike Association Oderbruch (Gewässer- und Deichverband Oderbruch), Seelow, is recipient of the provided money. The objective of the project is to develop a transboundary information and decision support system for a sustainable flood management in the Odra river basin in co-operation with Polish and Czech partners.

All space-time data of the Odra river basin (GIS Oder) relevant for decision making will be integrated in a transnational, homogeneous GIS-based information system. Based on this a decision support system for a sustainable flood management will be developed by implementing intelligent analysis tools in GIS ODER and the possibility of coupling with other models (e.g., model LISFLOOD of the JRC). As special model developments a polder flooding model and a stochastic flood planning and flood management model are planned. The development of the information system and the application of decision support is carried out for selected pilot areas (Upper Odra river, Lausitzer Neiße/Nysa Łużycka/Lužická Nisa, Middle Odra river, Ziltendorfer Niederung (Ziltendorf Lowlands)). Results of the project „Diffuse Entries in rivers of the Odra Basin“ (on behalf of the German Ministry for Environment, carried out by IGB, ZALF and others) are used. A co-operation with a planned project about Management of the Odra River Basin becomes apparent.

The objective of the project **OSIRIS** (Operational Solutions for the management of Inundation Risks in the Information Society) is the improvement of structures and procedures of flood management in large river basins using modern information and communication technology. Main objective is the development of instruments which allow all those involved (administration, disaster prevention, population) to take part interactively in all phases of the flood management (preparation, monitoring, defence, post-crisis-phase). The project is financed within the Fifth Framework Programme of the EC and is carried out for the Loire and Odra river basins in co-operation with 12 institutions in Germany, France, Italy, the Netherlands and Poland. Test areas within the Odra river basin are Kłodzko and Frankfurt / Oder. The aim of the project in these demonstration regions is to enhance the flood risk awareness of the population, to improve the efficiency of the flood protection and the quality of flood information, and to make the flood information faster available. The project was started in the beginning of 2000 and will be finished at the end of 2002.

A summary overview of the projects presented in Chapter 7.2.1 and Chapter 7.2.2. is given in Table 15.

Tab. 15: International projects on flood protection in the Odra river basin within the field of planning and information systems

planning basis and information systems to the topic flood				
projects	**schedule**	**sponsor**	**institutions**	**remark**
Oder-Auen-Atlas	01.01.1998-31.12.2000	Gerling Insurance, WWF, and others	WWF-Aueninstitut Rastatt Lower Silesian Fund for Sustainable Development Wrocław and others	catchment orientated data base for problems in environmental protection, GIS-based
ODERREGIO	1999 – 2001	EC-programme INTERREG II C	*instructor*: United Land-Planning Section Berlin-Brandenburg *participants*: planning agencies in Germany, Poland, and the Czech Republic *conducted by*: Company Infrastruktur & Umwelt, Potsdam and others.	transnational concept for pre-cautionary flood protection in the Odra river basin
FLODIS-ODER	1999-2002	Allianz Fund for Environmental Protection; ESRI® Inc. USA COMPAQ® German Association for Water Management and Civil Engineering (DVWK)	*recipient of funded money*: Water Bodies and Dike Association Oderbruch, Seelow *conducted* by WASY GmbH in co-operation with Polish and Czech partners	transboundary information and decision support system for a sustainable flood management in the Odra river basin (pilot projects)
OSIRIS	01.01.2000 – 31.12.2002	Fifth Framework Programme of the EC	*co-ordinator:* SOGREAH (Grenoble/France) *participants:* City Frankfurt/Oder, BTU Cottbus, IMGW Kraków and others	use of information and tele-communication technology in the case of flood

8 Summary and résumé

Functioning *flood forecasting systems* are an important pre-requisite for the protection of the population against flood hazards. Therefore, they lie under the special **responsibility of the State** *and the respective institutions*. A co-ordinated, *integrated system* consisting of flood forecast, flood warning, decision support, information, and reaction should be pursued. Besides the available resources of the financing organisations and the degree of co-operation between the agencies involved the requirements on such an **early flood warning system** depend on the specific hydrological and hydrometeorological conditions in the catchment and the river sections.

8.1 Summary of the present state of development of the operational flood forecast in the Odra river basin

In the Odra river basin exists a historically evolved variety of different methods and models for the flood forecast. They are adjusted to the different conditions of *summer and winter floods* as well as to the *different situations of the sub-catchments* in the Upper, Middle and Lower river reaches of the Odra river.

In the **area of the Upper Odra river on Czech territory** the *onset times* of the flood waves are *very short* due to the topography. The concentric river network increases the risk of an *overlapping of flood waves* of the different sub-catchments. Very dangerous flood situations arise from cyclonic *heavy rainfall* in the summer and from *rainfall* in spring which *coincides* with *rapid snowmelt*. Locally dangerous situations arise from *flash floods* triggered by convective heavy rainfall mainly in the summer half-year. The currently short warning lead times (for example only 6 h for the river gauge Bohumín on the Polish-Czech border) proved to be problematic for a more successful disaster prevention in 1997 (GRÜNEWALD, 2000).

After the Flood 1997 agreements about the *joint use* of data and models were made between the state-run hydrometeorological service *ČHMÚ Ostrava* and the *river basin authority Povodí Odry* in the Czech Republic. Furthermore, the development of the monitoring network was driven forward. The ČHMÚ adapted the *rainfall-runoff model HYDROG* developed and operated by Povodí Odry. The model contains, among others, *modules for the controlling of the reservoir systems*. However, at present, it is only in testing operation for some sub-catchments. Presently, a *snowmelt routine* is in development. The *coupling* with the *numerical weather model* ALADIN operated in Prague is in planning. Moreover, it is planned to develop a *common radar image* for the *mountainous region* together with data of the Polish radar network.

Taking these points into consideration a significant improvement of the flood forecast can be expected for the Upper Odra river catchment. An *extension of the flood forecast lead time* to 48 h for the river gauge Bohumín is planned. The future development strongly depends on the co-operation between ČHMÚ and Povodí Odry.

On the **Upper and Middle Odra river in Poland** the short onset times of the flood waves in the *tributaries of the Odra river* and the risk of *overlapping of their flood waves* in the Odra river are of significant importance for the course of the flood event. An instrument for prevention of such overlapping is the *controlled operation of the reservoirs*. First modules for this operation are implemented into the flood forecast models. On the Middle section of the Odra river *upstream of the city Wrocław polders* are situated which can contribute to relieve the flood situation. In the winter half-year, besides rainfall also *snowmelt* and possible hazards of *ice jams and ice shifting* have to be taken into consideration. A high *damage potential* exists in the urban areas, especially in Opole, Wrocław and Słubice - Frankfurt /Oder. Particularly, in the so-called „Water node" of Wrocław are complicated discharge conditions. Inundations from the sewage system and possible dike breaches bear additional risk potential.

Already previously to the Flood 1997 the *IMGW Wrocław* owned *several model systems* for the flood forecast for the Upper and Middle Odra river. They consist of *rainfall-runoff models* and *hydrodynamic modules* as well as *controlling routines for the reservoirs*. The *monitoring network* and the *data transmission* are still *insufficient*. The urgently needed modernisation and automation shall be carried out within the *SMOK-Programme* with funds from the World Bank. The future development will depend on the progress of the planned modernisation and on the adaptation of existing and currently developed models (MIKE 11, SOBEK) to the improved data basis. In 2000 the *radar station* Pastewnik was put into operation. This station can contribute to the planned *improvement of the meteorological forecast* by the use of numerical weather models.

On the **Border Odra** and the **Lower Odra rivers** the *travel times* of the flood waves coming from the upstream catchment are sufficiently *large* to disseminate respective warnings, to calculate scenarios, to make decisions and to execute the corresponding measures. It depends on the size and the temporal occurrence of the flood wave of the **Warta river**, if the peak and the duration of the Odra river flood wave is increased or if Odra water penetrates into the mouth of the Warta river. In the latter case the Warta river mouth serves as retention area and may contribute to a relief of the situation. By strong long-lasting northern winds *backwater effects from the Stettiner Haff / Zalew-Szczeciński* result in an increase of the water levels in the Odra river. Critical are, besides the water levels, the *higher flow velocities* at bottlenecks (e.g. Hohenwutzen) where in flood situations, the pressure on the dikes is strikingly high. Also the *duration* of the flood can be critical, because the soaking of the dikes increases the risk of dike breaches. Additionally, *erosion phenomena* weaken the stability of dikes and structures. Moreover, this Odra river section is characterised by lowland areas and various hydraulic engineering structures. There is a complex network of *polders*, *weirs* and *connection channels*, especially downstream of the weir Widuchowa. Diking enabled the *settlement* of former *large retention areas* (e.g. Oderbruch, Ziltendorfer Niederung) but increased the *damage potential*. The damage potential is also especially high in the double-city *Frankfurt/Oder-Słubice* which therefore is a critical point in disaster prevention.

At present, for the **Lower Odra river** *no continuous problem-adequate flood forecasting system* exists. Therefore, hydrodynamic model and the monitoring network of the *MRI Szczecin* could be used (Chapter 6.3.2).

At the *IMGW Poznań* – responsible for the Warta river and the Border Odra /Lower Odra river – forecasts are produced for selected river gauges on the Warta river as well for the river gauge Gozdowice (Odra). A stepwise development of a hydrodynamic model for the Warta river is planned. At present, the forecast for the river gauge Słubice is produced by the IMGW Wrocław. Still insufficient is the precipitation (Warta river) and river gauge monitoring network on Polish territory which shall be modernised.

At the *LUA Brandenburg regional office Frankfurt/Oder*, the present forecast for the **Border Odra** river is based on river *gauge relations*. On behalf of the LUA Brandenburg the *BfG develops* a *hydrodynamic flood forecasting model* for the Border Odra river but this will not be terminated before 2002 (STEINEBACH, 2000). The German *river gauge network* is *automated* and equipped with *data transmission*. The quality of the results of the planned BfG-model will significantly depend on the input data from Poland.

Special requirements on the flood forecast result from the *ice formation* and *ice shifting* on the Lower Odra river. The *forecast of ice floods* is extremely difficult. Whereas the process of ice formation can be modelled quite well, there are problems in modelling ice accumulation and ice drifting. For the planning and the preparation of the joint *German-Polish ice breaking operation* knowledge about temperature and precipitation conditions in the upstream catchment as well as the water equivalent of the existing snow coverage is necessary, to start the ice breaking from the Baltic Sea in time to ensure a safe ice removal.

On the **Lausitzer Neiße river** the situation is especially complex, because not only the Czech Republic and Poland, but also the two German Federal states of Saxony and of Brandenburg operate own monitoring networks and flood forecast models.

The already existing transnational flood forecasting system is based on a network of different paths of data exchange (Fig. 10, Chapter 6). The quality of the forecasts of the downstream party significantly depends on the transmitted data and forecasts from the respective upstream parties and the existing mutual confidence. A fertile inter-institutional and inter-state *co-operation* supported by the activities of the *ICPO* can certainly contribute to further development and improvement.

8.2 Approaches for the improvement of the operational flood forecast in the Odra river basin

The working group 4 of the ICPO recently published a „*Joint strategy and principles for the action programme flood protection in the Odra river basin*“. Therein the ICPO recommends to its member states to develop a modern flood information system for the entire catchment, so that early and accurate flood forecasts enable disaster prevention and pre-cautions (IKSO, 2000). The following tasks are considered to be urgent:

1. **Monitoring network:** Modernisation of announcement river gauges and precipitation measurement network and their equipment with data transmission technology
2. **Data collection and data transmission**: Technical building-up of the flood information system to ensure the work of the flood centres and of the announcement and precipitation measurement network, also in case of power failures and interruptions of communication lines (phone, radio, telex, fax)
3. **Flood warning system**: Installation and modernisation, respectively, of the telecommunication and media systems for the information of the public and for emergency alert
4. **Transboundary data exchange**: Facilitation of regional, national and transboundary information exchange for flood reporting
5. **Flood forecast models**: Development of discharge and water level forecast models and of precipitation forecast models for the flood generation areas of the Odra river and its main tributaries.
6. **Reaction:** Drawing-up of plans for flood defence on local level

(modified after ICPO, 2000).

With this strategy the main aspects for the improvement of the flood forecast and flood information system in the Odra river basin are addressed. It is now to the responsibility of the member states to execute these recommendations.

According to Chapters 4, 5 and 6 of this study the **concentration** of the individual *components into an integrated* modern **early flood warning system** has to be more emphasised. E. g., not only the modernisation of the telecommunication for the information of the public and the improvement of flood forecast models are required separately but rather their co-ordinated development. Number, variety and quality of the scientific-technical projects presented in Chapter 7 should provide the best basis for a stepwise development of such a modern instrument to protect the population against flood hazards in the Odra river basin.

8.2.1 Data collection and data supply

An **urgent task** for the Odra river basin is the further **modernisation** and **automation of the measurement systems** and the data transmission, especially in Poland. For the modelling, continuously measured real-time data are required. Their *transmission* has to be *ensured* also in case of floods. Especially for the Upper Odra river and the tributaries originating in mountainous regions a reinforced coupling of the flood forecast to numerical meteorological *precipitation forecasts* is needed to extend the forecast lead time. This requires the spatial registration of the precipitation by a dense ground network as well as by *satellite* and *weather radar data* and *quantitative precipitation forecasts* (KUNDZEWICZ et al., 1999). As presented in Chapter 6 varied activities are already launched within this issue.

8.2.2 Model structure and components

The IKSO demand for the development of runoff and water level forecast models is fulfilled by the Odra riparian states - partly in co-operation with research institutes and in international co-operation (Chapter 7).

Along the Odra river the topography, climate and hydrology of the basin are changing as well as the local conditions like size of settlements, hydraulic-engineering structures, damage potentials etc. That is why also for the Odra river it can be stated that there **is no universal hydrologic model** that can be used operationally for all situations and in all areas of the basin (SAMUELS, 1998).

For large river basins like the Odra river basin a **modular structure** must be recommended. Important modules are, for example, *rainfall-runoff models*, especially for the headwaters, models for the simulation of *polder* flooding and *dike breaches,* and models for the *operation of reservoirs and retention basins* in flood situations. For larger cities (e.g., Wrocław and Frankfurt/Oder -Słubice) the special conditions like the *sewage network* and *by-pass channels* have to be taken into consideration. On the Lower Odra river the special conditions of the lowlands, especially the Oderbruch, as well as the *backwater effects* from the Stettiner Haff are of importance. Here the operation of a multi-dimensional *hydrodynamic* model is recommendable. The special case of *ice floods* requires special attention.

With such a modular structure the *linking* of the different model components and systems is of special importance. The *interfaces* have to be clearly defined and the data exchange between the different modules has to be ensured. Overlapping model systems, e.g. on the Border Odra river, have to be *consistent* to each other (GALLOWAY JR., 2000).

The *individual models* should be *flexible* and *robust* regarding data supply and interfaces, so that also in case of breakdown of some stations or elements they still remain in working order.

Generally, it can be stated, that most of the existing flood forecast models in the Odra river basin are well developed regarding their structure and their application. Therefore, the development of completely new models does not appear that necessary. More efforts should be put into the **calibration** and **parameterisation** of the chosen models and modules for the respective area and river reaches. Undoubtedly, the application of models, which have been proved to be suitable in other river basins, has to be tested. When transferring such models extensive testing and parameterisation have to be made by the *operator*. E.g. the IMGW Wrocław is testing and parameterising the model systems MIKE 11 and SOBEK. Only after that procedure their future field of application and use is decided.
The *use of several models* for one area and one river reach, respectively, has the advantage that reoccurring model errors can be better identified and *error ranges* of model outputs can be better quantified.

8.2.3 Integration of model operators and users of model results

When taking over of other developments as well as when improving own operational flood forecasting models the interests and needs of the future **operators as well as** of the **users** of the model outputs have to be taken into account. The more the operators and users are integrated into a project, the more it can be *adapted to* their *needs*, but also the more their *experiences* can be *used*.

Direct **users** in the Odra river basin are in the Czech Republic ČHMÚ Ostrava and Povodí Odry, in Poland IMGW Wrocław and IMGW Poznań (Warta, Border Odra river), in Germany the regional offices of the LUA Brandenburg in Frankfurt/Oder and Cottbus as well as LfUG Dresden and StUFA Bautzen. For flood forecast and flood warning these institutions have to provide respective information and forecasts in case of floods.

Besides the directly involved institutions in flood forecast, especially the **users** (disaster prevention, planning agencies, insurances, industries with high risk potential etc.) have to be considered. These have to *make decisions* and have to *start measures* on the basis of the flood forecast. Therefore, they already have to be integrated into the conception of early flood warning systems, so that an effective conversion into action is ensured.

The responsible authorities for disaster prevention are – as presented in Chapter 3 – in the Czech Republic the flood prevention committees on district level, in Poland the agencies for crisis management and flood prevention committees, especially those on Voivodship level, and in Germany the district and municipal cities. Further users are forces that are directly involved into the flood defence like fire brigades, civil rescue services, army etc. In case of flood decisions have to be made and action executed within these structures. They need reliable and appropriate information about the flood situation and the course of the flood. Particularly, the responsible institutions for the flood defence and disaster prevention need better information about the *capabilities* and the *reliabilities* of *the flood forecast models in operation*. Repeatedly the users emphasise (e.g. on the co-ordination meeting on the 23.11.2000 at the office for fire, disaster prevention and civil rescue service /city administration Frankfurt/Oder), that during the Flood 1997 an information deficit resulted in misunderstandings and problems. Therefore, to those responsible for flood defence and disaster prevention, e.g. *information events* on the state of the flood forecast and the flood information systems should be offered.

The **decision makers** are increasingly more interested in the development of systems for *decision support*. In case of floods such systems offer several alternative solutions mostly in graphical form on the basis of geographic information systems with digital elevation models

(TODINI, 1992). Nowadays, it is no more sufficient to present the users and decision makers a pile of model outputs and to favour only a certain variant in advance. Instead the information have to be processed and *prepared according to the needs of the users* and have to be comprehensively presented (COUNSELL et al., 2000).
Thus, e.g. the project *FLODIS-ODER* in co-operation with Polish and Czech partners plans to develop a transboundary information and decision support system for a sustainable flood management on the Odra river. This information system shall be equipped with coupling interfaces to other models (e.g. the model LISFLOOD of the JRC). However, at present an operational use is not planned.

Suitable *interfaces* and *ways* for an extended **information of the public** have to be developed. At last, the directly affected citizens, industries and communities have also to be considered as users. They receive the flood warnings and the advises of the agencies that they *have to understand* to being *able to act autonomously*. „This participation of affected citizens and people is essential, because it reinforces the responsibility for the individual coping with problems and works against the attitude that external, state or other social forces are a priori responsible for the problem solutions“ (GRÜNEWALD et al., 1998, p. 122).
Thus, e.g. it is planned within the scope of the project *OSIRIS* to develop instruments for pilot areas, among others also for the Odra river basin, which allow all affected parties (administration, disaster prevention, population) to take part interactively at all phases of flood management (preparation, monitoring, defence, post-crisis phase).

In the *entire Odra river basin* there are still large deficits concerning *the linking of flood forecasting systems* with *decision support* and *information systems*. Besides the importance to be informed in time about the danger of a flood occurrence, the Flood 1997 showed how important it is to make decisions and to execute actions on this basis. Even though, flood protection is not direct issue of the EC-water directive, the demand for a stronger involvement of the public has also to be valid for the flood protection. Only together with the affected users and the public flood forecast as part of an early flood warning system can enable an effective protection of the population against flood hazard.

8.2.4 Use of pre-operational models

Floods mainly are results of randomly coincidences of a large number of combinations of different meteorological events and hydrological initial conditions within the catchment (GRÜNEWALD, 1995). The variety of (random) interactions – e.g. the missing of only one favourable or reducing variable – may decide about the occurrence of the event as „extreme flood“, „general flood“ or „no flood“. To *assess and simulate such various situations* the use of pre-operational models is appropriate. The special requirements on the pre-cautionary actions are resulting from this. They serve the *analysis* of different *planning scenarios* of changes within the river basins or hydraulic-engineering structures like, e.g. the construction of retention reservoirs, the declaration of flood plains, the use of environmental impact assessment, the optimisation of controlling strategies for reservoirs. With scenarios of dike breaches and inundation of urban areas *damage potentials* can be *calculated*. Special aspect like, e.g. erosion phenomena, can also be investigated.

An adjustment of flood simulation models to changes in the system conditions and in the data basis should be permanently possible (BERGER, 1991). Numerous measures within the Odra river basin, e.g. the construction of reservoirs, weirs, the declaration of site development etc. can be expected. These will influence the flood regime and the damage potential. *ODER-*

LISFLOOD (JRC-SAI Ispra) as well as *ODRAFLOOD* (GKSS and partners), which are catchment related models, are designed for such a pre-operational application.
With pre-operational systems previous floods can be analysed with regard to the improvement of the flood forecast and flood warning systems. The analysis of the different flood courses and causes can show, where and how modern early flood warning systems have to be implemented. Hazard events and sensitive situations can be identified and evaluated for the further development of the operational flood warning system (GRÜNEWALD & SCHÜMBERG, 2000). Pre-operational models have to fulfil extraordinarily high requirements, because they contribute to the political decision finding.
Under the aspects *transparency, robustness, monitoring network* and *calculating time* the direct use of pre-operational models for the operational flood forecast does not seem to make sense. Rather an applicable operational forecast model should be deduced from the model developed for the system analysis by simplifications (MORGENSCHWEIS et al., 1996). Especially the data basis for flood situations has to be thoroughly tested when transferring modules of pre-operational systems into the operational use.
In the end, it also applies here, that there is no „best" model for all possible problems. Several models should be used for the simulation of scenarios to get a certain range with regard to model uncertainties and the manoeuvring in decision making (CUNGE, 1992).

8.2.5 Transboundary co-operation

The three riparian countries and the flood forecasting centres, respectively, are different in structure and flood forecasting systems. At present, the individual countries strive for an operational *flood forecast independent* of the other riparian states. This is clearly illustrated by the example of the Lausitzer Neiße river, where not only the individual countries, but even the Federal states are operating and planning own monitoring networks and model systems.
Realistically, it has to be stated, that the present structures will still remain for a while and that within the administrative boundaries operation with the own chosen and developed model systems will continue. Thus, for an effective transboundary co-operation it will *not be possible* in the short-term, to develop **one** *model system* for the entire Odra river. However, imperatively there have to be developed *interfaces* for the different systems and models.

Undoubtedly, when planning transboundary co-operation the different interests and pre-requisites in the individual countries have to be considered:
The Czech Republic in the upstream position is relatively independent of others. The flood onset times are extremely short, the damage potential high and the complex reservoir system has to be controlled. Poland holds the largest part of the river basin and also the largest cumulative damage potential. Due to the short response time of the Upper reach Poland relies upon the data and information provided by the Czech side. This applies especially with regard to the operation of the reservoirs. Germany in the downstream position relies on the data and information provided by the Polish as well as by the Czech side. However, Germany has the advantage of long warning lead times. An important common interest with Poland lies within the ice defence on the Lower and the Border Odra river.

For a transboundary flood forecast it is unfavourable that meteorological data and forecasts, like e.g. of SNOW-D, or areal precipitation calculation are often provided *only to the respective state border*. The co-operation between Poland and the Czech Republic to prepare a *joint weather radar image* for the mountainous region has to be considered positively.

One of the main factors for the transboundary operative flood forecast systems is the organisation of the *data flow and the data exchange.* A common data basis and *standards*

have to be developed for that. Principally, the international data transfer is more prone to failures due to the many intermediate stations. The data exchange should be *automated*, the *formats compatible* (e.g. time discretisation) and the data basis *reliable*. By the use of *language modules* or previous defined *lists of terms* translation problems can *be reduced*. Actualisations (test runs) for the control of the system have to be made regularly.
To ensure data security and data use *interstate agreements* have to be made. E.g. an expert group of the ICPO is instructed to formulate the respective requirement on transboundary geographic information systems. In terms of a *transparent system* at least the information about data existing at several places should be made available to the *public* by a metadata server.

Reliability and *confidence* in the data of the other country are of foremost importance. In Poland the extreme extent of the Flood 1997 caused the destruction and substantial damaging of several river gauges. The IMGW Wrocław partly broke down as flood information centre because of flooding. However, one strove for the fulfilling of the bilateral duties. The tasks were temporarily taken over by the IMGW Poznań. After the Flood 1997 it became obvious, that on the German side the actions for disaster prevention could have been earlier and more efficiently organised, if the flood centres would have had more confidence in the information coming from Poland.

The *politics* has the *responsibility* to decide, which fields should be developed and improved, which data have to be made available, and how many financial resources should be invested into the development of early flood warning systems. However this requires more transparency between the potential agencies and institutions involved as well as an explicit avowal to such modern instruments. At present, it might be crucial, to improve not only the individual components in the individual countries, but the total system, which means that also aspects lying beyond the own area of operation are taken into account.

8.2.6 Co-ordination of ongoing and planned activities

When looking at the „numerous of projects", which were and are carried out on the topic „flood on the Odra river", it seems rational and necessary to more strongly emphasise possible interfaces and links between the individual projects and models. Thus, *redundancies can be minimised* and *synergetic effects can be created*.

Undoubtedly, the International Commission for Protection of the Odra river (ICPO) will carry the co-ordinating and linking key-function. All riparian countries (Czech Republic, Poland, and Germany) as well as the European Commission are represented within the ICPO. In contrast to the Commissions on Border Water Bodies, where only bilateral negotiations take place, the ICPO comprises the entire river basin. In future the *secretary office of the ICPO in Wrocław*, which unfortunately did not start operating fully until 2000, certainly will play an important role as *information and contact place* for the Odra river basin. For this purpose also the *internet* as public accessible medium should be used by the ICPO.
After the experiences of 1997 the missing working field „flood protection" was included into the ICPO by an own *Working Group Flood*. Within this working group exchanges of regular information about the most important transboundary projects within the field of flood protection on the Odra river take place. At present, an own expert group is preparing a report about the present state of the flood information service within the Odra river basin as well as requirements for the improvement of the system. This works are expected to be published in the middle of 2001.

The simplest and less work intensive activity is the *exchange of experiences*. Thus, experts from Poland, the Czech Republic, and Germany came together to a meeting organised by the German-Polish Commission on Border Water Bodies on the 11. July 2000 in Berlin for talks about the flood forecast models existing in the respective riparian countries of the Odra river basin. Further meetings of this kind, where other projects can be presented and information about new results can be exchanged, should follow.
An important pre-requisite, especially for the actual and future transboundary projects, is that the *„right“ partners are working together*. Already in the phase of application the institutional *structures* of the respective other country have to be adequately taken into consideration. The important Polish institutions – which are responsible for 89 % of the Odra river basin – are integrated as direct partners into the pre-operational orientated ODRAFLOOD-project. For the „European Flood Forecasting System EFFS“ this would be given indirectly by being based on the LISFLOOD model system (Chapter 7.1).
For the operational flood modelling it has to be tested early on which data are available and with which accuracy they can or have to be collected. A lot of hydrological information are not published. Therefore, a direct partnership or a stabile co-operation between the different regional water management institutions is indispensable. Even today some institutions and agencies of the riparian countries partly have a *rejecting* attitude towards to further projects concerning flood forecast and flood management. Reason therefore is that the information need does not appear to be manageable anymore. This attitude aggravates when the use of a project *remains unclear* to them or it seems that the project can *not be integrated* into already existing prospected results of previous projects.

The *relevance* of a new project beyond the already existing projects has to *be presented more transparently by the applicant* and has to be *evaluated more critically* by the funding institutions and organisations. To achieve a better coupling of the different projects, information about the state of development as well as about all important projects on the Odra river should be easier available than up to now, e.g. at a central site in the internet. The language barriers complicate the accessibility of such information. In principle though, it is the duty of the individual project applicant to inform himself about the state of development and to get into contact with other projects, users, and the ICPO. However, on part of the operators and the ICPO the exchange of experience and the *possibilities for co-operation* by means of *seminars*, *symposia* and *provisions of respective information material* should be promoted to a greater extent. Also here transparency is necessary to interconnect more effectively the already achieved work and the future projects.

8.3 Résumé

The presented study attempts to assess the *present* **state** *of the* **operational flood forecast in the Odra river basin**. For that one started with the legal and organisational basis as well as with the hydrological characterisations.

The *general state* of the *monitoring* and *flood forecast systems* is *very heterogeneous* for the individual Odra river sections as well as for the sub-systems.

Derived from the analysis of the flood forecasting systems and from the specific conditions in the Odra basin the central *requirement* is that the existing elements and systems of the flood forecast need not to be developed isolated but stepwise as **integrated components** of an **early flood warning system** (detecting - forecasting - warning - responding).

The installation of an **efficient monitoring system** and a **modular model structure** are included therein. In this conception the **future operators, decision-makers and the users** have to be **integrated**. Experiences and elements of **pre-operational flood forecasting models** have to be used. Generally, there are special requirements in the set-up of a **transboundary co-operation**. Furthermore, there is a high need for **co-ordination** of the current projects, which are related to the development of flood forecasting systems within the Odra river basin.

In detail the list of requirements can be represented as follows:

- ***Efficient monitoring system***
  The *existing monitoring network and data transmission* do not yet universally fulfil the requirements on an efficient monitoring system and have to be *modernised*. For the Upper Odra river a further integration of *meteorological services and products* (e.g. upgrading of the weather radar station, quantitative precipitation forecast, use of numerical weather forecast models) for *the extension of the forecast lead time* is necessary.

- ***Modular model structure***
  Due to the different hydrological conditions, there will be *no universal model*, which can be operationally applied to all situations and for all areas of the river basin. Thus, the flood forecasting system should be *modularly* structured. Main foci should be the use of *rainfall-runoff-models*, the modelling of the *controlling operation of reservoirs and polders* as well as the development of hydrodynamically based *dike breach and urban inundation scenarios*. Furthermore, the respective modules have to be adapted to the improved data basis. Primarily, for the entire Odra river the development of new model types is not that necessary but the reinforced *interlocking of different models and modules*. For sub-catchments (e.g. Lower Odra river), for which no operational flood forecast exist, suitable models based on carriers of regional experiences should be implemented.

- ***Pre-operational models***
  For the Odra river basin one developed and develops different pre-operational flood forecast models as *plannings aids*. They should also be used for the *analysis and conception* of early flood warning systems. With regard to the aspects of *pressure of time*, *transparency*, *robustness* and *limited data availability* their immediate use in case of floods is not reasonable. However, single modules should be *tested and adjusted for the operational use*.

- ***Involvement of future operators, decision-makers and users***
  The extern development of models requires a *close dialogue* with the model operators. New models and modules should use *long-term experiences* of the operators and should be *integrable* into the existing system. Besides this, also the *decision-makers and users* should be involved. To plan and execute effective defence measures, the *required information* from the flood forecast have to be provided in *comprehensive form*.

- ***Transboundary co-operation***
  Since in the near future the implementation of a joint *early flood warning system* for the entire Odra river seems improbable, *interfaces* for the interlocking of different flood forecast and flood information systems of the countries have to be created. This requires an *efficient data and information exchange* between the Czech Republic, Poland and Germany on the basis of respective *interstate agreements*.

- ***Co-ordination***
  To create *synergetic effects*, to *reduce redundancies* and to ensure the *integration into the envisioned early flood warning system*, the improvement of the co-ordination of the numerous „flood-projects" seems necessary. In principle, it is the duty of the individual applicant to *inform himself about the state of development* and to *get into contact with other projects, the operators and decision-makers as well as with the ICPO*. However, the information about completed, current by running and planned projects and measures as well as about the structure of the flood forecast and information system within the individual countries should *be easier accessible than up to now*. A *central place* for information (e.g. ICPO) using the internet, that provides *multi-lingual* the information, would be reasonable.

The **conversion** of the named requirements will be the more successful, the more it is accompanied by the intention to *develop the flood forecast along with the other components of a* **modern early warning system** (detecting – forecasting – *warning – responding*).

Because of the already existing preparations and the long forecast lead times the set-up of such an **early warning system** on the German-Polish **Border Odra** could **have pilot character** for the entire Odra river basin. Both countries together with the EC should have to create the respective *framework conditions* and to provide and open up resources. Based upon these experiences it certainly would be easier to develop and install a *modern and efficient early flood warning system* in the **entire river basin**.

References

BARTH, F. & P. HOMAGK (1992): *Hochwasser-Vorhersage-Zentrale Baden-Württemberg – Konzeption und operationeller Betrieb*. Symposium am 6.11.1992 „Hochwasservorhersage- ein Schlüssel zu effektivem Hochwassermanagement“, Tagungsband LfU Karlsruhe

BERGER, H. E. J. (1991): *Flood forecasting for the river Meuse*. In: Hydrology for the Water Management of Large River Basins (Proceedings of the Vienna Symposium, August 1991). IAHS (International Association of Hydrological Sciences) Publ., No. 201: 317-328.

BFG (1997): Bundesanstalt für Gewässerkunde (BfG): *Das Oderhochwasser 1997*. Bericht für die Arbeitsgruppe „Aktionsplan Oder“ der IKSO. BfG, Berlin, 29.08.1997.

BFG (1998): Bundesanstalt für Gewässerkunde (BfG): *Der Hochwassermeldedienst im Odereinzugsgebiet – unvollständige Materialsammlung*. BfG, Berlin, 1998.

BGR (1997): Bundesanstalt für Geologie und Rohstoffe (BGR): *Risikopotentiale im geologischen Untergrund der Oderdeiche*. BGR, Berlin, October 1997.

BUCHHOLZ, W. (1997): *Analiza przebiegu Powodzi 1997 na dolnej Odrze (Analysing the 1997 flood in the Lower Odra section).* Forum Naukowo-Techniczne, Pówódz 1997, Vol. 2, Ustroń k. Wisły, 10.-12.09.1997: 109-120.

BUCHHOLZ, W. (2000): *Water motion of the Lower Odra river*. MRI Szczecin (unpublished report).

BUREAU (1896): Bureau des Ausschusses zur Untersuchung der Wasserverhältnisse in den der Überschwemmungsgefahr besonders ausgesetzten Flußgebieten (BUREAU): *Der Oderstrom, sein Stromgebiet und seine wichtigsten Nebenflüsse – eine hydrographische, wasserwirtschaftliche und wasserrechtliche Darstellung.*
Band I: Das Stromgebiet und die Gewässer
Band II: Gebietsbeschreibungen der einzelnen Flußgebiete
Band III: Strom- und Flußbeschreibungen der Oder und ihrer wichtigsten Nebenflüsse,
Dietrich Reimer, Geographische Verlagshandlung, Berlin, 1896.

COUNSELL, CH., EL GAMMAL, E. & P. SAMUELS (2000): *Demonstration of a decision support system for assessing the impacts of engineering work and environmental change on flood risk – the Thames catchment study*. In: Bronstert, A., Bismuth, Ch. & L. Menzel [Eds.] (2000): European Conference on Advances in Flood Research. Proceedings Vol. 1; PIK-Report 65, Potsdam, 2000: 87-98.

CUNGE, J.A. (1992): *Real-time flood forecasting: Models, methods & software in hydroinformatics era.* In: Saul, A.J. [Ed.] (1992): Floods and flood management. Kluwer Academic Publishers, Dordrecht, The Netherlands.

CZAMARA, W. & WOJARNIK, K.(1999): *Możliwości poprawy jakości wody retencjonowanej w zbiornikach zaporowych górnej i środkowej Odry* (Influence of water reservoir retention on flood waves in the Upper and Middle Odra). In: Odra i jej Dorzecze - Powódz 1997. Konferencje XXI (TOM 2). Kudowa Zdrój. 7.-9.September 1998, Zeszyty Naukowe – Akademii Rolniczej we Wrocławiu. Nr. 339: 213-222.

DGJ (1986): *Deutsches Gewässerkundliches Jahrbuch, Rheingebiet, Teil III, Abflußjahr 1986.* Landesamt für Wasser und Abfall Nordrhein-Westfalen, Düsseldorf.

DGJ (1989): *Deutsches Gewässerkundliches Jahrbuch, Rheingebiet, Teil I, Abflußjahr 1989.* Landesamt für Umweltschutz Baden-Württemberg, Karlsruhe.

DGJ (1995): *Deutsches Gewässerkundliches Jahrbuch, Elbegebiet, Teil II Abflußjahr 1995.* Landesumweltamt Brandenburg, Potsdam.

DUBICKI, A. & MALINOWSKA-MAŁEK, J. (2000): *Operacyjne wykorzystanie modeli hydrologicznych na Odrze i w jej dorzeczu*. In: Seminar of the German-Polish Border Water Bodies Commission W1 about flood forecast models in the Odra river basin on 11. July 2000 in Berlin.

DUBICKI, A. (1999): *System ostrzegawczo-prognostyczny IMGW dla gornego i srodkowego dorzecza Odry*. In: Tagung Internationales Umweltrecht mit Schwerpunkt Wasser- und Abwasserrecht vom 7.-9.6.1999 in St. Marienthal.

DYCK, S. [Ed.] (1980): *Angewandte Hydrologie. Teil 2. Der Wasserhaushalt der Flußgebiete*. 2. überarbeitete Aufl. Berlin, VEB Verlag für Bauwesen. Berlin, Munich: Verlag W. Ernst & Sohn.

EWS (1998): International IDNDR-Conference on „*Early Warning Systems for the Reduction of Natural Disaster*", Potsdam, 7.-11. September 1998.

FAL, B. (1997): *Powódź tysiąclecia*. Wiedza i życie, 1997, Nr. 10.

FELDMANN, A. D. (1994): *Assessment of forecast technology for flood control operation*. In: Rossi, G. et al. [Eds.]: Coping with Floods. Kluwer Academic Publishers, The Netherlands, 1994: 445-458

FISCHER, K. (1907): *Sommerhochwasser der Oder von 1813 bis 1903.* Jahrbuch für die Gewässerkunde Norddeutschlands, Besondere Mitteilungen Bd. 1 Nr. 6, Berlin.

FREYDANK, E. (1986): *Berechnung und Prognose der Eisverhältnisse auf der Oder*. Abhandlungen des Meteorologischen Dienstes der DDR, Nr. 135 (Band XVIII), Akademie-Verlag Berlin 1986.

FRÖHLICH, W. (1998): *Water-level forecast for the river Elbe in Germany with the ELBA-System*. In: Czech Hydrometeorological Institute [Ed.] (1998): Workshop on Flood Forecasting, Prag, 4.-5. May 1998: 89-96.

FRÜHWALD, D. (1999): *Quantitative Niederschlagsvorhersage mit numerischen Modellen – Gegenwärtiger Stand und zukünftige Entwicklung im Deutschen Wetterdienst.* In: Hydrologische Dynamik im Rheingebiet. Deutsches Nationalkomitee für das IHP/OHP, Koblenz, Berichte Heft 13: 193-204.

FÜGNER, D. (1995): *Hochwasserkatastrophen in Sachsen.* Tauchaer Verlag, Taucha.

GALLOWAY JR., G. E. (2000): *Transboundary flood management: the case of the Red River of the North United States and Canada*. In: Bronstert, A., Bismuth, Ch. & L. Menzel [Eds.]: European Conference on Advances in Flood Research. Proceedings Vol. 1; PIK-Report 65: 582-591, Potsdam, 2000.

GKSS & PARTNERS (1999): BMBF-Projektantrag *Simulation von Hochwasser im Einzugsgebiet der Oder mit einem gekoppelten Modellsystem*. GKSS Geesthacht, IMGW Wroclaw, MRI Szczecin, DLR Cologne, 1999.

GRÜNEWALD, U. et al. (1998): *Ursachen, Verlauf und Folgen des Sommer-Hochwassers 1997 an der Oder sowie Aussagen zu bestehenden Risikopotentialen. Eine interdisziplinäre Studie*. Deutsche IDNDR (International Decade for Natural Desaster Reduction) – Komitee für Katastrophenvorbeugung e. V., Heft 10a (Short version), Heft 10b (Long version), Heft 10e (English version), -Serie No. 10, Bonn 1998.

GRÜNEWALD, U. & SCHÜMBERG, S. (2000): *Das Oderhochwasser 1997 – Ursachen, Verlauf, Schlußfolgerungen und historischer Vergleich*. In: Erfurter Geographische Studien Band 9 (in press).

GRÜNEWALD, U. (1995): *Rappoteursbericht zum Themenbereich Landnutzung und Versiegelung.* In: Hochwasser in Deutschland unter den Aspekten globaler Veränderungen. Bericht über das DFG/IDNDR-Rundgespräch am 09. October 1995 in Potsdam, PIK-Report No. 17: 37-45.

GRÜNEWALD, U. (2000)*: Hochwasserschutz, Hochwasservorhersage im unteren Teil der Grenzoder*. In: Linde, H. [Ed.]: Drittes Internationales Oder-Colloquium. Wirtschaft, Schifffahrt und Ökologie im Unteren Odertal. Colloquiums-Bericht. Schwedt/Oder 20. August 1999. Verein zur Förderung des Oderstromgebietes e. V. Berlin, January 2000.

GÜNTHER, TH. (1998): *Operational estimation of areal precipitation and real time forecast of snow cover development/meltwater release (model systems BONIE and SNOW-D).* In: Czech Hydrometeorological Institute [Ed.] (1998): Workshop on Flood Forecasting, Prague, 4.-5. May 1998: 43-52.

GÜNTHER, TH. (1999): *Verfahren zur operationellen Abschätzung von Gebietsniederschlägen und zur Vorhersage der Schneeschmelze.* In: Materialienband zum Workshop Hydrometeorologie an der Brandenburgisch-Technischen Universität Cottbus, 25.-26.02.1999: 110-123.

HAD (2000): *Hydrologischer Atlas von Deutschland (HAD).* Herausgegeben vom Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit; Projektleitung Bundesanstalt für Gewässerkunde, Institut für Hydrologie der Universität Freiburg. Berlin, 2000.

HAGGETT, C. (1998): *An integrated approach to flood forecasting and warning in England and Wales*. Journal of the Chartered Institution of Water and Environmental Management 12(6): 425-432.

HANDMER, J., KEYS, C. & J. ELLIOTT, J. (1999): *Achieving lasting change in multi-organizational tasks: the case of flood warnings in Australia.* Applied Geography 19: 179-197.

HOMAGK, P. & M. MOSER (1998): *Verbesserung von Hochwasservorhersagen durch hydrometeorologische Daten Teil II: Möglichkeiten und Verbesserungen von Hochwasservorhersagen durch die Einbeziehung von hydrometeorologischen Daten und Produkten.* DGM 42 (1): 23-27.

HOŠEK, A. (1998): *The present possibilities towards improving the forecasting flood service in the Czech part of the Upper Odra river catchment. (Aktualne możliwości usprawnienia prognoz powodziowych w Czeskiej części dorzecza górnej Odry*). In: Odra i jej Dorzecze - Powódz 1997. Konferencje XXI. Kudowa Zdrój. 7. – 9. September 1998, Zeszyty Naukowe - Akademii Rolniczej we Wrocławiu. Nr. 339: 35-40.

HOŠEK, A. (2000): *Hlásná a předpovědní povodnová služba v česke části povodí Odry.* Information material for this study. ČHMÚ Ostrava.

HÜTTL, R. F. (2000): *DFNK Forschungsschwerpunkt Brandenburg*. Vortrag auf dem ersten Forum Katastrophenvorsorge „Extreme Naturereignisse und Vulnerabilität" des DFNK (Deutschen Komitee für Katastrophenvorsorge e. V.) 29.-30. September 2000 in Freiburg i. Brsg.

IKSE (1998): International Commission for the Protection of the Elbe river (IKSE): *Strategie zum Hochwasserschutz im Einzugsgebiet der Elbe*. IKSE, Magdeburg, October 1998.

IKSMS (1999): International Commission for the Protection of the Moselle and Saar rivers (IKSMS): *Aktionsplan Hochwasser im Einzugsgebiet von Mosel und Saar*. IKSMS, Trier, January 1999.

IKSO (1999): International Commission of the Protection of the Odra river (IKSO): *Das Oderhochwasser 1997.* Report of the Working Group Flood of the IKSO, Wrocław 1999.

IKSO (2000): International Commission for the Protection of the Odra river (IKSO): *Gemeinsame Strategie und Grundsätze zum Aktionsplan Hochwasserschutz im Einzugsgebiet der Oder.* IKSO Arbeitsgruppe Hochwasser, Wrocław, December 2000.

IKSR (1997): International Commission for the Protection of the Rhine river (IKSR): *Hochwasserschutz am Rhein – Bestandsaufnahme.* Bericht der Projektgruppe Aktionsplan Hochwasser IKSR, Koblenz, March 1997.

IKSR (1998): International Commission for the Protection of the Rhine river (IKSR): *Aktionsplan Hochwasser*. Projektgruppe Aktionsplan Hochwasserschutz IKSR, Koblenz, March 1998.

IMGW (1975): Institute of Meteorology and Water Management (IMGW), Authors collective: *Powódź w sierpniu 1972r*. Monografia, WKiŁ Warszawa, 1975.

IMGW (1983): Institute of Meteorology and Water Management (IMGW): *Podział hydrograficzny Polski*. Warszawa, 1983.

IMGW (1999): Institute of Meteorology and Water Management (IMGW): *System Monitoringu i Osłony Kraju (SMOK)*. IMGW, Warszawa 1999.

IMGW (2000 a): Institute of Meteorology and Water Management (IMGW): *Final report about Sobek model - Upper and Middle Odra river (from Malczyce to Nowa Sol)*. ARCADIS Heidemij Advies / WL|delft hydraulics. IMGW, Wrocław, 2000.

IMGW (2000 b): Institute of Meteorology and Water Management (IMGW): *Information material about the application of MIKE 11 at the IMGW Wrocław* as supplement for this study. IMGW, Wrocław, 2000.

IMGW (2000): Institute of Meteorology and Water Management (IMGW): *System osłony powodziowej w Polsce*. Material IMGW Wrocław, 2000.

INGRAM, J. (1997): *Lessons taught by floods in the United States of America.* In: Deutsches IHP/OHP-Nationalkomitee, River Flood Disasters, ICSU SC/IDNDR Workshop, Koblenz, Germany 1996. IHP/OHP-Berichte Sonderheft 10: 5-12.

JAHRBUCH DER SCHIFFAHRT 1964 - Ein Rundblick über die internationale See- und Binnenschiffahrt (1965): *Eisbekämpfung auf der Oder*. Ministerium für Verkehrswesen, Hauptverwaltung der Schiffahrt, Berlin, 1965: 111-116.

KIMLOVÁ, M. (1999): *Využití systému RAMAP pro předpovědi extrémních hydrologických jevu. (Utilisation of the RAMAP system to forecast extreme hydrological events)*. In: Proceedings of Workshop 99 „Extreme hydrological events in catchments", 25. October 1999, Reg. Nr. 103/99/1470, Prague. Czech Technical University in Prague, Faculty of Civil Engineering and the Czech Scientific and Technical Society of Water Engineers.

KINKOR, J. (2000): *Flood protection in the Czech Republic*. Discussion paper for the UN/ECE-Seminar on Flood prevention and protection, Berlin 7.-8. October 1999. Proceedings of a UN/ECE Seminar on Sustainable Flood Prevention, UN, Geneva, March 2000.

KOWALCZAK, P. (1998): *Flood 1997 - hydrological and meteorological context*. In: Bronstert, A. Ghazi, A., Hladný, J., Kundzewicz, Z. & L. Menzel [Eds.]: The Odra/Oder Flood in Summer 1997. Proceedings of the European expert meeting in Potsdam, 18. May 1998. Potsdam, PIK-Report 48: 53-60.

KOWALCZAK, P. (2000): Information material for this study. IMGW Poznań.

KRAMER, M., BRAUWEILER, CH., JANSSEN, G., DUBICKI, A., WOZNIAK, Z., ROTKO, J., DAMOHORSKY, M. & V. STEJSKAL (2000): *Nationale und internationale juristische Regelungen des Hochwasserschutzes der Oder – Ein trinationaler Rechtsvergleich der Oder-Anliegerstaaten Deutschland, Polen und Tschechien.* Internationales Hochschulinstitut Zittau, Institut für Ökologische Raumentwicklung Dresden, Instytut Meteorologii i Gospodarki Wodnej Wrocław, Towarzystwo Prawa Ochrony Srodowiska Wrocław, Karls-University Prague im Auftrag des Umweltbundesamtes Berlin; June 2000.

KUBÁT, J. (1998): *Flood forecasting and warning services in the Czech Republic*. In: Czech Hydrometeorological Institute [Ed.] (1998): Workshop on Flood Forecasting, Prague, 4.-5. May 1998: 143-148.

KUBÁT, J. (1999): *Společené ukoly meteorologické a hydrologické služby českého hydrometeorologicického ustavu*. (*Joint aims of meteorological and hydrological services of the Czech Hydrometeorological Institute)*. Meteorologické Zprávy (Meteorological Bulletin) Vol. 52 (6) (http: //www.chmi.cz-/reditel/sis/metzpr/mz526kub.html)

KUBÁT, J. (2000 a): *Flood Forecasting in the Czech Republic*. Discussion paper for the UN/ECE-Seminar on Flood prevention and protection, Berlin 7-8 October 1999. Proceedings of a UN/ECE Seminar on Sustainable Flood Prevention, UN, Geneva, March 2000.

KUBÁT, J. (2000): *1997/1998 floods in the Czech Republic: Hydrological evaluation*. In: Marsalek, J., Watt, W. E., Zeman, E. & F. Sieker [Eds.] (2000): Flood issues in contemporary water management, Proceedings of the NATO Advanced Research Workshop on Coping with Flash Floods: Lessons learned from recent experience. 16.-21. May 1999 Malenovice, CZ, Kluwer, Dordrecht, Boston, London, 2000, Nato Science Series 2: Environment Security Vol. 71: 25-40.

KUNDZEWICZ, Z.W., SZAMAŁEK, K. & P. KOWALCZAK (1999): *The Great Flood of 1997 in Poland*. Hydrological Sciences Journal 44 (6): 855-870.

LAWA (1993): Länderarbeitsgemeinschaft Wasser (LAWA): *Vergleichende Übersicht über den gegenwärtigen Stand des Hochwassermeldedienstes in Deutschland*. Statusbericht ausgearbeitet vom LAWA-ad hoc-Arbeitskreis „Hochwasservorhersagen", State 07/1993.

LfUG (2000): Sächsisches Landesamt für Umwelt und Geologie (LfUG): *Organisation des Hochwassernach-richtendienstes im Freistaat Sachsen.* Übersicht, Stand 02/99, Working material of LfUG, Dresden.

LPB (1996): Landeszentrale für politische Bildung Baden-Württemberg (LPB): *Die Oder.* Deutschland und Europa, Ausgabe 2/96 Heft 33, LpB 1996.

LUA (1994): Landesumweltamt Brandenburg (LUA): *Eine Zusammenfassung, Auswertung und Bewertung des vorhandenen Informationsmaterials über die Oder und ihre deutschen Nebenflüsse*. Fachbeiträge des Landesumweltamtes, Potsdam, 1994.

LUA (1995): Landesumweltamt Brandenburg (LUA): *Hochwasserschutz in Brandenburg – Handbuch für die Hochwasserabwehr an Gewässern und Deichen im Lande Brandenburg.* Potsdam, October 1995.

LUA (1997 a): Landesumweltamt Brandenburg (LUA): *Die Oderdeiche sind wieder dicht.* Brandenburger Umweltjournal Dezember 1997 Heft 25: 25-26.

LUA (1997): Landesumweltamt Brandenburg (LUA): Jahres-HQ Werte der Pegel Eisenhüttenstadt und Hohensaaten-Finow, Datenübergabe, Nov. 1997.

LUA (1998): Landesumweltamt Brandenburg (LUA): *Das Sommerhochwasser an der Oder 1997.* Fachbeiträge anläßlich der Brandenburger Ökologietage II; Studien und Tagungsberichte Band 16, March 1998.

MALINOWSKA-MAŁEK, J. & A. DUBICKI, A. (2000): *Współpraca w zakresie osłony hydrologicznej między Rzeczypospolitą Polską i Republiką Czeską*. Informationsmaterial für diese Studie, IMGW Wrocław, 2000.

MAŁKIEWICZ, T. & S. BARTOSIEWICZ (1997): *Stan obiektów i urządzeń hydrotechnicznych drogi wodnej Odry.* Międzynarodowa konferencja „Odra – szanse i wyzwania w świetle doświadczeń europejskich (International conference „Odra river – development opportunities and challenges from the European perspective"), Wrocław 4-5 XI 1997.

MIERKIEWICZ, M. (1993): *Hydrologiczne modele prognostyczne opad-odpływ i transformacji fali dla ważniejszych dopływów Odry*. Wiadomości. Tom XVI (XXXVII) Zeszyt 4: 37-53.

MLUR (1999): Brandenburgische Ministerium für Landwirtschaft, Umweltschutz und Raumordnung (MLUR): „*Zeitplan bei Erneuerung der Oderdeiche wird eingehalten*“. Press release on 29. June 1999, MLUR, Potsdam, 1999.

MORGENSCHWEIS, G., GÖPPERT, H.G., IHRINGER, J., E. J. PLATE (1996): *Hochwasservorhersage zur adaptiven Steuerung von Talsperren im Einzugsgebiet der Ruhr*. Deutsche Gewässerkundliche Mitteilungen DGM 40 (6): 234-243.

MÜNCHNER RÜCK. (1997) Münchener Rückversicherungs-Gesellschaft: *Überschwemmung und Versicherung*. Veröffentlichung, Munich 1997

NALBERCZYNSKI, A. (1999): *The general flood protection strategy for the Upper and Middle Odra river basin after the great flood of July 1997.* Discussion paper for the UN/ECE-Seminar on Flood prevention and protection, Berlin 7.-8. October 1999. Proceedings of a UN/ECE Seminar on Sustainable Flood Prevention, UN, Geneva, March 2000.

OPPERMANN, R., GLOS, E. & J. ILSE (1991): *Wasserstandsvorhersage für die Grenzoder mit dem Programmsystem HYDRA*. Deutsche Gewässerkundlichen Mittelungen DGM, 35 (2): 52-57.

PARKER et al. (1994): *Real-time hazard management: flood forecasting, warning and response.* In: Penning-Rowsell, E. C. & M. Fordham [Ed.] (1994): Floods across Europe. Hazard assessment, modelling and management. Middlesex University Press, London 1994: 135-166.

PLATE, E.J. (1997): *Vorhersage von Abflüssen in der Hydrologie*. In: Schmitz G.H. [Ed.] (1997): Modellierung in der Hydrologie. Symposium aus Anlaß des 30-jährigen Bestehens der Dresdner Schule der Hydrologie vom 22.-24. September 1997, Dresden. Technische Universität Dresden, Tagungsband: 15-27.

PLATTE, P. (2000): *Konzept zur Katastrophenprävention nach der IDNDR-Dekade*. Arbeitsmaterial zur Sitzung des Wissenschaftlichen Beirates des Deutschen Komitees für Katastrophenvorsorge e.V., 05.12.2000, Bonn.

POVODÍ ODRY (1999): *Retention function of dams within water system*. Information broschure, Ostrava, CZ.

POVODÍ ODRY (2000): *Flood forecasting and control using the HYDROG system*. Brochure of Povodí Odry, Ostrava, CZ.

PRITCHARD, V. (1996): *The new flood warning system*. In: Proceedings of the Institution of Civil Engineers-Muncipal Engineer 1996. Vol.115, Iss.1: 20-27.

RADCZUK, L. (1997): Supplement to the study of Grünewald, U. et al. (1998): Ursachen, Verlauf und Folgen des Sommer-Hochwassers 1997 an der Oder sowie Aussagen zu bestehenden Risikopotentialen. Deutsche IDNDR-Reihe 10b, Bonn, April 1998.

REFSGAARD, J. C. & K. HAVNØ (1997): *New developments in modelling, framework for decision support*. In: Ribamod – River basin modelling, management and flood mitigation – Concerted action. Proceedings of the first expert meeting Copenhagen, 10.-11. October 1996, European Commission: 73-88.

ŘIČICOVÁ, P. (1999): *Metody a modely hydrologických prognóz ve vztahu k extrémním hydrologickým jevum.* (Methods and Models for hydrological predictions in relation to extreme hydrological events). In: Proceedings of Workshop 99 „Extreme Hydrological events in catchments“, 25. October 1999, Reg. Nr. 103/99/1470, Prag. Czech Technical University in Prague, Faculty of Civil Engineering and the Czech Scientific and Technical Society of Water Engineers.

RUHE, C., WARRACH, K., LOBMEYR, M. & H.-T. MENGELKAMP (1999): *Distributed hydrological modelling over the Odra drainage basin*. In: Proceedings of the 14th Conference on Hydrology, American Meteorological Society. 10.-15. January 1999, Dallas, Texas.

RZGW (1998): *Generalstrategie für den Hochwasserschutz im Einzugsgebiet der Oberen und Mittleren Oder nach dem Juli-Hochwasser 1997.* Regional Water Management Authority Wrocław. Translation from Polish text, Wrocław 1998.

ŠÁLEK, M. (1998 a): *Meteorological causes of the floods in July 1997 in the Czech Republic*. In: Bronstert, A. Ghazi, A., Hladný, J., Kundzewicz, Z. & L. Menzel [Eds.]: The Odra/Oder Flood in Summer 1997. Proceedings of the European Expert Meeting in Potsdam, 18. May 1998. Potsdam, PIK-Report 48: 53-60.

ŠÁLEK, M. (1998): *The use of remote sensing methods at the flood events in July 1997*. In: Czech Hydrometeorological Institute [Ed.]: Workshop on Flood Forecasting, Prague, 4.-5. May 1998: 43-52.

SAMUELS, P.G (1998): *An overview of the activities of RIBAMOD.* In: Bronstert, A. Ghazi, A., Hladný, J., Kundzewicz, Z. & L. Menzel [Eds.]: The Odra/Oder Flood in Summer 1997. Proceedings of the European expert meeting in Potsdam, 18. Mai 1998. Potsdam, PIK-Report 48: 151-160.

SCHÄDLER, B. & B. PARMET (1999): *Die internationalen Anstrengungen zum Ausbau der Wasserstands- und Durchflußvorhersagen im Rheingebiet*. In: Hydrologische Dynamik im Rheingebiet. Deutsches Nationalkomitee für das IHP/OHP, Koblenz, Berichte Heft 13: 205-213.

SCHÄDLER, B. (2000): *Rechtzeitige Hochwasserwarnung und Verlängerung der Vorhersage als Mittel zur Schadensverminderung.* 3. Rhein-Symposium Ökologie und Hochwasservorsorge, 15.-17. June 2000, Cologne, IKSR (in preparation).

SCHAFFERNAK, F. (1935): *Hydrographie*. Akademische Druck- und Verlagsanstalt, Graz, 24. unveränderte Auflage, 1960.

SCHMITT, A. (2000): *Länderübergreifendes Hochwassermanagement im Oder-Einzugsgebiet – Projektergebnisse.* Abschlussbericht im Rahmen des Stiftungskollegs für internationale Aufgaben 1999/2000 der Robert Bosch Stiftung GmbH, October 2000.

SMU (1998): Sächsisches Staatsministerium für Umwelt und Landesentwicklung (SMU): *Hochwasserschutz in Sachsen*. Materialien zur Wasserwirtschaft 1/1998, Dresden, November 1998.

SOCHOREC, R. (1997): *Hydrologické aspekty povodňové situace v povodi odry v červenci 1997.* ICID – CIID: Provodně a krajina 97` - sbornik přednášek, Brno.

STARY, M., SEBLOVA, H. & B. TURECEK (1998): *The operative control of the passage of floods*. In: Babovic & Larsen [Eds.]: Hydroinformatics '98 Rotterdam, Balkema, 1998: 831-836.

STEINEBACH, G. (2000): *Wasserstandsvorhersage für die Oder*. Hydrologie und Wasserbewirtschaftung 44 (2): 96-97.

STROŃSKA, K., BOROWICZ, A., KITOWSKI, K., MICHALIK, G., JØRGENSEN, G., VAN KALKEN, T. & M. BUTTS (1999): *MIKE 11 as flood management and flood forecasting tool for the Odra River, Poland*. 3rd DHI Software Conference, Helsingør, June 1999.

TADEUSZEWSKI, B. (2000): *Wpływ polderu Słonsk na przebieg wysokich stanów wody na Odrze poniеżej ujścia Warty*. In: Seminar of the German-Polish Border Water Bodies Commission W1 about flood forecast models in the Odra river basin on 11. July 2000 in Berlin.

THIELE, W. & M. BÜTTNER (1999): *Hochwasservorhersagemodell für die Lausitzer Neiße.* Commentary report on behalf of the Sächsischen Landesamtes für Umwelt und Geologie (Saxon Agency for Environment and Geology), Erfurt, 1999.

TODINI, E. (1992): *From real-time flood forecasting to comprehensive flood risk management decision support systems.* In: Saul, A.J. [Ed.] (1992): Floods and Flood Management. Kluwer Academic Publishers, Dordrecht, The Netherlands, 1992: 313-326.

TRÖMEL H.-P. (1997): *22. März 1947 – Bruch des Oderdeiches bei Reitwein*. Brochure published by Landkreis (District) Märkisch-Oderland.

UHLEMANN, H.-J. (1999): *Historisches vom Strom – Die Oder – ihre Entwicklung vom Natur – zum schiffbaren Strom*. Band XVII. Verlag Dr. Neufang KG, Gelsenkirchen, 1999.

UN/ECE (2000): UN/ECE-Seminar on Flood prevention and protection, Berlin 7.-8. October 1999. Proceedings of a UN/ECE Seminar on Sustainable Flood Prevention, UN, Geneva, March 2000.

UN/ECE (2000 a): *Guidelines on sustainable flood prevention.* (as adopted by the Parties to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes at their second meeting), The Hague, Netherlands, 23.-25. March 2000. UN Geneva, September 2000.

WKP (1997): *Materiały Wojewódzkiego Komitetu Przeciwpowodziowego w Legnicy, we Wrocławiu i w Zielonej Górze* (Material of the der Voivodship Flood Committees in Legnica, Wrocław and Zielona Góra) to the Flood 1997.

ZALESKI, J. (1998): *Programme assumptions for modernisation of the Oder Water System, Programme ODRA 2006.* Wrocław, June 1998.

Abbreviation index

Abbreviation/ Abkürzung	Country/ Land	English/ Englisch	German/ Deutsch	Polish/ Polnisch	Czech/ Tschechisch
AHPS	USA	National Weather Service Advanced Hydrologic Prediction System	Verbessertes hydrologisches Vorhersagesystem des Nationalen Wetterdienstes		
BfG	D	Federal Institute of Hydrology	Bundesanstalt für Gewässerkunde		
BMBF	D	Federal Ministry of Science and Technology	Bundesministerium für Bildung und Forschung		
BMU	D	Federal Ministry of Environment Protection	Bundesministerium für Umweltschutz (Bundesumwelt-ministerium)		
BSH	D	Federal Maritime and Hydrographic Agency Rostock	Bundesamt für Seeschiffahrt und Hydrographie Rostock		
BTU Cottbus	D	Brandenburg Technical University Cottbus	Brandenburgische Technische Universität Cottbus		
ČHMÚ	CZ	Czech Hydro-meteorological Institute	Tschechischer hydrometeorologischer Dienst		Český hydrometeorolo-gický ústav
DFNK	D	German Research Network Natural Disasters	Deutsches Forschungsnetz Naturkatastrophen		
DHI	DK	Danish Hydraulic Institute	Dänisches Hydraulisches Institut		
DKKV	D	German Committee for Disaster Reduction within the International Strategy for Disaster Reduction (ISDR)	Deutsches Komitee für Katastrophenvorsorge e. V.		
DLR	D	German Aerospace Centre	Deutsches Zentrum für Luft- und Raumfahrt e. V.		
DWD	D	German Meteorological Service	Deutscher Wetterdienst		
ECE	UN	Economic Commission for Europe	Europäische Wirtschaftskommission		
EEA	EU	European Environment Agency	Europäische Umweltbehörde		
FAO	UN	Food and Agriculture Organisation of the United Nations			
GKSS	D	GKSS Research Centre Geesthacht	GKSS Forschungszentrum Geesthacht		
IDNDR	UN	International Decade for Natural Disaster Reduction	Internationale Dekade zur Katastrophenvorsorge		
IGB	D	Institute of Freshwater Ecology and Inland Fisheries, Berlin	Institut für Gewässerökologie und Binnenfischerei, Berlin		

IKSE	CZ, D	International Commission for the Protection of the River Elbe	Internationale Kommission zum Schutz der Elbe		Mezinárodní Komise pro Ochranu Labe (MKOL)
IKSMS	D, F, L	International Commission for Protection of the River Moselle and Saar	Internationale Kommission zum Schutz von Mosel und Saar		
IKSO	D, PL, CZ, EU	International Commission for the Protection of the River Odra	Internationale Kommission zum Schutz der Oder	Międzinarodowy Komisja Ochrony Odry (MKOO)	Mezinárodní Komise pro Ochranu Odry (MKOO)
IKSR	D, F, CH, NL, L, EU	International Commission for Protection of the Rhine	Internationale Kommission zum Schutz des Rheins		
IMGW	PL	Institute of Meteorology and Water Management	Institut für Meteorologie und Wasserwirtschaft	Instytut Meteorologii i Gospodarki Wodnej	
JRC	EU	Joint Research Centre of the EU	Gemeinsame Forschungsstelle der EU		
LfUG	D	Saxon Agency for Environment and Geology	Sächsisches Landesamt für Umwelt und Geologie		
LUA	D-BB	Environmental Agency Brandenburg	Landesumweltamt Brandenburg		
MLUR	D-BB	Brandenburgian Ministry of Agriculture, Environmental Protection and Spatial Planning	Brandenburgisches Ministerium für Landwirtschaft, Umweltschutz und Raumordnung		
MRI	PL	Maritime Research Institute, Szczecin	Institut für Gewässerforschung Stettin	Instytut Morski Szczecin	
NWS	USA	National Weather Service	Nationaler Wetterdienst		
PHARE CBC	EU	launched in 1989 it is currently the main programme for the European Union's financial and technical co-operation with the countries of central and eastern Europe (http://europa.eu.int/comm/enlargement/pas/phare/index.htm)	seit 1989 das zur Zeit wichtigste Programm für finanzielle und technische Kooperation mit den Mittel- und Osteuropäischen Ländern		
PIK	D	Potsdam Institute for Climate Impact Research	Potsdam-Institut für Klimafolgenforschung		
Povodí	CZ	River Basin Authority	Flussgebietsverwaltung		Povodí akciová spoleěnost
RIZA	NL	Institute of Inland Water Management and Waste Water Treatment	Institut für Binnenwasserwirtschaft und Abwasserbehandlung		
RZGW	PL	Regional Water Management Authority	Regionales Wasserwirtschaftsamt	Regionalny Zarząd Gospodarki Wodnej	
SAI	EU	Space Application Institute			

SMOK	PL	System for Automation of Measurements and Monitoring Stations	System zur Automatisierung der Mess- und Monitoringstationen	System monitoringu i osłony kraju	
SMU	D-SA	Saxon Ministry for Environmental Protection	Sächsisches Ministerium für Umweltschutz		
StUFA	D	Environmental State Agencies, Saxony	Staatliche Umweltfachämter, Sachsen		
UBG	D	Technical State Agency for Environment, Saxony	Staatliche Umweltbetriebsgesell-schaft, Sachsen		
UN		United Nations	Vereinte Nationen		
VHD Povodí	CZ	Water Management Centre of the River Basin Authority	Wasserwirtschaftliche Steuerungszentrale der Flussgebietsverwaltung		Vodohospodářský dispečink Povodí a. s.
WASY	D	Institute for Water Resources Planning and System Research ltd.	Gesellschaft für Wasserwirtschaftliche Planung und Systemforschung mbH		
WMO	UN	World Meteorological Organisation			
WSA	D	Federal Waterway and Navigation Administration	Wasser- und Schifffahrtsamt Eberswalde		
WSD Ost	D	Federal Waterway and Navigation Authority East	Wasser- und Schifffahrtsdirektion Ost		
WWF		World Wide Fund for Nature			
ZALF	D	Centre for Agricultural Landscape and Land Use Research Müncheberg	Zentrum für Agrarlandschafts- und Landnutzungsforschung Müncheberg		

model	description
ALADIN	Numerical Meteorological Weather Model, France
ARC/EGMO	Mesoscale Water Catchment Model, PIK
ARCHE	Urban Inundation Model, DLR
BONIEOP	Operative Areal Precipitation Model, DWD Offenbach
EFFS	European Flood Forecasting System
FLORIJN	Flood Forecast Model for Rhine river sections on the basis of SOBEK
GESIMA	Geesthacht Simulation Model of the Atmosphere Non-Hydrostatic Simulation Model, GKSS Geesthacht
HBV	Operational Flood Forecast and Flood Management Model, Swedish Institute of Meteorology and Hydrology
HYDROG	Model System for Simulation and Operative Controlling of the Water Management Structures, Povodí Odry, Czech Republic
LAM	Local Area Model; Numerical Meteorological Weather Model, Bracknell (Great Britain)
Deutschland-Model	Numerical Meteorological Weather Model for Germany, DWD Offenbach
EUROPA-Model	Numerical Meteorological Weather Model for Europe, DWD Offenbach
MIKE 11	Operational flood forecast and flood management model, Denmark
R-R-model	Rainfall-runoff-model
SEROS	Surface Energy and Routing System, coupling of SEWAB and routing scheme, GKSS Geesthacht
SEWAB	Surface Energy and Water Balance, land surface scheme, GKSS Geesthacht
SNOW-D	Model for the Calculation of gridbased data of the water equivalent regarding the water release of the snow cover and the acutal precipitation events, DWD Offenbach
SOBEK	Hydrodynamic Model, the Netherlands, (developed by WL | Delft Hydraulics and RIZA)
TOPMODEL	Rainfall-Runoff-Model with Topographic Index
TRIM	Hydrodynamic Model, GKSS Geesthacht
UMPL	Unified Model Poland, numerical meteorological weather model, University Warsaw
WaterGAP	Makroscale Water Model for Simulation of Climate and Land Use Changes, University of Kassel

Appendix

Tab. 16: Important names in Polish, Czech and German language

Polish	Czech	German
waters		
Biała Głuchołaska	Bělá	Biele
Bóbr		Bober
Morze Bałtyckie		Ostsee
Nysa Kłodzka		Glatzer Neiße
Nysa Łużycka	Lužická Nisa	Lausitzer Neiße
Odra	Odra	Oder
Olza	Olše	Olsa
Opawa	Opava	Oppa
Ścinawka	Stěnava	Steine
Warta		Warthe
Witka	Smědá	
Zalew Szczeciński		Stettiner Haff
Zatoka Pomorska		Pommersche Bucht
geographical names		
Beskidy		Beskiden
Brama Łużycka	Lužicka Brána	Lausitzer Pforte
Brama Morawska	Moravská Brána	Mährische Pforte
Góry Odrzańskie	Oderské Vrchy	Odergebirge
Moravska Beskidy	Moravskoslezské Beskydy	Mährische Beskiden
Pradziad	Praděd	Altvater
Śnieżka	Snėžka	Schneekoppe
Sudety		Sudeten
cities		
Bielinek		Bellinchen
Bohumín	Bohumín	Oderberg
Gorzów/Wlkp.		Landsberg
Gozdowice		Güstebiese
Gryfino		Greifenhagen
Jelenia Góra		Hirschberg
Katowice		Kattowitz
Kłodzko		Glatz
Kostrzyn		Küstrin
Opole		Oppeln
Ostrava	Ostrava	Mährisch Ostrau
Poznań		Posen
Praga	Praha	Prag
Szczecin		Stettin
Warszawa		Warschau
Widuchowa		Fiddichow
Wrocław		Breslau
Zielona Góra		Grünberg

Tab. 17: Important Odra river gauges in Poland, the Czech Republic, and Germany

Polish river gauges on the Odra river

river gauge	kilometer site*	drainage area [km²]	rise in area [km²]	important tributaries
Chałupki (Annaberg)	20.7	4 666.2		
Krzyżanowice (Kreuzenort)	33.6	5 874.8	1 208.6	Olza
Racibórz-Miedonia (Ratibor)	55.5	6 744.0	2 077.8	Psina
Koźle (Kosel)	97.2	9 173.6	2 429.6	Kłodnica
Krapkowice (Krappitz)	124.7	10 720.6	1 547.0	Osobłoga
Opole (Oppeln)	152.2	10 989.2	268.6	
Ujście Nysy (Neißemündung)	180.6	13 454.9	2 465.7	Mała Panew
Brzeg Most (Brieg-Brücke)	199.1	19 731.6	6 276.7	Nysa Kłodzka
Oława Most (Ohlau-Brücke)	216.5	19 981.1	249.5	
Trestno (Treschen)	242.1	20 561.2	580.1	
Brzeg Dolny (Dyhernfurth)	284.7	26 428.0	5 866.8	Oława, Ślęża,
Malczyce (Maltsch)	304.8	26 812.4	384.4	Bystrzyca, Widawa
Ścinawa (Steinau)	331.9	29 583.8	2 771.4	Kaczawa
Głogów (Glogau)	392.9	36 393.8	6 810.0	Barycz
Nowa Sól (Neusalz)	429.8	36 780.3	386.5	
Cigacice (Tschicherzig)	470.7	39 887.6	3 107.3	
Nietków (Nettkow)	490.5	40 396.7	509.1	
Połęcko (Pollenzig)	530.6	47 152.0	6 755.3	Bóbr
Słubice (Dammvorstadt)	584.1	53 382.0	6 230.0	Nysa Łużycka
Gozdowice (Güstebiese)	645.3	109 729.1	56 347.1	Warta
Widuchowa (Fiddichow)	701.8	110 524.3	795.2	

Source: IMGW, 1983

* *Beginning of kilometer counting at the mouth of the Opava (Oppa) river*

Czech river gauges on the Odra river and its tributaries

river gauge	river	drainage area [km²]
Svinov	Oder	1 615.1
Opava	Opava	929.6
Branka	Moravice	716.3
Děhylov	Opava	2 039.1
Ostrava	Ostravice	822.7
Bohumín	Oder	4 662.3
Věřňovice	Olše	1 068.0
Jesenik	Bělá	116.9

Source: SOCHOREC, 1997

German river gauges on the Odra river

river gauge	site on the river [km]*	drainage area [km²]
Eisenhüttenstadt	554.1	52 033
Frankfurt (Oder)	584.0	53 580
Kietz	614.8	53 752
Kienitz	633.0	109 093
Hohensaaten-Finow	664.9	109 564
Stützkow	680.5	112 143
Schwedt	690.6	112 950
Gartz/Westoder	8.0	113 910

Source: BFG, 1997

* *Beginning of kilometer counting at the mouth of the Opava (Oppa) river*

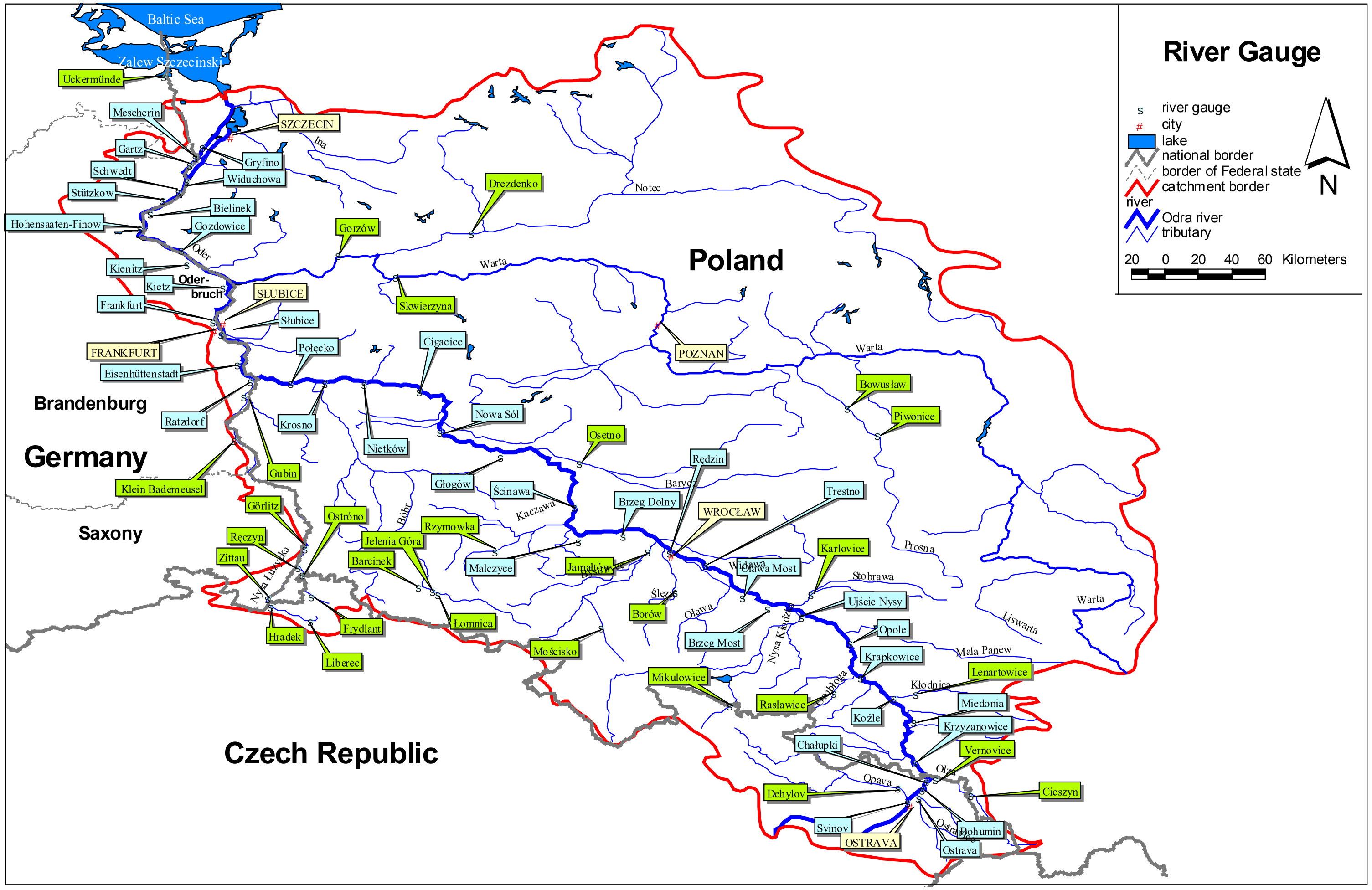


Fig. 20: River gauges

Tab. 18: Used polders on the Odra river

no.	name	flooding area [ha]	storage volume [mio m³] (different flooding depths)
	Upper and Middle Odra river		
1	Obrówiec	277	3.7
2	Bąków	420	5.4
3	Żelazna	200	1.7
4	Czarnowąsy	220	3.2
5	Rybna	825	12.0
6	Zwanowice	160	2.0
7	Kruszyna	41	1.6
8	Brzezina	257	3.5
9	Oława-Lipki	3 000	30.0
11	Blizanowice-Trestno	210	3.8
10	Oławka	1 070	12.0
12	Kiełcz-Tarnów Bycki	815	15.0
13	Połupin	4 125	70.0
14	Krzesin-Bytomiec	1 200	20.0
	Lower Odra river		
15	Criewener Polder (A)	1 400	53.0
16	Schwedter Polder (B)	1 300	40.0
17	Fiddichower Polder (10)	1 700	35.0
18	Międzyodrze (Gryfino, Szczecin, Gotow)	6 000	no information
	Warta river		
19	Słonsk	no information	480.0
20	Konin-Pyzdry	no information	230.0

Sources of data:
No. 1-14: RZGW, 1998
No. 15-17: LUA, 1997 a
No. 18: BUCHHOLZ, 1997
No. 20-21: Information by IMGW Poznań

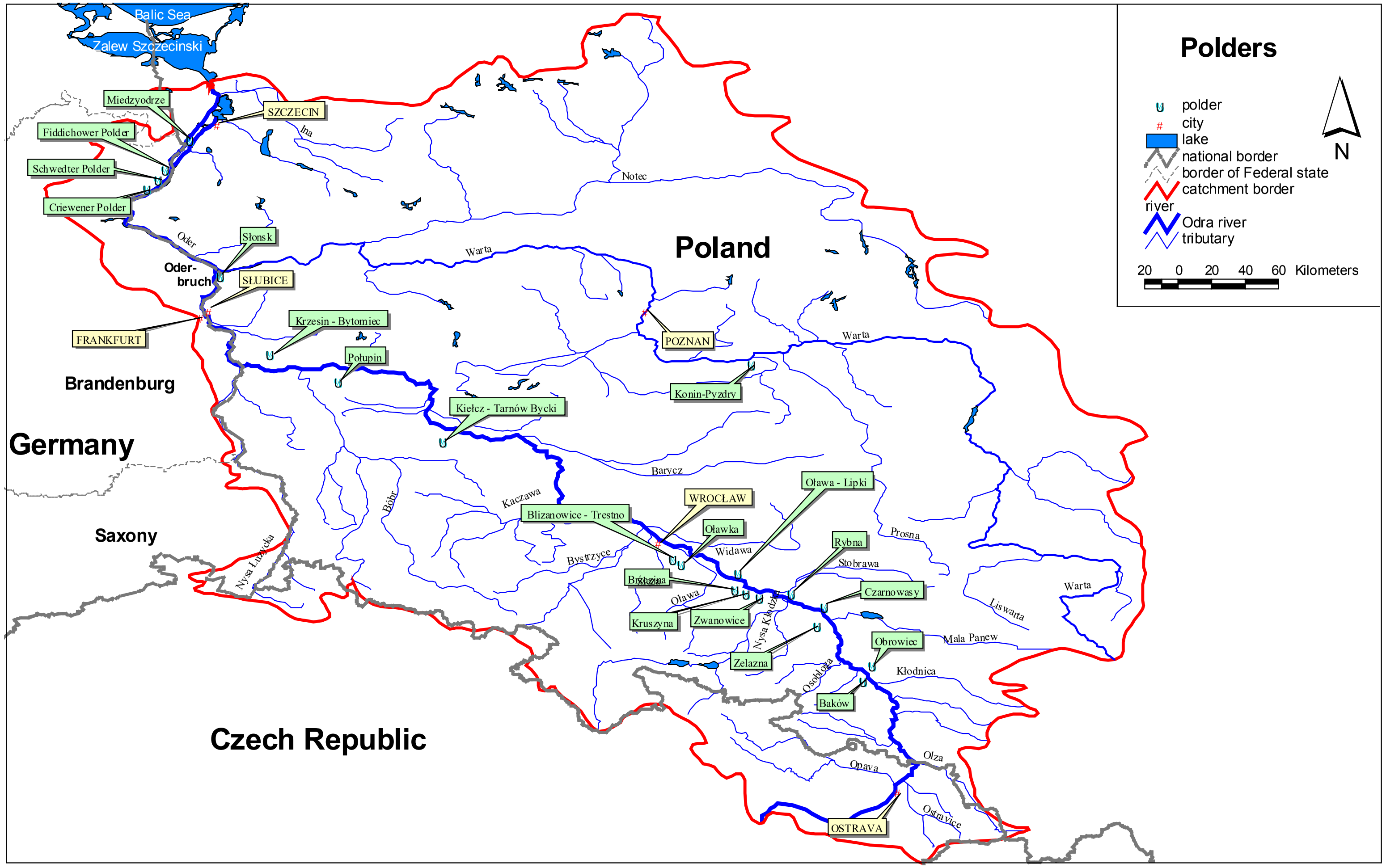


Fig. 21: Polders

Tab. 19: Polish reservoirs

reservoir	river	site	drainage area	storage capacity				area at storage level	administration
				storage at storage level	flood protection storage				
					in total	controll-able	uncontroll-able		
		[km]	[km²]	[mio. m³]	[mio. m³]	[mio. m³]	[mio. m³]	[km²]	(Water Management Agency (German: Wasserwirtschaftsdirektion= WWD)
Jeziorsko	Warta	484.3	9 063.3	202.80	21.50	-	21.50	42.30	District-WWD Poznań
Otmuchów	Nysa Kłodzka	75.8	2 361.0	124.46	38.64	15.27	23.37	19.76	District-WWD Wrocław
Turawa	Mała Panew	18.5	1 422.8	106.20	13.70	3.00	10.70	20.80	District-WWD Wrocław
Nysa	Nysa Kłodzka	64.0	3 262.5	113.60	27.92	7.86	20.06	20.42	District-WWD Wrocław
Dzierżno Duże	Kłodnica	32.6	528.9	94.00	7.00	5.50	1.50	6.20	District-WWD Gliwice
Mietków	Bystrzyca	48.0	715.4	70.56	4.10	4.10	-	9.20	District-WWD Wrocław
Pilchowice	Bóbr	192.2	1 208.7	54.00	30.00	26.00	4.00	2.40	Energy stations ZW S.A. Jelenia Góra
Słup	Nysa Szalona	8.0	392.0	38.40	7.30	2.41	-	4.89	District-WWD Wrocław
Pławniowice	Pot. Toszecki	0.2	123.3	29.15	2.41	0.60	-	2.44	District-WWD Gliwice
Leśna	Kwisa	87.0	304.5	18.00	8.00	5.00	3.00	1.40	Energy stations ZW S.A. Jelenia Góra
Bukówka	Bóbr	263.1	58.5	16.75	1.85	0.60	1.25	1.99	District-WWD Wrocław
Złotniki	Kwisa	91.7	289.4	12.40	1.90	-	1.90	1.25	Energy stations ZW S.A. Jelenia Góra
Dzierżno Małe	Drama	1.1	132.0	12.30	2.80	2.80	-	1.28	District-WWD Gliwice
Dobromierz	Stregomka	62.2	80.7	11.35	1.35	0.95	0.40	1.03	District-WWD Wrocław
Poraj	Warta	763.7	389.0	25.10	8.20	2.70	5.50	2.78	Steelworks „Częstochowa“
Lubachów	Bystrzyca	72.2	149.5	8.00	2.00	1.60	0.40	0.50	Energy stations ZE Wałbrzych
			total	937	179	78	94		

Data source: IKSO, 1999

Tab. 20: Czech reservoirs

reservoir	river	site	drainage area	discharge		storage					water level at storage level	area at storage level
				mean discharge (1931-80)	HQ_{100}	last reserve	usable storage	flood protection storage		controlled total storage		
								controlled	uncon-trolled			
		[km]	[km²]	[m³/s]	[m³/s]	[mio. m³]	[mio. m³]	[mio. m³]	[mio. m³]	[mio. m³]	[m a. s. l.]	[km²]
Slezská Harta	Moravice	55.83	464.3	5.47	231	7.57	182.85	12.03	16.30	202.44	497.00	8.787
Kružberk	Moravice	45.03	556.7	6.46	257	4.02	24.58	6.93	0.00	35.53	431.50	2.802
Šance	Ostravice	45.77	146.3	3.25	313	2.48	44.18	6.14	8.69	53.07	504.59	3.047
Morávka	Morávka	18.82	63.3	1.79	215	0.40	4.39	5.24	1.28	10.02	515.64	0.745
Olešná	Olešná	10.69	33.6	0.57	87	0.30	3.20	0.00	0.91	3.50	303.71	0.784
Žermanice	Lučina	25.02	45.4	0.57 a) 1.99	80	0.97	18.47	5.82	0.00	25.26	294.00	2.484
Těrlicko	Stonávka	12.45	81.6	1.12 b) 1.27	146	0.65	22.01	1.72	1.72	27.39	276.70	2.512
Baška*	Baščica		12.3			0.40	0.60	0.10		1.10		
					total	16.79	300.28	37.98	28.9	358.31		

a) with water transfer from Moravka
b) with water transfer from Repičanka

Data sources: IKSO, 1999; *Radczuk, 1997

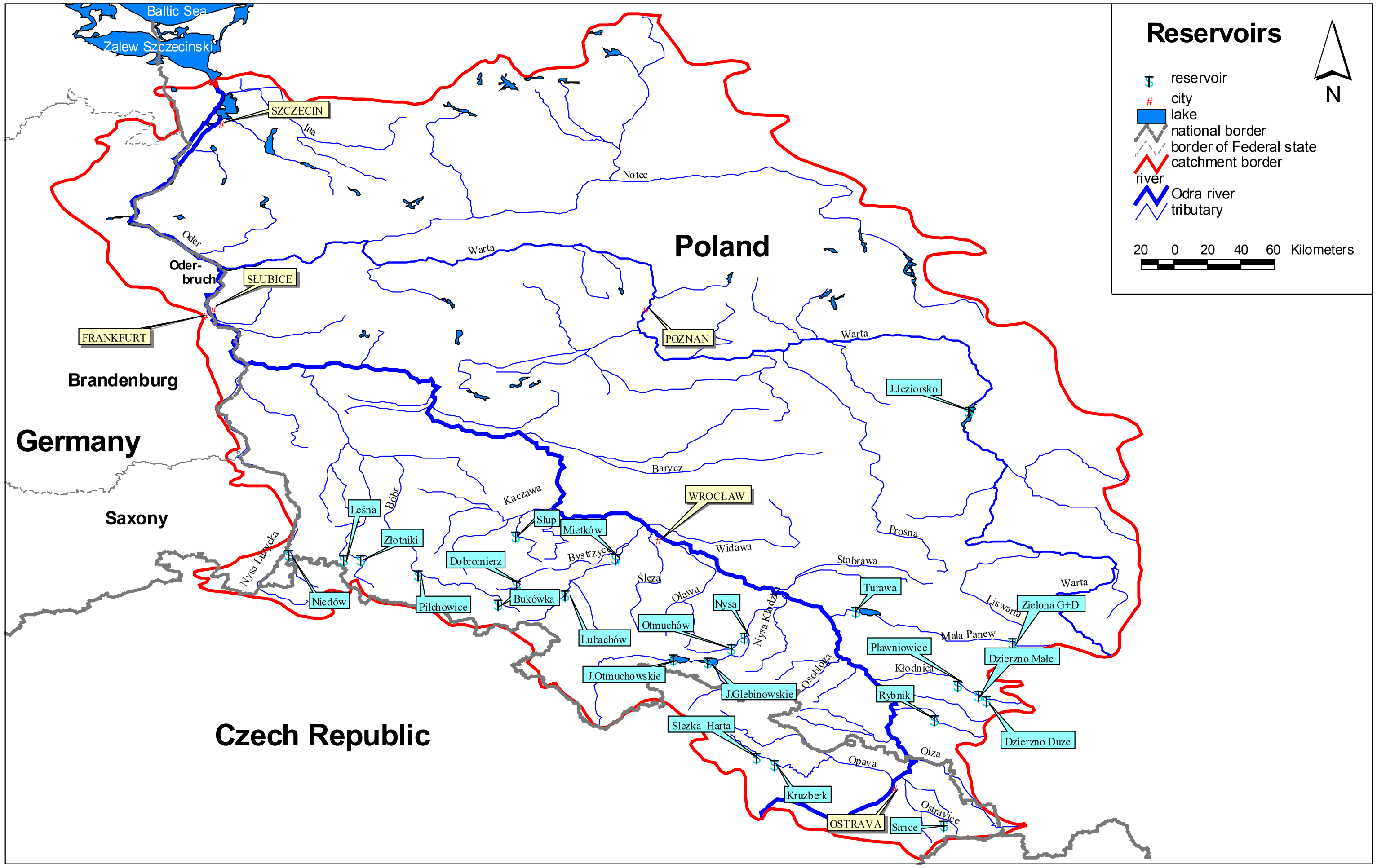


Fig. 22: Reservoirs

Tab. 21: Survey of the projects of Chapter 7

projects on flood modelling and forecast for sub-catchments and river sections, respectively				
project	**schedule**	**sponsor**	**institutions**	**remark**
MATRA (SOBEK) Polish-Dutch bilateral co-operation	01.06.1997 – 30.06.1999	Dutch Ministry of Foreign Affairs	*co-ordinator:* Company Arcadis Heidemij Advies *involved:* Institutions of the field water management in Poland and the Netherlands, among others, IMGW Wrocław	Among others transfer of one-dimensional hydrodynamic simulation model SOBEK
Improvement of the flood forecasting system in the Upper Odra river basin	since 1997/98	Czech Republic	ČHMÚ Ostrava; Povodí Odry	improvement of the monitoring network and implementation of the R-R-model HYDROG
Hydrological and meteorological monitoring, forecasting and protection system (Pol.abbreviation SMOK)	01.01.1998 – 31.12.2000	Loan of the World Bank	IMGW	improvement of the monitoring network improvement of the meteorological and hydrological forecast systems
MIKE 11 Polish – Danish project	May 1998 – November 2000	DEPA (Danish Environment Protection Agency)	*co-ordinator:* DHI (Danish Hydraulic Institute) *Involved:* IMGW Wrocław; RZGW Wrocław; IMGW Warsaw	transfer of Danish flood management technology (Software MIKE 11)
Hydrodynamic model of the BfG	01.07.1999 – 30.06.2002	LUA Brandenburg	BfG (Federal Institute of Hydrology)	development of a hydrodynamic model for the Border Odra

international projects for flood simulation				
project	**schedule**	**sponsor**	**institutions**	**remark**
ODER-LISFLOOD: Part of the project Natural Hazards of the EC-JRC	01.01.1999 – 31.12.2000 (extended to 2002)	EC-JRC project to support the IKSO	*co-ordinator:* SAI of the Joint Research Centre of the EC in Ispra, Italy *consultatively integrated:* IMGW Wrocław; RZGW Wrocław; ČHMU Prague; LUA Brandenburg; Saxon Agency for Environment and Geology and different research institutions and companies of the Odra riparian states	R-R-model for the Odra river basin without Warta river and Lower Odra river
ODRAFLOOD	01.01.2000 – 31.12.2002	BMBF project upholder DLR	*co-ordinator:* GKSS (Research Centre Geesthacht) *direct project partners:* IMGW Wrocław; MRI Szczecin; DLR Cologne; BTU Cottbus	simulation of flood events in the Odra river basin including the Warta river basin with a coupled model system

planning basis and information systems to the topic flood				
projects	**schedule**	**sponsor**	**institutions**	**remark**
Oder-Auen-Atlas	01.01.1998-31.12.2000	Gerling Insurance, WWF, and others	WWF-Aueninstitut Rastatt Lower Silesian Fund for Sustainable Development Wrocław and others	catchment orientated data base for problems in environmental protection, GIS-based
ODERREGIO	1999 – 2001	EC-programme INTERREG II C	*instructor*: United Land-planning Section Berlin-Brandenburg *participants*: planning agencies in Germany, Poland, and the Czech Republic *Conducted by*: Company Infrastruktur & Umwelt, Potsdam and others.	transnational concept for precautionary flood protection in the Odra river basin
FLODIS-ODER	1999-2002	Allianz Fund for Environmental Protection; ESRI® Inc. USA COMPAQ® German Association for Water Management and Civil Engineering (DVWK)	*recipient of funded money*: Water Bodies and Dike Association Oderbruch, Seelow *conducted* by WASY GmbH in co-operation with Polish and Czech partners	transboundary information and decision support system for a sustainable flood management in the Odra river basin (pilot projects)
OSIRIS	01.01.2000 – 31.12.2002	Fifth Framework Programme of the EC	*co-ordinator:* SOGREAH (Grenoble/France) *participants:* City Frankfurt/Oder, BTU Cottbus, IMGW Kraków and others	use of information and telecommunication technology in the case of flood