12 WATER RESOURCE SYSTEMS PROJECTS

12.1 THE WATER RESOURCE SYSTEM OF THE HORNAD RIVER BASIN

The area of the Hornád River Basin is 4346.31 km^2 at the Czechoslovak frontier. The important left-bank tributaries are: the Levočský Stream (153.28 km^2), the Svinka Stream (344.56 km^2), the Torysa River (1348.98 km^2) and the Olšava Stream (339.54 km^2). On the right bank the Hnilec River is the most important tributary (654.9 km^2).

The WRS also includes the basin of the Bodva River (890.37 km^2) and the upper basin of the Poprad River (transbasin diversion to the Hornad River basin) as far as Matějovce (311.07 km^2).

Table 12.1 The reservoirs of the WRS in the Hornád River basin

No. of point	Name	River (Stream)	Q_a $[m^3 s^{-1}]$	MQ $[m^3 s^{-1}]$	A_z $[10^6 m^3]$	Capital costs $[10^6$ Kčs$]$
1	Hranovnica	Hornád	1.03	0.20	24.4	189
2	Levoča	Levočský	0.43	0.07	10	127
3	Markušovce	Levočský	1.00	0.19	27.6	116
4	Hrabušice	Hornád	2.42	0.46	72.4	330
5	Helcmanovce	Hnilec	5.55	1.09	133.8	926
6	Ružín I	Hornád	16.00	3.00	48.5	existing
7	Ružín II	Hornád	16.00	3.63	2.5	existing
8	Kysak	Hornád	17.50	3.85	10	
9	Obišovce	Svinka	1.91	0.45	40.4	83
10	Krivany	Torysa	1.96	0.32	43.5	292
11	P. N. Ves	Lutinka	0.41	0.06	23.2	355
12	N. Šebastová	Sekčov	1.90	0.32	14.2	94
13	V. Myšla	Olšava	1.62	0.33	29.6	60
14	Bukovec	Ida	0.65	0.11	21.4	190
15	N. Medzev	Bodva	1.26	0.19	24	
16	Jasov	Bodva	1.44	0.21	74.5	422
17	Jablonov	Turňa	0.42	0.06	11.1	108
18	Tichý potok	Torysa	0.885	0.149	27.3	

For a representation of its basic properties and behaviour, the WRS was first of all defined on a rough discriminating (not detailed) level. The goals of the system, its elements and its environment were specified.

Definition of the system on a rough discriminating level (screening model)

The *water reservoirs* are the main elements of the system. From 25 reservoirs that were investigated in this basin by Kos *et al.*, 1979, the following were excluded: Palcmanská Maša (transbasin diversion to the basin of the Slaná Stream – the hydrological influence was considered approximately in hydrological data, and small reservoirs under 10 mil. m^3 of storage with local importance. The list of reservoirs included in the model and their basic parameters are given in Table 12.1.

The model considered the following goals of the WRS (related to control points 20 to 31) that significantly influence the behaviour of the WRS in the Hornád River basin: municipal, industrial and irrigation water supply, dilution of flows for water quality management and hydropower production. Other less significant goals were ignored in the model.

System with detailed discriminating level (simulation model)

Simulation modelling was the basic technique for the system on the detailed discriminating level. Systems analysis proved that for the discriminating level of the General Water Plan the network of points obtained as the output of the system defined on the rough discriminating level was sufficient (Kos and Zeman, 1976), and a more detailed division was not necessary. The schematic representation of the system is shown in Fig. 12.1.

The comparison of the alternatives to WRS was carried out on the basis of a minimum capital costs objective[1]) with some reliability constraints, as the problem of determination of benefits from the multi-purpose WRS has not yet been solved.

In WRS with a priority municipal and industrial water supply, the occurrence-based reliability[2]) of the municipal water supply was 97–99% and of the industrial water supply was 95–97%.

As the period of available monthly flows records was 30 years the values for reliabilities higher than approx. 97% could not be reliably computed by the deterministic simulation model. Therefore, (especially for drafts higher than 70% of the annual mean flow) the generated stochastic monthly time series should be used as the input of the stochastic simulation model. There were few such reliability requirements in WRS of the Hornád River basin and a deterministic simulation model with

[1]) The OMR (operation, maintenance and repair) costs were assumed as a linear function of capital costs.

[2]) The occurrence-based reliability is defined as the ratio of the number of years without water deficits to the total number of years under study plus one (see 6.3.7).

the observed time series for the period 1931 – 1960 were applied. The required operation without deficits in this period offered a reliability greater than 97%, thus satisfying the reliability requirement.

In similar hydrologic conditions where a more detailed investigation was performed by stochastic models, the operation of WRS without deficits in the period

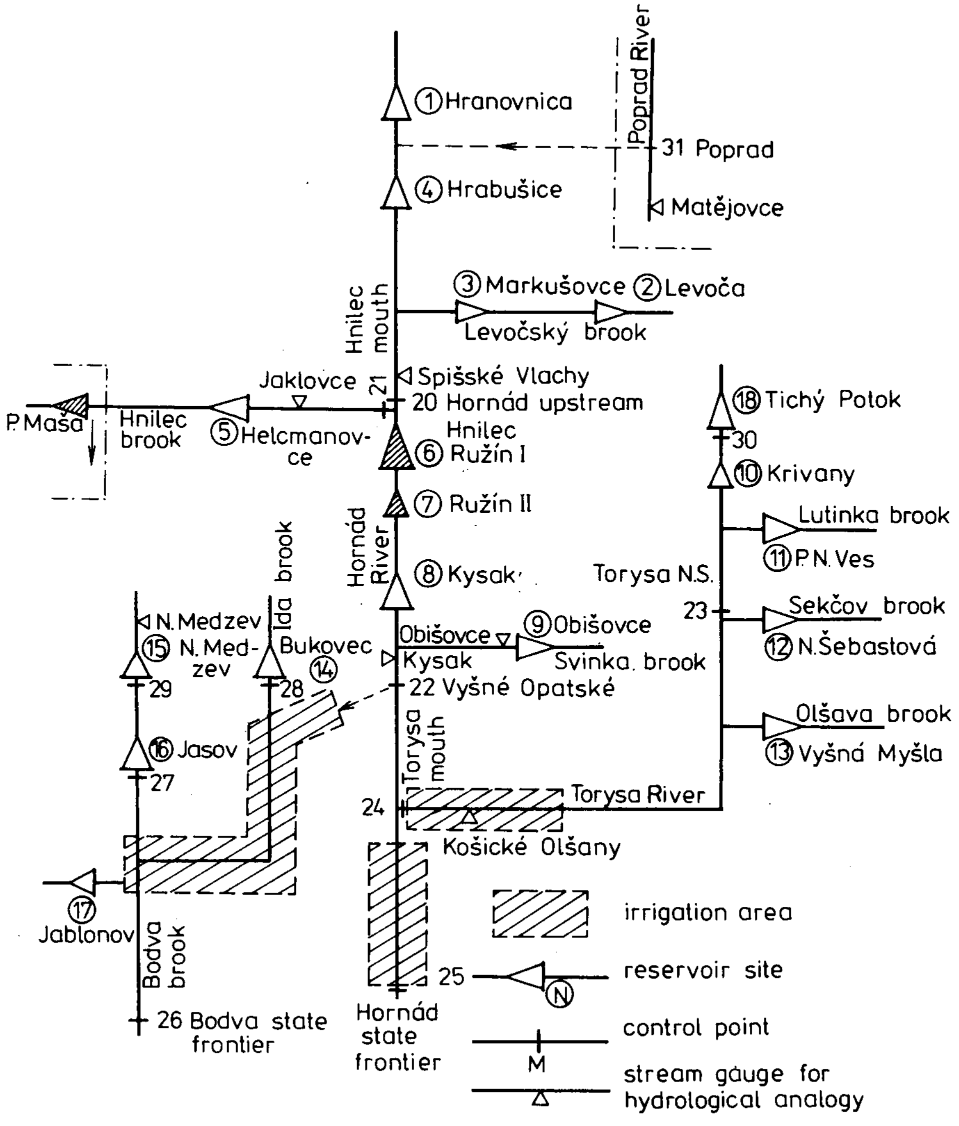

Fig. 12.1 Schematic representation of the WRS in the Hornád River basin

1931 – 1960 offered 95 – 97% reliabilities. If a 99% reliability was required, the draft determined by the deterministic simulation model using the period 1931 to 1960 has to be reduced by 10 – 20% (Kos *et al.*, 1967 – 1970). These estimates were used in the WRS of the Hornád River and the operation of reservoirs with a direct withdrawal from the reservoirs pools for the municipal water supply was analysed more throughly by statistical methods.

Input values of the model

a) *Hydrological data.* The mean monthly flows were observed in 8 stream gauging stations (see Fig. 12.1) in the period 1931 – 1960. In stations where the data were not complete the missing data were filled in by the regression method. The completed

Table 12.2 Estimates of WRS demands for the time horizons 1985 and 2000

No. of point	Name of point	River Stream	MQ [$m^3 s^{-1}$]	C [$m^3 s^{-1}$]		W [$m^3 s^{-1}$]		Irrigation*)	
				1985	2000	1985	2000	1985	2000
20	Upstream of the Hnilec S.	Hornád	1.16	0.02	0.05	0.12	0.14		
21	The Hnilec stream mouth	Hnilec	1.62	0	0	0.05	0.05		
22	Upstream of the Torysa R.	Hornád	4.48	1.04	1.14	1.19	1.33	9300 (18.6)	16 625 (33.25)
23	Upstream of the Sekčov S.	Torysa	0.45	0.07	0.08	0.13	0.14		
24	The Torysa R. mouth	Torysa	0.80	0	0	0	0	0	3700 (7.4)
25	State frontier	Hornád	4.3	0	0	0	0	0	3500 (7)
26	State frontier	Bodva	0.28	0.02	0.03	0.02	0.02		
27	Jasov	Bodva	0.21	0	0.01	0	0		
28	Bukovec	Ida	0.11	0.51	0.51	0	0		
29	N. Medzev	Bodva	0.11	0	0.64	0	0		
30	Tichý potok	Torysa	0.15	0.73	0.73	0	0		
31	Poprad	Poprad	0.98	0	0	0	0		

*) The demands are in the form A (B) where A is the area of irrigation (10^3 ha) and (B) is the annual irrigation water requirement (10^6 m^3/year).
The irrigation water requirements are partitioned into the monthly values in the following way: April 4%, May 17%, June 21%, July 24%, August 22%, September 10%, October 2%.

and adjusted monthly flows in the gauging stations were recorded on magnetic tape. If the gauging stations did not correspond to the dam sites or use points (control points), it was necessary to make adjustments in the simulation model based on the drainage areas or annual mean flows ratios.

b) *Demands.* At the time of analysis (1978) only two reservoirs existed: Ružín I and its short-term release control reservoir Ružín II (with a weekly operating cycle). The purpose of the Ružín I reservoir is to provide an industrial water supply for the Eastern Slovakia Ironworks in Košice and other industries in this area; to dilute streamflows near the mouth of the Torysa River (with a 90% reliability); to use a part of the storage for flood control; hydroelectric power generation and the development of facilities for water-related recreation. The operation depends on the river flow regulation requirements at points Ružín I (3 m^3 s^{-1}), Kysak (6 m^3 s^{-1}), and the Hornád River downstream of the confluence with the Torysa River (10 m^3 s^{-1}).

Meeting the constraints imposed by the last two points depends on reservoir content (and an increase of water supply reliability) thus, a reduction of reliability to 90% is achieved. In this simulation model two alternatives of the operation of the Ružín reservoir for hydroelectric power generation were investigated, i.e., (a) a model with a priority of hydropower to river flow regulation for waste water dilution, and (b) a model without this priority (with some losses in hydropower benefits due to the greater variation of the head). In other reservoirs of the system the primary hydroelectric power generation is not important (i.e., without pumping power plants).

The estimation of steady withdrawals of water for municipalities (sites 27, 28, 29 and 30) and for industry (mainly for the Eastern Slovakian Ironworks and for industries in the towns of Košice and Prešov) for years 1990 and 2000 are given in Table 12.2, where C is the consumption and W is the part withdrawn without consumption (numerically equal to the return flow or waste flow).

At the time of analysis, large-scale irrigation in the basin of the Hornád River did not exist. The plan for its development and the within-year pattern of withdrawals is given in Table 12.2 at points 22, 24 and 25.

The minimum acceptable flows were determined using the principles of the General Water Plan. The values of the minimum acceptable flows MQ for the control points are given in Table 12.2 and for reservoir sites minimum acceptable releases are shown in Table 12.1.

Flood control is not included as a direct goal in the model, however, the flood control storage volumes of reservoirs, determined by the flood control model, are considered.

The *water quality* requirements are included in dilution impact. At points where water pollution needs to be treated, the possibility of enhancing the draft was investigated in relation to an increase of available reservoir storage upstream of those points. If the costs of the additional storage are related to the draft, the cost of dilution can then be calculated.

Evaluation of the basic alternative

The basic alternative of the WRS design and operation is related to the demands estimated for the years 1985 and 2000. A list of the reservoirs that would be necessary to meet these demands is given in Table 12.3.

Table 12.3 Basic alternative to reservoir development until 1985 and 2000

No. of point	Name	River (Stream)	Active storage $[10^6\ m^3]$	
			1985	2000
6	Ružín I	Hornád	48.5	48.5
7	Ružín II	Hornád	2.5	2.5
9	Obišovce	Svinka	0	6.3
12	N. Šebastová	Sekčov	14.2	14.2
14	Bukovec	Ida	21.4	21.4
15	N. Medzev	Bodva	0	24
18	Tichý potok	Torysa	27.3	27.3

Decomposition of system to subsystems

The simulation model of the WRS in the Hornád River basin and the capacity of the computer do not require the decomposition of the system into subsystems. Therefore, the basic model was developed for the whole system. However, the reduction of computer time was achieved by calculations using the following subsystems:

– the subsystem of the Torysa River basin as far as point Prešov,

– the subsystem of the Hornád River upstream of the confluence with the Torysa River, including the transbasin diversion from the Poprad River and to the Slaná Stream and to irrigation in the Bodva River basin,

– subsystem of the Bodva River basin.

Computation of the alternatives of the subsystems and their evaluation

The hydrological water resources potential given by the feasible dam sites in the area investigated is higher than the demands for the system until the year 2000. In subsystems the relationship between reservoir storage and the draft at important control points was calculated (see Fig. 12.2). In this relationship, the demands estimated for the year 2000 and the low flow augmentation at the points investigated were satisfied. The latter requirement can be considered as the river flow regulation for the constant draft. In a configuration of the subsystems a number of reservoirs combinations were assumed. For a reduction in computer time, the reservoirs (without special function in WRS) were classified, using the ratio of capital costs and released draft, and the reservoirs with the lower values of this ratio were included in simulation models.

a) The Subsystem of the Torysa River Basin Closed at Point Prešov

Most economic activity is concentrated in the town of Prešov, and therefore this point (23) was chosen as an important control point for the subsystem. By the year 2000, the capacity of the Tichý Potok and Nižná Šebastová reservoirs will be exhausted. As the Vyšná Myšla reservoir is downstream of point Prešov, the draft at this point can be influenced by the Krivany and P. N. Ves reservoirs only.

The maximum draft at point Prešov is 2.65 $m^3 s^{-1}$ and subtracting the minimum

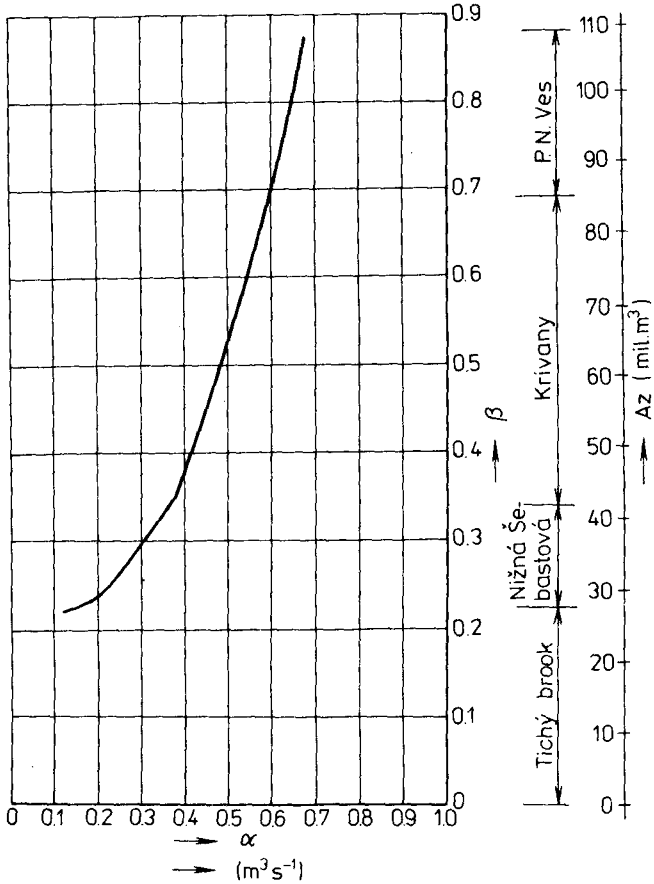

Fig. 12.2 The relation between draft and storage $\alpha = f(\beta)$ at point 23 α = draft/mean annual flow, β = active storage/mean annual flow converted to mil. m^3, A_z = active storage

flow and demands $MQ + C + W$ the remaining "commitment" is 1.98 $m^3 s^{-1}$. This maximum requires the capital costs of 646.6 mil. Kčs (approx. \$ 30 × 10^6) for the construction of the Krivany and P. N. Ves dams. The results in the form of the relationship between draft and storage are presented in Fig. 12.2.

b) The Subsystem of the Hornád River Upstream of the Confluence with the Torysa River

The most important point in this subsystem is the site Vyšné Opatské (No. 22). The model assumes water supply for irrigation below the confluence of the Torysa and the Hornád Rivers.

The transbasin diversion from the Poprad River significantly influences the subsystem and therefore only the Ružín (I and II) and Obišovce reservoirs are necessary to meet the demands. Other reservoirs form an additional commitment function. Using the ratio of capital costs and draft as a minimizing criterion, the reservoirs were placed in the following sequence: Kysak, Hrabušice, Markušovce, Helcmanovce, Hranovnica, Levoča. Using additional criteria, this order can be changed (e.g., Hrabušice has a negative environmental impact on the protected wilderness area "Slovakian Paradise"), but the form of the relationship of draft and storage $\alpha = f(\beta)$ (see Fig. 12.2) would not change significantly. The maximum commitment is $MQ_{com} - MQ_{req} = 11.3 - 4.48 = 6.82\, m^3 s^{-1}$ and the required maximum of added capital costs is 1771 mil. Kčs (approx. \$ 90 × 10^6). Most of these costs go to the Helcmanovce dam (926 mil. Kčs – approx. \$ 50 × 10^6), which is the second key dam in this basin (the first is the Ružín dam).

If the requirements were lower, it would be convenient and effective to change the order of construction as this dam is advantageous for high capacities, and the construction of a dam with a small total storage would "spoil" the site.

c) The Subsystem of the Bodva River

The most important point in this basin is the crossing of the Bodva River at the state frontier (No. 26). In an analysis, the relationships to the subsystem of the Hornád River basin were taken into account (the withdrawals from Bukovec and N. Medzev reservoirs for municipal water supply in the Košice area), as was the transbasin diversion for large-scale irrigation. Using this assumption, the draft commitment can be applied to Jablonov and Jasov reservoirs (in that order). At point No. 26 the additional draft is 2.04 $m^3 s^{-1}$, involving capital costs of 529,6 mil. Kčs (approx. \$ 25 × 10^6).

Conclusions

The problems of WRS in the Hornád River basin were investigated, at first, on a rough discriminating level and then in more detail, using a simulation model. For better determination of the reliability of the withdrawals for the municipal water supply, the method of mathematical statistics was used (with Pleshkov's and Gugly's diagrams). The completion of the hydrological time series was performed by regression analysis, and the validity of this method was verified by Ripple's diagram. A comparison of the results of the different models was used for the verification of the results. This method is often called *multi-modelling*. The application of different methods is really an experiment with models. While experimentation with one model can find the response to input data assuming some given structure of the system, experimentation with several models can test the structural assumptions. The systems approach in combination with the comparison of the results of the solution of one issue by different methods is a progressive way of dealing with the problems of WRS.

12.2 THE WATER RESOURCE SYSTEM OF THE ODRA RIVER BASIN

An example of water resources problem assessment with simulation models and chance-constraint models application is the Project of the Water Resource System of the Odra River Basin (1974).

In this basin, which comprises the industrial centre of Ostrava and its surroundings, the water resources requirements are high as compared with the potential water resources of this area. The isolated water resources facilities cannot meet the demands: therefore a WRS exists, and it is to be developed.

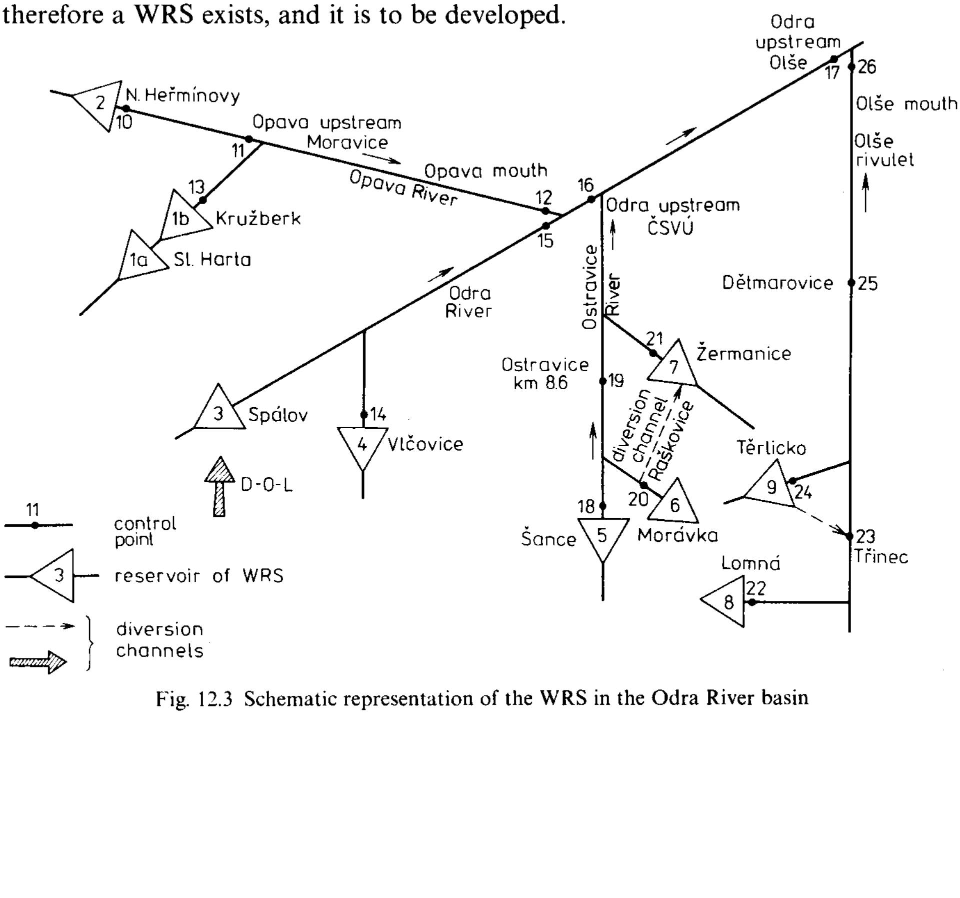

Fig. 12.3 Schematic representation of the WRS in the Odra River basin

The area covers the basin of the Odra River with its tributaries – the Opava, the Ostravice and the Olše Rivers (Fig. 12.3). A characteristic feature is the relatively high concentration of inhabitants and industry in this area. Coal-mining, thermal power plants and ironworks dominate the industrial scene accompanied by the chemical and machinery industries. In view of the climatic and soil conditions, agricultural development is not so important in this area as in others.

The *systems approach* was used at two discriminating levels. First, a model on a *rough discriminating level* was developed, the main interactions were defined, investigated and later used in the simulation model. Some goals were not considered in the simulation model, but they have an impact on input parameters, and some goals were ignored according to the planning level of the General Water Plan.

The WRS was defined on a rough discriminating level to meet the following goals:

– the development of the municipal water supply,
– the development of the industrial and irrigation water supply,
– flood control and its relation to water supply demands,
– water quality control, prevention of pollution, waste water treatment and environmental enhancement,
– hydroelectric power generation,
– navigation, inland waterways and river treatment,
– water-related sports and recreation,
– fisheries,
– stabilization of the riverbed, transport of liquid pollutants,
– minimum acceptable flows.

For the construction of the model on the rough discriminating level and for the determination of the main impacts of WRS, the isolated effects of reservoirs and diversions were used, calculated in the case studies of the General Water Plan and in the Project of Rational Water Management in the Basin of the Odra River in 1972.

The investigation on the detailed discriminating level was focused on issues that have the greatest impact on the WRS and which are the consequence of the social, industrial, environmental and ecological implications in the Odra River basin. Namely:

– the municipal water supply,
– the industrial water supply,
– minimum acceptable flows,
– flood control,
– prevention of river pollution,
– facilities for water-related sports, recreation and conditions for wildlife.

For systems with a rough discriminating level a *technical and economic input-output model* was used as a screening model. Systems with a detailed discriminating level were modelled using a *simulation model.*

The main *goal* of WRS in the Odra River basin was the municipal and industrial water supply. The irrigation water requirements and primary hydroelectrical power generation (i.e., with the exception of pumping power plants) were secondary goals in this basin. Flood control requirements were incorporated as the flood control storage volumes of reservoirs. Recreation influences the operation of WRS by requirements for recreation pool maintenance in the summer months.

Recreational activities are not permitted on the municipal water supply reservoirs. In future developments, some controlled forms of recreation (e.g., swimming, fishing, etc., but not motor boating) are to be permitted in the multi-purpose Slezská Harta reservoir, which has the main purpose the municipal water supply. At present, recreational facilities have been developed and will develop further on the shores of the Těrlicko and Žermanice reservoirs. Due to a concentration of requirements for many purposes in this area, reservoirs cannot be operated giving priority to recreation even in the summer months. The resulting reliability of a recreation pool is,

Table 12.4 Requirements in WRS of the Odra River basin

Control point of WRS, River (Stream)		Time horizon			
		2000		2015	
	M_j	$W_{m,j}$	$C_{m,j}$	$W_{m,j}$	$C_{m,j}$
	$[m^3 s^{-1}]$				
N. Heřmínovy, the Opava R.	0.57	–	–	0.8	–
Opava R., upstream of the Moravice R.	0.61	–	–	–	0.57
Opava R., mounth	1.46	0.10	0.48	0.14	0.68
Kružberk, the Moravice R.	0.34	–	2.89	–	3.78
Vlčovice, the Lubina Str.	0.11	0.24	–	0.24	–
Odra R., upstream of the Opava R.	0.49	–	1.08	–	1.15
Odra R., upstream of the Ostravice R.	2.21	–	1.46	–	1.47
Odra R., upstream of the Olše R.	3.46	2.5[y])	–	2.5[y])	–
Šance, Ostravice R.	0.30	–	1.6	–	1.6
Ostravice R., km 8.6	0.76	0.2	1.0	0.2	0.95
Raškovice, Morávka R.	0.16	–	0.6	–	0.6
Žermanice, Lučina R.	0.08	–	0.99	–	0.99
H. Lomná, Lomná S.	0.07	–	0.38	–	0.38
Třinec, Olše R.	0.32	0.68	–	0.68	–
Těrlicko, Stonávka S.	0.11	–	0.33	–	0.33
Dětmarovice, Olše R.	0.76	–	1.69	–	1.58
Olše R., mouth	0.97	–[z])	–	–[z])	–

[y]) a parameter indicating low flow augmentation; this flow is to be increased by 4.5 $m^3 s^{-1}$ (2000) and 4.08 $m^3 s^{-1}$ (2015) respectively due to waste water effluents.

[z]) the flows are increased by 0.72 $m^3 s^{-1}$ by waste water effluents.

therefore, reduced, which must be regarded as the main impact of WRS on recreation.

The main energies of water quality management in the General Water Plan were focused on organic waste. In the Odra River basin, however, the salt concentration in some waste waters is enormous, due to industrial waste water and water pumped from mines. In WRS design this problem is treated preferentially by calculation the low flow augmentation for waste water dilution. Therefore, the possibility of regulating the flow of the Odra River by means of reservoirs, in the town of Ostrava, was investigated as a secondary goal, so as not to interfere with the primary goals – river flow regulation at other control points of the WRS. Water quality enhancement in the lower part of the Odra River can provide for future withdrawals of water for cooling purposes in industry.

The water *requirements* in the WRS have been collected, processed and grouped at control points of the WRS in the form of system inputs. The grid of control sites in the simulation model was determined in such a way as to specify the points of the main impact and main requirements and the points where it was possible to sum up these impacts. Some reservoir sites are also control points, if water is diverted from reservoirs or if water is withdrawn immediately downstream of the reservoir. The

Table 12.5 The stream gauging stations on the WRS of the Odra River basin

Station	River (Stream)	Station	River (Stream)
Spálov	Odra	Opava, Polní street	Opava
Studénka	Odra	Kružberk	Moravice
Petřvald	Lubina	Branka	Moravice
Svinov	Odra	Děhylov	Opava
N. Heřmínovy	Opava	Šance	Ostravice
Morávka, reservoir site	Morávka	Jablunkov	Olše
Sviadnov	Ostravice	D. Lomná	Lomná
Olešná, reservoir site	Olešná	Ropice	Olše
Žermanice, reservoir site	Lučina	Těrlicko	Stonávka
Ostrava I.	Ostravice	Věřňovice	Olše
Bohumín	Odra	Mikulovice	Bělá

water supply requirements were classified as withdrawals without consumption $W_{m,j}$, consumption $C_{m,j}$ and acceptable minimum flows MI_j in month m and site j (see section 6.3.6). Alternative values are listed in Table 12.4.

The basic objective of the WRS in the Odra River basin was the necessary reliability of drafts and river flow regulation for water supply. The deterministic simulation model was used for operation without water shortages with the observed input time series in the period 1931 – 1970. The reliability of this model was estimated at 98.7% (based on Chegodayev's method). This value was verified by a chance-constrained model of the sub-system, including the main Slezská Harta and Kružberk reservoirs and for the corresponding alternatives the reliability was approximately

Table 12.6 Reservoirs in the WRS of the Odra River basin

Reservoir, River (Stream)	Storage [10^6 m^3]		Minimum reservoir release [m^3 s^{-1}]
	Total	Active	
1 *Existing reservoirs*			
Kružberk, Moravice R.	35.5	24.0	0.74
Šance, Ostravice R.	54.2	45.8	0.30
Morávka, Morávka R.	10.1	4.4	0.11
Žermanice, Lučina R.	20.1	18.5	0.07
Těrlicko, Stonávka S.	24.4	22.0	0.10
2 *Reservoirs planned by 2000*			
H. Lomná, Lomná S.	16.1	15.6	0.07
Slezská Harta, Moravice R.	158.0	150.0	0.67
Vlčovice, Lubina S.	21.0	15.0	0.11
3 *Reservoirs after 2000*			
N. Heřmínovy, Opava R.	100.5	95.0	0.57
Spálov, Odra R.	121.0	119.6	0.13

97%. This value was acceptable for the objectives of the General Water Plan. The monthly time series in streamflow gauging stations were the basic hydrological input data. These data were corrected, adjusted and completed and in some cases reduced to uncontrolled flows using the values of water level variation, withdrawals and effluents. The time series with a shorter observation period than 1931 – 1970 were completed to this period. The models for the analysis of the WRS in the Odra River basin used the monthly flows at points listed in Table 12.5.

The uncontrolled monthly flows at control points of the WRS were defined as a linear function of the nearest gauging station flows, using the ratio of the mean annual flows.

The hydrological data for flood control design were focused on the sub-system of the Ostravice River basin, where the systems approach was necessary. The observed and standard design floods in the station Šance (Ostravice R.), Morávka (Morávka R.), and Sviadnov (Ostravice R.) were used as input data.

In the basin, 19 reservoir sites were examined for the purposes of the WRS. Five reservoirs have been constructed, three have been designed and are to be built by the year 2000 and two reservoirs after the year 2000 (see Table 12.6). The diversion channels in WRS are the Rašovický channel from the Rašovice weir to the Žermanice reservoir (see Fig. 12.3), the diversion channel from the Těrlicko reservoir to the industrial centre of Třinec and after the year 2000, the transbasin diversion channel from the Teplice reservoir to the Odra River. The function of further channels was incorporated by summing up the requirements at the control points of the WRS.

In the design two groups were considered, i.e., satisfying the demands on the WRS by: a) the water resources of the Odra River basin using the reservoirs and the diversion channels inside the basin, and b) by the co-operation of these reservoirs with the transbasin diversion from the Teplice reservoir in the Water Resources and Transportation System Danube – Odra – Labe.

Conclusions

According to the problematic balance between the demands and water resources, the optimization of water resources of the WRS in the Odra River basin was based on such methods of reservoir operation that would prove the feasibility of meeting the increase of requirements until the year 2000 and 2015.

The reservoirs on some rivers have been built and their hydrological potential is used and almost exhausted. The possibility of enlarging the system by further reservoir storage is limited, and by the year 2015, the utilization of all the suitable reservoir sites is assumed with the exception of the Spálov reservoir, the construction of which depends on the Water Resource and Transportation System Danube – Odra – Labe and not on the demands in the basin of the Odra River alone.

The optimization in the simulation models was focused on two groups of choices, i.e.:

a) groups with a water supply objective and other requirements satisfied by the reservoirs in the Odra River basin, and

b) groups with objectives satisfied by a combination of the reservoirs operating in the Odra River basin and the Water Resources and Transportation System Danube – Odra – Labe, or its first stage, the transbasin diversion from the Teplice reservoir on the Bečva River.

The optimization of the reservoir operation was based on the issues of the municipal water supply of the waterworks system "Northern Moravia" (that is to include the present sub-system of the Ostrava Area Water Works) and the sub-system of the

Kružberk and Slezská Harta reservoirs and their co-ordination with other WRS requirements.

Having found and verified such an operation we interrupted the optimization process as the feasibility proof of such operation was sufficient for the discriminating level of the General Water Plan and the accuracy of the input parameters.

The economic comparison of these two groups: a) and b) proved the greater effectiveness of the second group, b), which has better economic indices and a higher development flexibility surpassing the time horizon of the year 2015 and making the WRS more adaptable for further demands. However, this group of choices is related to the implementation of the Water Resources and Transportation System Danube – Odra – Labe, which will in future cover the whole territory of Czechoslovakia and form an international inland waterways system.

The examples given may seem to overestimate the importance of the input and output data and to underestimate the role of the inner structure of the simulation model and the computer process. This attitude conforms to the methods used before the computer era with better insight into computation, and an objection might be raised that in present simulation models the calculation procedure is not explicitly described in the application to the investigated WRS. However, the number of relationships and constraints that have to be considered has increased in such a way that a cybernetic and systems approach with simulation modelling is now necessary. The simulation procedures provide, in the mutual relationship and dependence, the basic water resources calculation (see Section 6.3.6) in the system, and they form the basis for the simulation SIM-WRS programming language (or other languages). Using such programs or simulation languages, the designer or planner of the WRS (with the exception of programmers that try to improve the inner structure of computation) are not interested in the inner structure and use the cybernetic "black box" approach to study the system response to the set of system inputs by the simulation model.

An explicit (step-by-step) description of computation, including the inner structure, is only possible for simple examples (see Chapter 4). Such a description is not possible for large systems (e.g., with three or more reservoirs and say 10 sites) and in a large scale WRS, and the purpose of such description would be questionable as it would be retrogressive compared to the systems approach method used for WRS analysis on different discriminating levels.