THE UPPER-TISZA FLOOD IN MARCH 2001

Shortered version

This publication is a shortened English version of the book
with the same title,
Initiated by the Upper-Tisza Water Authority and produced with
the cooperation of VIZITERV Consult Ltd.

Authors of Chapters:

I.	Chapter	Board of Authors
II.1-5.	Chapter	dr. Karoly Konecsny
II.6.	Chapter	dr. Zoltan Balint
II.7.	Chapter	dr. Zoltan Balint – dr. Karoly Konecsny
III.	Chapter	Gaspar Bodnar – Andor Kerti – Gábor Horvath – dr. Zoltan Balint – Lajos Illes
IV.1.	Chapter	Gaspar Bodnar – Andor Kerti
IV.2.	Chapter	dr. Istvan Kertai – Lajos Illes – dr. Lajos Szlavik
IV.3.	Chapter	Lajos Illes – Andor Kerti – Gaspar Bodnar
IV.4.	Chapter	Lajos Illes – dr. Zoltan Balint
IV.5.	Chapter	Lajos Illes

Cooperated in Writing:
Water Authority of Sub-Carpathia
„Waters of Romania" the Szamos-Tisza Water Authority, Cluj

2004, Nyíregyhaza

I. INTRODUCTION

In the period of 1998-2001 big and dangerous floods developed in the Tisza-Valley. The river showed a different face each time, and the tasks of the flood control management at regional and national levels were also different.

After the March 2001 flood the Upper-Tisza Environmental and Water Directorate together with VIZITERV Consult Ltd embarked upon the important and useful task of writing a professional book on the hydrological characteristics of the flood, on the events and experiences of the flood control activities and on the new flood management conceptions, development plans and programs. The present booklet is the shortened version of the above book.

The authors hope that the experiences published in the book will be of great use in combating future floods in the Upper-Tisza region and the development programs will be completed before a next disaster could occur.

Editorial Board

II. Hydrology of the Flood

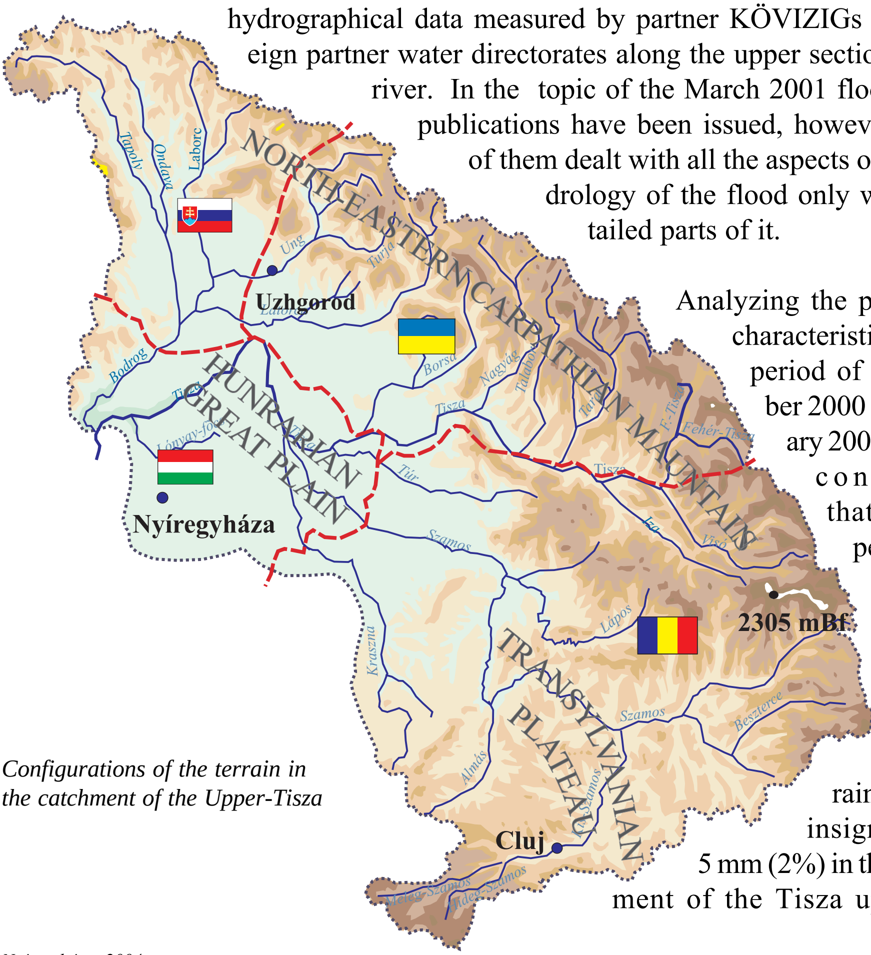
II.1. Hydrological features of the flood wave

The catchment area of 35,870 km upstream the confluence of the Tisza and Bodrog Rivers is shared by four countries (Ukraine, Romania, Slovakia, Hungary). The geographical features of this catchment are precisely described in various studies and books, which have been published in this field.

Previous to the flood in March 2001, major flood events occurred in December 1947, May 1970, December 1993, December 1995 and in November 1998 on the Upper-Tisza. The hydrological observations and conclusions of these have been published on several occasions.

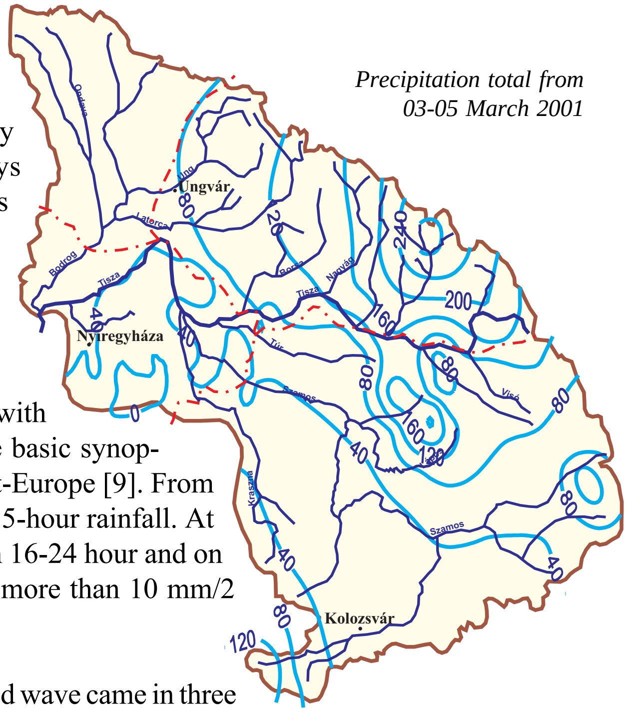
The hydrological assessment of the March 2001 Upper-Tisza flood was carried out by the FETIKÖVIZIG, based on the hydro-meteorological and hydrographical data measured by partner KÖVIZIGs and foreign partner water directorates along the upper section of the river. In the topic of the March 2001 flood some publications have been issued, however, none of them dealt with all the aspects of the hydrology of the flood only with detailed parts of it.

Analyzing the pre-flood characteristics in the period of November 2000 – February 2001 we can conclude, that in this period the excess precipitation above the mean rainfall was insignificant, 5 mm (2%) in the catchment of the Tisza upstream



Configurations of the terrain in the catchment of the Upper-Tisza

Tivadar. However, at some places in March the double or triple amount of the mean monthly precipitation fell, mainly due to the extremely rainy days between 03 – 05 March. As far as water levels are concerned, on 1st, 2nd and 3rd March the water stages were 1.5 – 2.0 m under the long-term March average.



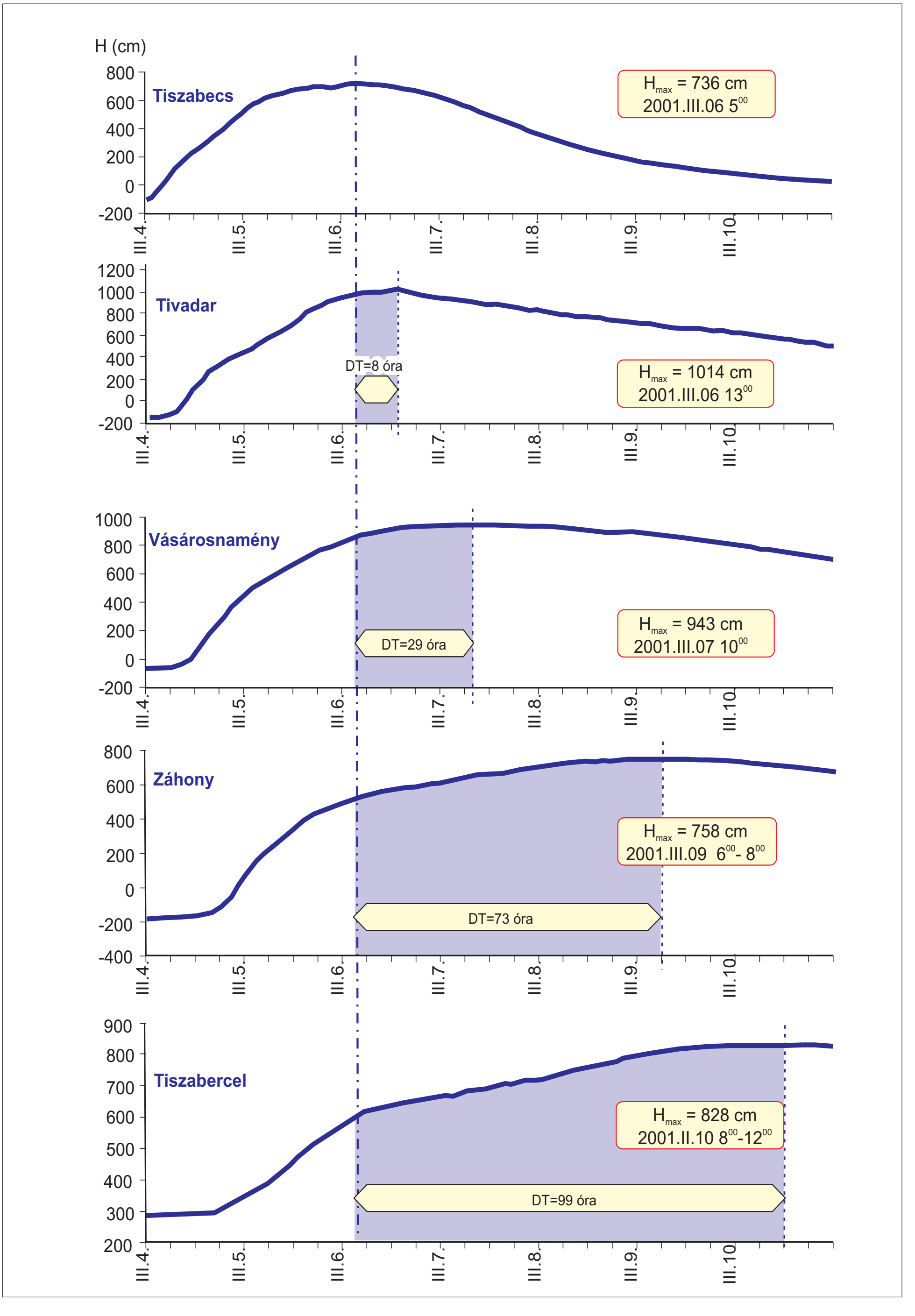
Precipitation total from 03-05 March 2001

Early in March a cyclonal field with West-East axis characterized the basic synoptic situation in Central- and West-Europe [9]. From 03 to 05 March there was a 50-55-hour rainfall. At the peaks on 3rd March, between 16-24 hour and on 5th March, between 10-13 hour more than 10 mm/2 hours intensity was measured.

The precipitation causing the flood wave came in three surges. The intensive rain began on the morning of 3rd March and the last surge ended on the afternoon of 5th March. In Trans-Carpathia, precipitation exceeding 200 mm was registered at several locations, with the maximum of 296 mm in Oroszmokra in the Tarac Valley. Here the March average precipitation is 70-80 mm.

In just three days 132 mm rain and significant amount of snow with 70 mm water content, altogether more than 200 mm precipitation fell onto the catchment. The water from the torrential rainfall and from the intensive snowmelt due to sudden rise in the temperature could only partly store up, because the soil on the mountain slopes was basically frozen, at lower altitudes it was soaked and the water retention of late-winter, bare forests was insignificant. On the upper sections of the rivers intensive rise of water level began on 03 March at night.

Tarac



Flood hydrographs and times on the Hungarian section of the Upper-Tisza

The Tivadar bridge section (06 March 2001)

Composite flood waves were forming, for example at Raho 3 subsequent surges of precipitation with very short intervals created 3 peaks of flood waves. On the river sections in Hungary the flood hydrographs show single flood waves only.

From the maximum intensity of the precipitation surge at 10.00 – 13.00 hour on 05 March to the flood peak of Raho (575 cm) only 16-18 hours passed and it was only 13 hours at Tiszabecs (736 cm). In three days as high as 8.5 m water rise was measured at Tiszabecs and 12.0 m at Tivadar before the peaking.

On 4th March from 4 to 6 o'clock the intensity of the rise was the highest at Tiszabecs with 79 cm/2 hours, however, it was even higher at Tivadar between 8 and 10 o'clock on 04 March with 96 cm/2 hours. During the flood parallel with the visual observation of the water gauges the remote sensing system of the Upper-Tisza Water Directorate was continuously in operation, providing data with 5-minute frequency of the water stage, precipitation and air temperature from 10 stations in Hungary and 2 in Trans-Carpathia.

The height and time of the flood peaks and the differences compared to the highest ever measured water level at main water gauges are as below.

Tisza Rahó	575 cm / March 5. 16 hours	+ 75 cm
Tisza Técső	745 cm / March 5. 16 hours	+19 cm
Tisza Tiszabecs	736 cm / March 6. 5 hours	+ 28 cm
Tisza Tivadar	1014 cm / March 6. 13:10 hours	+ 56 cm
Tisza Vásárosnamény	943 cm / March 7. 10 hours	+ 20 cm
Tisza Záhony	758 cm / March 9. 6 hours	+ 7 cm
Túr Garbolc	580 cm / March 6. 12 hours	– 66 cm
Túr Sonkád	629 cm/ március 6. 10 hours	+ 33 cm

No.	River, Stream	Water gauge	Previous max/year	Flood alert level			Peak flood level, Marcs 2001	
				I	II	III	cm	day/hour
1	Tisza	Rahó	500/1998	350	390	460	575	05./17
2		Visóvölgy	362/1998	150	200	260	420	05./19-20
3		Nagybocskó	598/1970	309	320	420	623	05./18
4		M.sziget	436/1998	230	280	350	485	05./20-21
5		Técső	726/1998	270	570	600	745	05./18.
6		Huszt	428/1998	215	280	310	528	05./19-21
7		Tiszaújlak	696/1970	233	516	626	686	06./8
8		Tiszabecs	708/1998	300	400	500	736	06./5
9		Tivadar	958/1998	500	600	700	1014	06./13
10		Vás.namény	923/1998	600	700	800	943	07./10
11		Lónya	853/1970	-	-	-	872	08/10-16
12		Záhony	751/1888	500	600	700	758	09./6
13		Csap	1328/1998	980	1118	1220	1347	09./6
14		Dombrád	890/1888	600	700	800	818	09-10/18-2
15		Tiszabercel	882/2000	600	700	800	826	10./8-12
16		Tokaj	928/2000	600	700	800	847	12./2-14
17	Fekete-Tisza	Körösmező	464/1964	400	430	460	396	05./14
18	Fehér-Tisza	Láposmező	264/1970	70	110	150	175	05./18
19	Visó	Borsa Pojána	159/1972	60	100	150	112	05./17
20		Majszin	170/1970	80	140	220	135	05./20
21		Leordina	386/1970	130	220	320	265	05./21
22		Visóbeszterce	520/1970	220	300	370	470	05./22
23	Cisla	Borsabánya	102/1974	80	130	190	62	05./18
24	Vasér	Felsővisó	226/1970	100	150	220	250	05./20
25	Oroszi	Visóoroszi	225/1970	140	190	240	250	05./20
26	Kaszó	Kaszómező	276/1998	-	-	-	315	05./16
27	Iza	Szacsal	250/1970	40	100	150	150	04./9
28		Stramtura	352/1978	200	280	380	390	04./13-14
29		Farkasrév	512/1970	300	390	520	510	05./18-19
30	Mara	Farkasrév	342/1970	180	260	360	345	05./18-19
31	Tarac	Királymező	363/1998	300	350	400	382	05./16
32		Nyéresháza	349/1962	120	170	230	319	05./16
33	Talabor	Alsókalocsa	360/1998	150	180	200	398	05./
34	Nagyág	Ökörmező	478/1957	129	172	209	330	04./
35		Huszt	685/1947	420	470	550	600	05./20
36	Borzsa	Dolha	547/1998	267	309	316	502	05./16
37		Salánk	890/1998	570	600	765	870	06./4
38	Túr	Túterebes	566/1970	360	420	540	540	05./23
39		Garbolc	646/1970	300	400	450	580	06./12
40		Sonkád	596/1970	300	400	450	629	06./10
41	Szamos	Szatmárnémeti	885/1970	500	600	900	650	07./6-7
42		Csenger	902/1970	500	650	700	668	07./12
43		Tunyogmatolcs	1040/1970	-	-	-	819	07./14-22
44	Kraszna	Ágedőmajor	651/1970	470	550	580	331	06./20
45		Kocsord	702/1980	450	530	580	522	07./14-22
46	Lónyay-fcs.	Kótaj	899/2000	650	700	800	825	11./4-8

Floodwater peaks in March 2001

Tisza–Vásárosnamény (06 March 2001)

It took 13 hours for the flood peak to travel 143 km from Tecso to Tiszabecs, which is 11km/h average speed. To cover the distance between Tiszabecs and Tivadar took 8 hours (4.9km/h), Tivadar-Vasarosnameny took 21 hours (1km/h), Vasarosnameny-Zahony took 34 hours (1.7km/h) and Zahony-Tiszabercel took 26 hours (2.3 km/h). Along the sections with dikes the water stayed 20-50 cm above the highest ever measured (HEM) level for 14-38 hours.

Higher than HEM water stages formed on the Tisza between Raho and Zahony, on the tributaries in Trans-Carpathia and on the lower sections of the River Tur. The water stage exceeded the HEM by 75 cm at Raho in Trans-Carpathia and by 56 cm at Tivadar in Hungary. Downstream the Zahony section of the Tisza the water did not reach the HEM level.

The peak water stages of the flood were affected by over-toppings and dike breaches. At 13.30 and 14.30 hours on 6th March the peak reached the Tarpa-Tivadar section and nearly at the same time the dike breached. Through the opening 140 million m^3 water flew from the flood bed of the Tisza towards the sub-catchment in Bereg.

A hydrological statistical evaluation was carried out, based on the available 50-100-year peak level time series. This study suggests that the probability of the peak water stages were: 0.5 % at Tiszabecs and Tivadar (200 years average returning period), 1.0 % at Vasarosnameny, 2.0 % at Zahony and 6.0 at Tiszabercel.

During the floods of December 1947, November 1998 and March 2001 there were dike breaches at several places in Trans-Carpathian, which besides causing millions of m^3 water flow out of the riverbed resulted in water level reduction. In case a full and effective levee section is constructed at the places of the above mentioned breaches and in the Técso és Huszt Basins the flood water level may rise by more than 50 cm. Without the breaches presumably as high as 760-790 cm peak level could have developed at Tiszabecs. The peak would have been 1040-1060 cm at Tivadar.

The highest discharge, 4190 m^3/s was measured on the Tisza on 6th March 2001. This was the highest ever measured discharge on the Upper-Tisza. The measurements were taken by 3 teams of FETIVIZIG and by hydrological experts who came to help from Budapest and Debrecen. The experts of Ukraine and Romania estimated the peak discharge based on hydraulic calculations: Rahó 938 m^3/s, Máramarossziget 2244 m^3/s, Técso 3380 m^3/s, Huszt 3400 m^3/s.

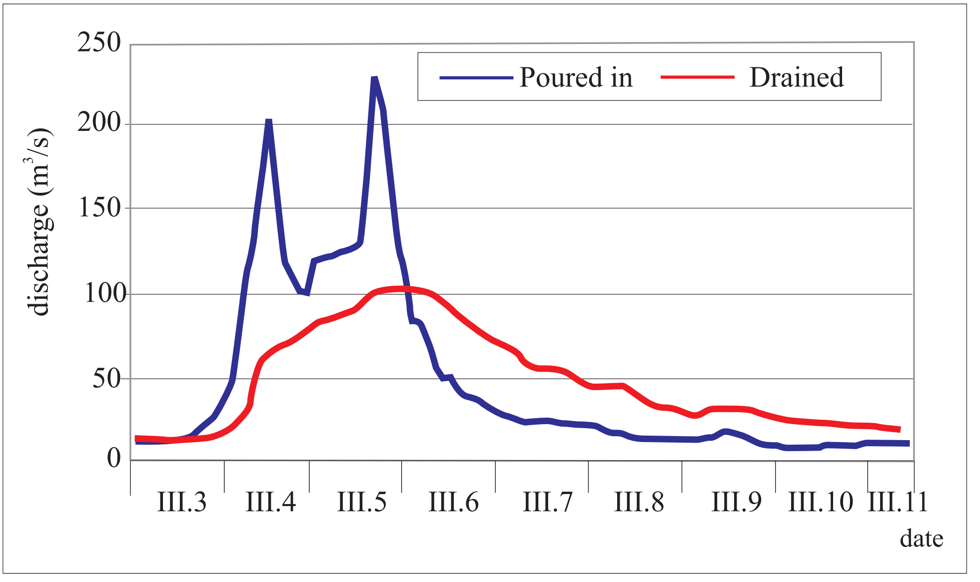
Based on the Q-H relation between the discharge of the rising and recessing part of the hydrograph is similar to that of the previous floods, in case of higher water levels it is 500-700 m^3/s. The maximum runoff rate at some mountain catchments was really high: At Fernezely 1608 l/s km^2, on the Kaszó at Kaszómezo 1549 l/s km^2, on the Túrc at Nagygérce 1497 l/s km^2, on the Tarac at Királymezo 1162 l/s km^2.

According to the above study the probabilities of the peak discharges in March 2001 upstream the Tisza-Szamos confluence were as follows: Tiszabecs 0.8 % (120 years), Tivadar 0.6 % (150 years). Vásárosnamény 2.0% and Záhony 2.5 %.

II.2. Hydrological features of the flood in the catchment of the River Tur

The peak (629 cm) at the Garbolc gauge arrived at 10.00 o'clock, 2 hours earlier than the peak was observed at Sonkád, which is further downstream, and exceeded the HEM by 33 cm. The duration of the HEM was 6 hours. The backwater effect of the Tisza as well as a considerable mass of water overflowing the dike of the Palád Creek on the Ukrainian side, together with water coming from the breach at Tiszabökény all contributed to the extremely high water stages to form. The above factors increased the water stage by 10-20 cm. The probability of the 580 cm peak at Garbolc was 5% and the peak of 622cm at Sonkád was 3%, the probability of the discharges was in the range of 3-12%.

In the period of 3rd-6th March 13.2 million m^3 water was kept back in the Kányaháza Dam on the Romanian section. The maximum discharge flowing into the dam reached 229 m^3/s, while the drained maximum outlet was 106 m^3/s. The flood reduction effect was extremely strong, 54%. This resulted in a 60-80 cm water stage drop in the frontier region.



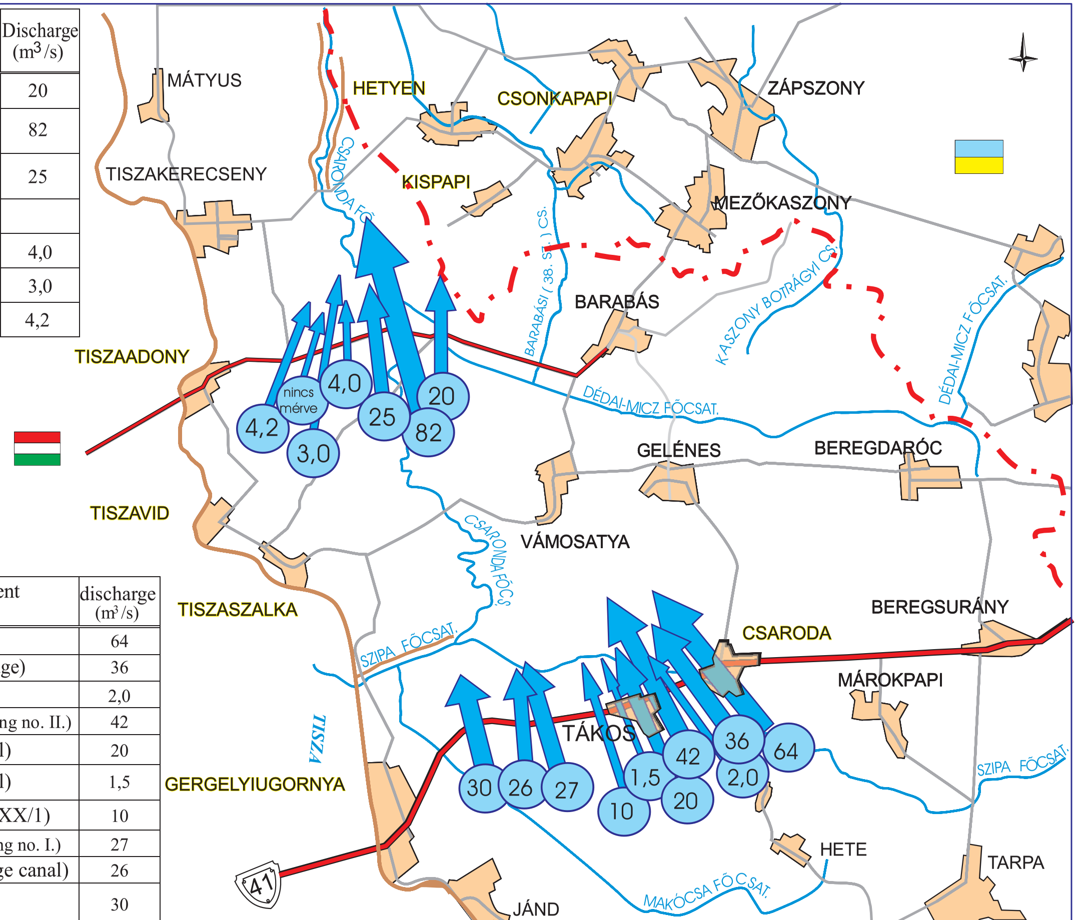
Discharges poured and drained into the Kányaházi reservoir from 03-11 March 2001

II.3. Recession of the water flowing out through the dike breach

The dike breach on the right side bank of the Tisza between Tivadar and Tarpa happened early in the afternoon on 6th March 2001 at two locations, which later increased to the size of 110 cm and 145 cm respectively. On 9th March the water flowing through the breach was stopped. The mass of water having flown out of the riverbed was 140 million m^3. The water was spreading rapidly. Because of the high water stages it was not possible to open the Eszeny sluice, thus flood mitigation on the inundated areas was hindered.

From 9th March discharges were daily measured at 12 places along Road no. 41 and at 8 places along the highway between Tiszaadony and Barabás. Twice a day the size and location of the inundated areas was surveyed from the air by visual observation. Continuous water balance calculations were done for the changes of the storage in the three areas divided by the 2 highways. Comparing the results of water balance calculations with the results of visual observations, it can be concluded the two results very much correspond to each other. While renewing the Bereg localization plans in 2001-2002 sophisticated two dimension modelling was carried out. During this the Bereg flooding in 2001 was evaluated and modelled as well.

Measurements along the Tiszaadony - Barabás road	Discharge (m^3/s)
Dédai-Mitz canal	20
Water, overtopping the road	82
Csaronda canal (road crossing)	25
Cross-cutting number 2.	
Canal no.39. I.	4,0
Canal number 39. II.	3,0
Cross-cutting no. I. (14 m long)	4,2



Stream	Location of measurement along road no. 41.	discharge (m^3/s)
Szipa main canal	Csaroda village	64
	Road section 62+850 (r/w bridge)	36
Canal no. XIX.	Road section 62+700	2,0
	Road section 62+600 (croos-cutting no. II.)	42
	Center of Tákos village (canal)	20
	Center of Tákos village (canal)	1,5
	Drainage canal at Tákos (no. XX/1)	10
	Road section 58+100 (cross-cutting no. I.)	27
	Road section 57+800 (drainage canal)	26
Makócsa canal	Road section 56+800	30

Transferred discharges across Highway 41 and the Tiszaadony-Barabás road (m^3/sec) (based on the discharge taken on 09 March 2001).

II.4. Summary

- Causes of the unusually huge and intensive flood on the Upper-Tisza in March 2001: average 132 mm rainfall for three days; 70 mm plus melted snow-water; unfavourable, winter conditions of the surface in the catchment.

- On the Ukrainian and Romanian sections of the river, from Rahó to Tiszabecs, the peaks exceeded the highest ever-measured water stages (Rahó: by 75cm). Along the Hungarian section, between Tiszabecs and Záhony, the peak was also above the highest ever measured level (by 7-56cm), which had a 0.5-2.0% probability. The duration of the HEM stages was 14-38 hours.

- The discharge of 4190 m^3 /s at the Tivadar section is considered a record figure for the entirely Upper-Tisza. Unlike on the Mid-Tisza, on the Upper-Tisza not only the highest ever-measured water stages have risen, but also the peak discharges have been on the rise during the past decades. During the period of 1970-2001 at Tivadar the peak water stage rose by 1.5m and the flood peak discharge saw a 33% increase.

- Despite the above peaks, the peak water stages and discharges in March 2001 were lower than the possible highest water stage and discharge according to the geological features of the river.

- The mass of water flowing out through the two dike breaches on the right bank of the Tisza was 140 million m^3. Both the arial surveys that were made at the same time and the models prepared afterwards proved the correctness of the calculations and the correctness of the measures and arrangements that were based on them.

- Returning the water from the inundated area to the Tisza was possible partly through Channel Szipa but mainly through Eszenyi sluice. The drainage was largely hindered by the second flood wave running on the first one, because of which the sluice could be opened 8 days later than the average,

- Without the dike breaches the water stages would have been 0.5 m higher, at the same time the maximum discharge would have been 1000 m^3 more but in case of more unfavourable precipitation conditions and with larger snow water mass the peak water stages could have been higher and the peak discharges bigger. The simulations have shown the possibility of the same.

- Results of comparing analysis and probability calculations show that the volume of the Upper-Tisza flood in March 2001 have been unique in several aspects for the past 150 years which have passed since the river regulation. Despite of the above-mentioned fact, this flood cannot be considered as outstanding, for floods of similar volume can be expected in the future as well.

III. Flood management

III.1. Preparations for flood protection

We cannot specify a certain date as the beginning of preparations for flood management because it is a continuous activity. The following activities are part of the preparations: evaluating and analysing the process and the experience of the previous flood control; carrying out certain tasks based on the above analysis, monitoring and improving the flood protection system as a whole and in details, forming the protection organization, involving cooperating partners and putting the cooperation in practice. Among the big floods of the 1990s, the flood wave in November 1998 was an outstanding one. During this the highest ever-measured flood water level was measured on Hungarian section of the Upper-Tisza up to Lónya and in the mouth-area of its tributaries.

The experiences gained from the 1998 flood made the review of the study called *Development of the flood control system in the Upper-Tisza district* necessary. The *updated development study* was completed by 1999 by VIZITERV Consult Ltd., in close cooperation with the FETIVIZIG. According to an assessment covering the whole territory of the Upper-Tisza Water Directorate, the following were considered as most urgent: 111 sections of total length of 134.2 km with cumulative danger, out of which 34 sections with cumulative danger on the length of 46.8 km were located upstream Vásárosnamény.

In the territory belonging to the Upper-Tisza Water Directorate the total length of levee sections is 544.0 km, out of which 541.0 km is earth dike, 111 m is flood protection wall and 3.0 km is high bank. In March 2001, the height of 276 km flood protection dike did not reach the stipulated standard (design flood level + 1.0m), although due to accelerated dike reinforcement following the 1998 November flood, the length of the critical sections decreased by 29 km in two years time. A clear proof of the acceleration is the fact that only 6.4km dike was reinforced during the first two years of the development of the Upper-Tisza flood protection system. Along the levee sections controlled by the Upper-Tisza Water Directorate there are 162 structures and delivery pipe crossings, out of which the directorate maintains 128. The average age of the structures is 60-110 years. Some of the dike keepers' houses are 50-60 years old, while others were built after the 1970 flood (25-30 years ago) and a small proportion of the houses was built during the past years. The total number is 62 houses, with 11 wanting renovation or rebuilding. Protection material in sufficient quality and quantity; storage places for material and equipment required for flood management are available, meeting the stipulated standards set in the Flood and Drainage Regulation. The average age of the flood protection machinery exceeds 20 years. The VIZIG practically does not own any transportation vehicles or earth moving machines since the separation of the production units, so this type of machinery can be obtained from contractors only.

For interoffice communication within the directorate the so called ‘special purpose’ networks are used. Among these the UHF network is the strongest, which covers the whole operational area. Financed from Hungarian aid, basic stations of flood communication and remote sensing were installed in Ukraine in 1999, which provide faster and more accurate information exchange compared to the previous ones.

The technical coordination of flood control is carried out by the responsible directorate. The state administration functions, according to the regulations in force, are coordinated by the county protection board, of which the water directorate is member in case of flood control. The organization and operation protection unit of the water directorate is given in the Water Damage Prevention Regulation, where the decision making levels and responsibility hierarchy are precisely defined. From 1998 water damage prevention is organized according to the ISO 9002 quality control.

Besides the technical and legal background, the operation of the organization is largely determined by the personal conditions and by the qualification level, experience and required number of the employees involved. Due to administrative measures taken during the past years, the number of workers at the directorate participating in flood control has dropped to 345 by 2001. Thus, the directorate is not able to carry out flood control tasks even with the help of delegated water management forces, let alone with its own personnel. As a result, they had to involve extra capacity by frame contracts. In case of the March 2001 flood the work force belonging to the water directorate was 20-30% of the total taking part in the flood control. The same applies for the machinery and transportation vehicles. The Disaster Management, which has organized 9 complex flood control teams in our county, is a very good partner. There is very good relationship with representatives of the police and army forces as well.

At the directorates flood control squads with special training and equipment have been set up. The difficulty is, that the FETIVIZIG cannot supply the required transportation vehicles needed for flood control, so these have to be obtained through contracts. The total number of staff in the squad is 100, out of which 50 people are employees of the directorate, 48 people of the FETIVIZ Ltd., and 2 people have contracts.

III.2 Flood forecasting

The success and efficiency of the Upper-Tisza flood forecasting is highly influenced by the number, correctness and fast transfer of the measured data. In case of manual transfer (telephone, fax) of manually, off-line measured precipitation, water stage, discharge, evaporation and other data the flood management can experience a situation that there is no ample time for the immediate introduction of the flood control arrangements – also considering the time needed for the preparation of the actual forecast. Thus, during the 2001 flood, the information supplied by the on-line system partly installed but not completed in 2000 in cooperation by Hungary and Ukraine, had special importance. At that time in Trans-Carpathian there were only hydrological on-line stations in operation, most of the data had to be taken and collected manually. The off-line ground network was supplemented by: The meteorological radar in Nyíregyhaza-Napkor, the Meteosat satellite and the special precipitation quantity forecast supplied by the National Meteorological Services.

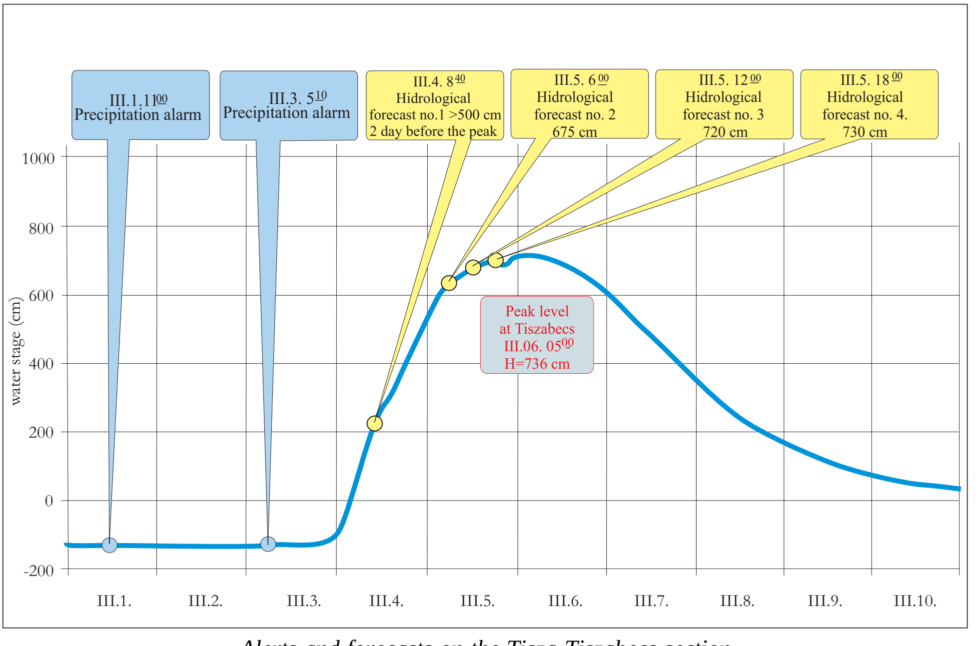
During the flood control in 2001 statistically based methods and methods elaborated in the past decades were mostly used. Later a forecasting model, called ‘EJEL’, based on numeric regression calculation was created at the Upper-Tisza Water Directorate. This model forecasts the floodwater stages and their expected time. This computer program is flexible and can be applied in any cases depending on the available data. Its input data can include both measured and estimated figures. This makes it possible to complete missing data and quickly assess various hypothetical situations.

During the 2001 flood, forecasting precipitation was the task of the National Meteorological Services exclusively while, according to the decentralization going on for years, the FETIVIZIG supplied the water stage forecasts for all the stations of the Upper-Tisza, in some cases consulting with the Water Resources Research Institute. The University of Technology of Budapest made some experimental hydrodynamical calculations and precipitation runoff modelling. The cooperation was excellent from all the partners.

The first warning about the expected large volume of precipitation came from the National Meteorological services on 3rd March, although this forecast gave far lower figures than the real precipitation was later (28% of the real). In contrast with the territorial average precipitation forecast of 10-20mm, at the beginning of the flood on 3rd March it was 57mm, on 4th 46mm. Taking the catchment in Ukraine, upstream Tivadar into consideration (where the flood situation was the most serious), the above proportion was even worse, for the forecasted figures (15mm) did not even reach the 25% of the real precipitation. The territorial average was 270% of the forecasted one from 2nd-5th March.

It can be concluded, that the territorial average precipitation forecasts for the Upper-Tisza supplied by the National Meteorological Services were useful from a warning point of view, however, they were not suitable as a basis of hydrological forecasting and especially not as a basis of operative flood control measures.

The first hydrological information and forecast was issued at 8.40, on 4th March by the experts of the Upper-Tisza Water Directorate, right after the first surge of the three-day precipitation in the Tisza river-head. Considering the uncertainty of the precipitation volume forecasts, only estimations could be done at that time. On 4th



Alerts and forecasts on the Tisza-Tiszabecs section

March the intensive precipitation continued and had another surge, so by the 5th morning it was obvious that the flood wave would be near the highest ever measured level on the upper sections of the Tisza. The forecast justifying *emergency preparedness* was issued at 12.00 on 5th March. Besides the Tisza the River Tur needed special attention as well, because of the expected peak water stage.

After reviewing all the hydrological forecasts issued during the flood, it can be concluded, that the Tiszabecs forecast was very good. It was suitable bases for the government to order emergency alert. The backwater effect upstream the Tivadar bridge section caused the flood wave to exceed the forecasted height by 14cm, to be precise it kept this height as long as the dike breach a few km downstream caused a sudden water level drop. The fact, that the water stages at Vásárosnamény and Záhony did not reach the forecasted value (although both remained in the confidence range), is due to the above mentioned dike breach. A further proof to this is, that the forecasts made for Záhony after the breach, remained within the range of +/- 15 cm.

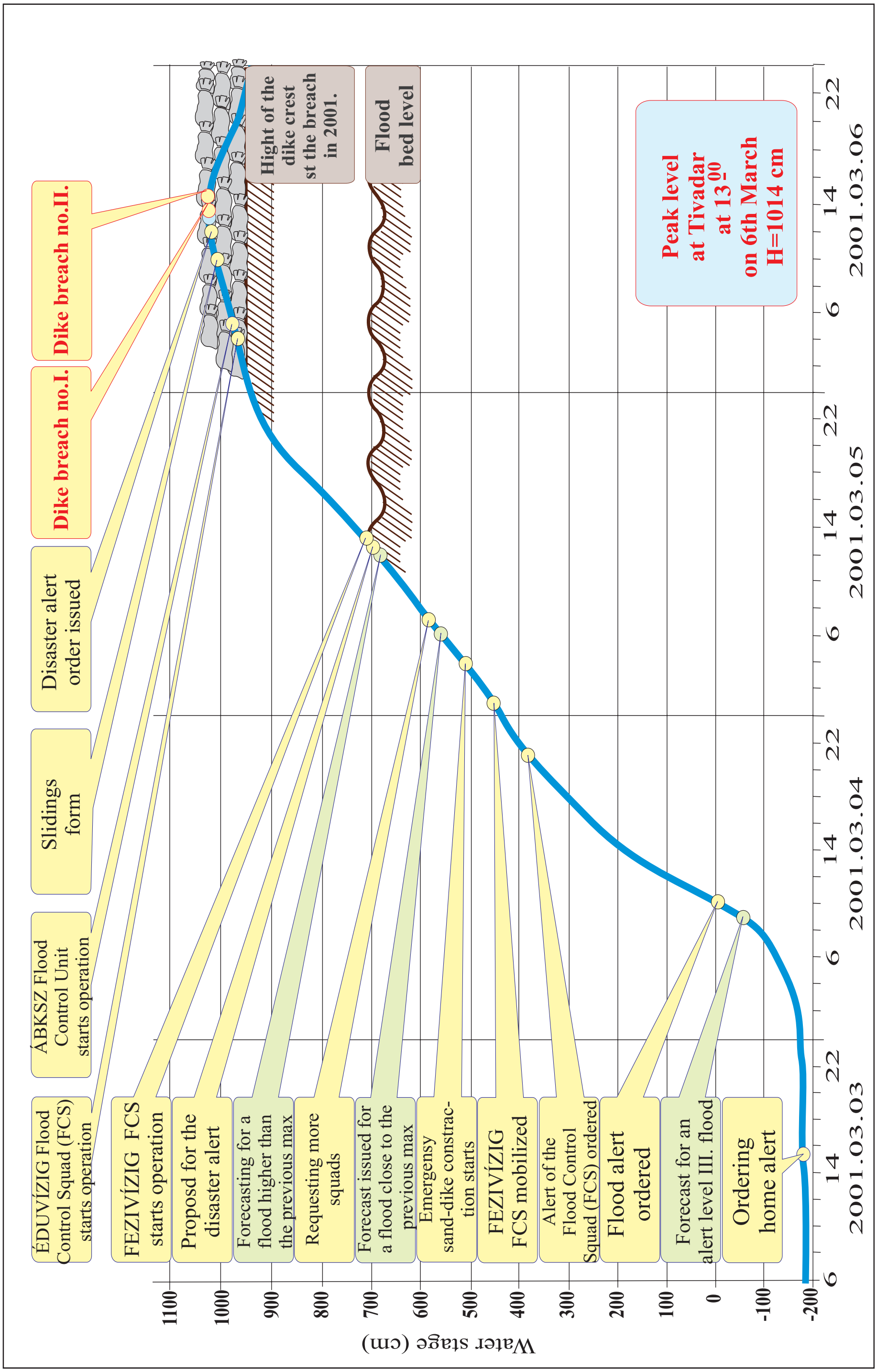
III.3. Flood control activities

A general review of flood control

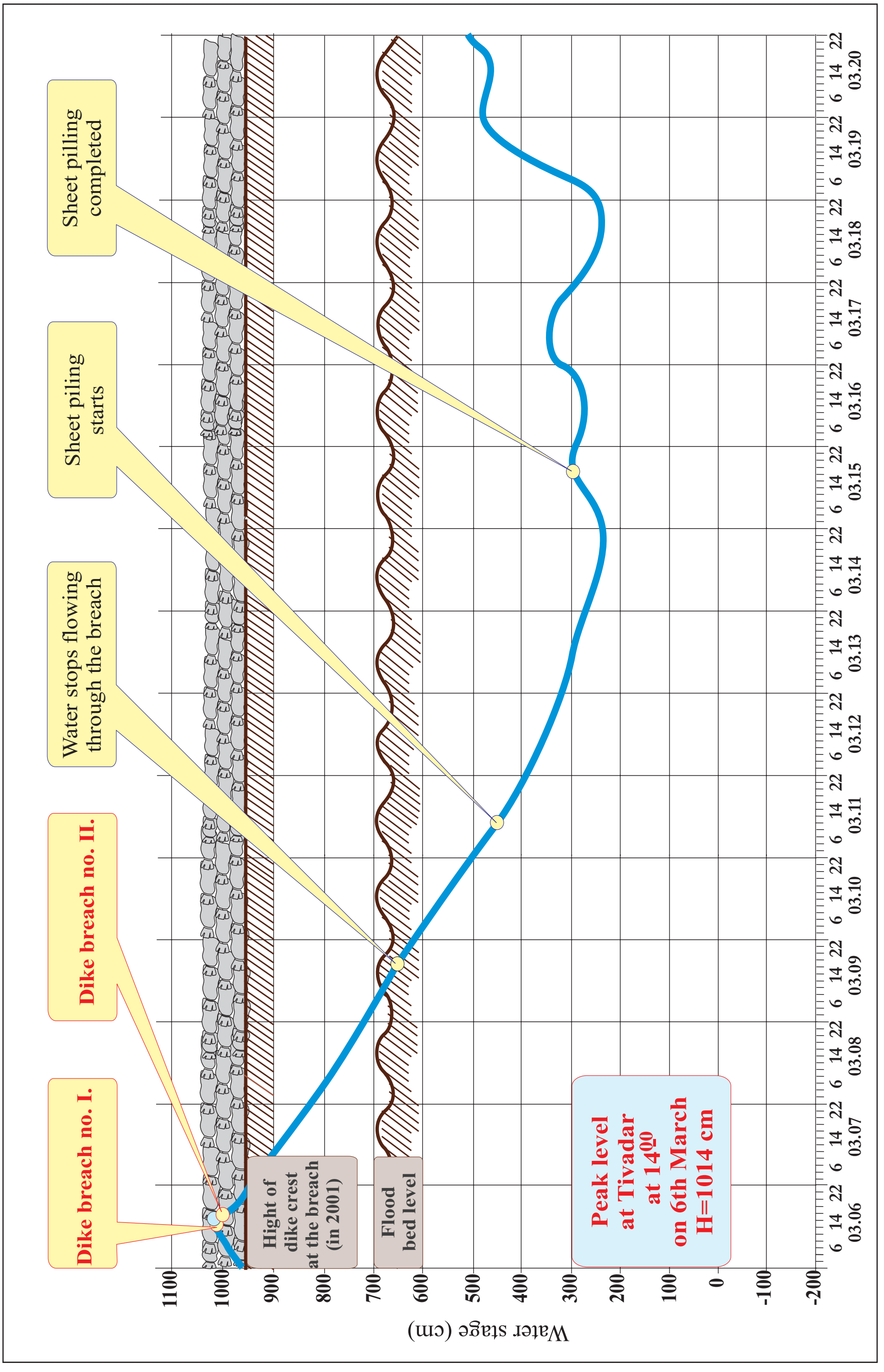
Based on the first precipitation forecasts of the National Meteorological Services it was likely that the Upper-Tisza water stages would reach the 1st grade alert level, so the director of the directorate ordered home-preparedness for the protection team on 3rd March. Based on the fresh water stage forecasts (3rd grade flood wave) at 10.00 on 4th March 1st grade flood alert was already introduced despite the 170cm water stage at Tiszabecs, which was still far below the 300 cm 1st grade alert stage. In the mean time collecting and assessing information coming from abroad was continuously done.

Being aware of the newest precipitation and water stage data from abroad the flood control commander ordered preparedness for the flood control squad of the directorate at 0.45 on 5th March. The squad left for Vásárosnamény, the flood control section leaders received the necessary instructions and assembling the Protection Board in the morning was initiated. Following the forecast at 6.00 a.m. the flood control management of the VIZIG asked the National Technical Coordinating Body (NTCB) for technical commanders, flood control squads and special teams. Based on the extreme flood wave forecast the NTCB ordered the flood control squads of the ÁBKSZ, ÉDUVIZIG, KDVVIZIG, ADUVIZIG, KDTVIZIG, TIVIZIG, KÖTIVIZIG, KÖVIZIG, ATIVIZIG to go to the spot and secured proper number of staff from every water directorate where there was no flood alert.

The first meeting of the County Protection Board took place at 9 o'clock on 5th March and ordered the flood control boards of Fehérgyarmat and Vásárosnamény to commence their activities from 16.00 5th March, and the mayors to double-check and correct the evacuation plans and to mobilize public forces, to get ready 9 complex teams of civil guards, to contact the army, to secure the roads for the transportation vehicles, for border crossing and for the arrival of the flood control squads.



Flood control measures compared to the flood hydrograph at Tivadar – I



Flood control measures compared to the flood hydrograph at Tivadar – II

On 5th March, based on the new precipitation and water stage data coming from abroad the forecast made certain, that upstream Záhony higher water than the highest ever measured water stages can be expected everywhere, so emergency alerts was initiated for the section at Tiszabecs-Záhony on the Tisza and for the flood region of the Szamos and Kraszna. At 12.00 on 6th March 2001 the government ordered emergency alert for the Záhony-Tiszabecs section on River Tisza and for the flood area of the Rivers Szamos and Kraszna, which was effected by backwater. Later, with retroactive effect emergency alert was ordered for River Tur as well. A length of 280.55 km of dikes was involved in the emergency alert.

Following the flood alert order the entire flood control organization of the directorate commenced preparations for fighting the forecasted flood wave. The section commanders and technical specialists took their positions, checked flood control stocks and the condition of the levees and informed the local governments about the situation to come. The Flood Control Committee arranged the transfer of stock, secured further equipment, human forces and machinery and informed the public. Keeping continuous contact with the national and foreign partners, the flood management made decisions and arrangements according to the changes of the flood situation.

Fresh forecasts made obvious that a bigger flood wave than that of 1998 could be expected. Thus, at dawn on 5th March extremely intensive protection activities commenced on the Tiszabecs-Vásárosnamény section of the Tisza, where the forecasted water stages mostly exceeded the highest ever measured level and the design water level and the dikes were in the poorest condition, the height deficiencies were the largest. As a result of the effort they managed to keep up with the rising water level by constructing emergency dikes to avoid the water overtopping the dikes and emergency dikes in large volume.

On the 07-08 Tarpa-Vásárosnamény section, on the right bank of the Tisza, where later dike breaches happened, the transportation of sand, filling and fixing sandbags already began at the time when the river was still in the riverbed. The flooding was extremely intensive, next day at noon the water levelled the height of the emergency dike, built from sandbags. Along the non-constructed Tarpa section at several places the slope on the protected side slid from the axis of the crest at some places. Prior to and at the same time with the sliding leakages appeared, however, they managed to stop them. The flood control forces tried to support the slidings, however, it was impossible to fix all of them due to their large number, rapid forming and the worsening conditions. At 13.30 at one sliding the crest suddenly collapsed and the water broke out to the protected side with a very big intensity and the

Process of the dike breach

dike breach was unavoidable. In an hour's time the water broke through at two other locations at the same time and in a short while the two break-through washed together and another breach happened. There was no chance to stop the water. At Tivadar the Tisza had its peak with 1014 cm water stage, which was 56 cm higher than the one in 1998 and 149 cm higher then water stage in 1970. Before the dike breach at 13 hrs 30 min on 6th March, a 30 km long emergency dike had been built along the upper section of the Tisza, in hardly more than a day. Five flood control squads with 234 workers, 9 teams of civil guards with 450 people, 1200 soldiers, 2600 human force, altogether 6000 people plus were working on the levee sections on 6th March. 150 local plus 180 partner water directorate employees carried out the technical management.

On the Vásárosnamény-Tokaj section and along the Lónya main canal, the flood-control-section leaders made preparations for the flood control expecting an above the highest ever measured floodwater stage. The flood wave had its peak at Vásárosnamény at 10.00 on 7th March, exceeding the highest ever- measured water stage by 18 cm. On the left and right side levees between Vásárosnamény and Záhony, at some places the water levelled or overtopped the crest and come 20-30 cm close to it along longer sections. To increase durability, it was important to fight other dangerous flood phenomenon such as soaking, softening. The height and cross-section deficiency of the dikes was obvious, and the difficult approach of the freebands along the feet of the dikes caused problems. Along the Vásárosnamény-Záhony high-bank section protection was also necessary, the highway was under water too. Similar difficulties occurred on the Záhony-Tiszabercel section, where the Záhony peak exceeded the highest ever measured water level at 6.00 on 9th March. The height of the dike here was sufficient. Emergency dikes were constructed mainly for prevention purposes along the Lónya main canal and along the joining main canals with not sufficiently high dikes and excess weight stone bands were built at dikes with small cross-sections.

A high, although not extreme flood wave formed on the River Tur as well, the peak at Garbolc was 66 cm lower than the highest ever-measured water stage. The flood control activities were organized according to the forecast. Special attention was given to the lower, mouth section, where due to backwater effect, higher than the highest ever-measured water stage could be expected. Being aware of this, along the lower dike sections emergency dikes were built to increase the height. The flood control situation on the Tur was greatly changed by the water flooding out through the dike breaches on the left bank of the Tisza in Ukraine, which having broken though the levee of the Batár in Ukraine poured into the basin of the Palád Creek. The unexpected, extremely large volume of water caused intensive flooding at the right side dike of the Palád, then passing it overtopped the dike. The overtopping could be ended only the next day, due to its intensity. The larger part of the water pouring from the Ukrainian dike breaches reached the flood wave on the Tur, as a result of this overtopping form on unexpected sections. At the 12+000 and 12+400 left sections where dead riverbeds crossed the levees, slidings formed. Despite the protection efforts, the dike later collapsed and overtopping formed. The overtopping did not completely wash the dikes away so it took a comparatively short time to close them.

On River Szamos an independent 2nd grade flood wave formed, thus there were no flood phenomena along the developed, upper sections. On the lower, mouth section, however, emergency preparedness was necessary, due to the backwater effect of the Tisza. The River Kraszna had no independent flood wave, emergency alert was ordered on its mouth section.

More than 15 000 people took part in the flood protection and confinement. The total expense of the water directorates was HUF 3 280 million. The damage done in the structures (dikes, roads, water regulation structures, buildings and drainage structures) under the supervision of the directorate was over 7 billion HUF.

During the damage assessment following the dike breach, the damage of more than 3200 buildings were registered. Based on the damage assessment, the Government of the Republic of Hungary took 100% responsibility, within defined framework, to compensate the damage from the central state budget, in a total value of HUF 32 billion. The reconstruction work was done by the BEREG RECONSTRUCTION COMPANY, which united 6 big building companies of 3 counties. Involving 240 contractors, 10 thousand people were working in the peak time. The reconstruction commenced on 8th May 2001 and it ended on 21st December.

Causes and circumstances of the dike breaches

According to the decree about flood- and drainage protection no. 10/1997. (17.07) KHVM 12§ (7) the leader of the National Technical Flood Control Committee commanded the formation of a Board of Experts at 20.20 on 6th March to identify the technical causes of the dike breaches, to record the circumstances of dike damages, to work out recommendations in order to avoid similar catastrophes in the future. The Board of Experts studied all the available technical and flood protection documentations, carried out local survey and soil tests, interviewed competent people in order to secure correct, reliable basis for its expert opinion. They had the following statements:

About the right bank breaches of the Tisza:

At sections where a series of slides cutting into the crest of the dike were observed…in the saturated zone of the reduced body of the dike through the reduced seepage length, the seepage gradient exceeded the critical value, therefore the dike crest breached. The causes of the breach were basically the pressure gradient in the structured body in the dike and subsidence of the earth body with nearly vertical borders. The length of the breach was 5-6 m at the beginning then gradually grew in length and depth and eventually it extended to 110 m and 140 m respectively. There was no chance at all to stop this process.

Summarizing the geo-technical problems the following constant conditions and immediately triggering factors can be listed:

- Constant conditions:
  - dikes with not described height,
  - loose, worn out dike body (this caused seepage factor, although the dike was constructed from proper material)
- Immediate, triggering, interactive factors, which resulted in the soaking of the dike on the protected side:
  - saturated dike body, due to previous precipitation,
  - seepage pressure, caused by extreme load,
  - emergency dike overtopping at places.

If we consider that the dike breach occurred 25-35 cm below the forecasted, but finally not formed, peak and calculate the possible force on the dike section and the forecasted height of the flood wave and the increased durability, we have to conclude that the dike breach would have been unavoidable even if it had been possible to keep the height of the emergency dike. As a consequence of the above, the dike breach was only a question of time."

About damages along River Tur: The cause of the unexpectedly high water stages along the mid- and lower sections of the Tur was the water pouring from the dike breach on the left bank of the Tisza at Bökény and Királyháza (altogether 150 million m3), which happened at 15.00 and 16.00 on 5th March. The water overtopped the right side dike of the Palád and radically increased its discharge. The fact, that the Palád carried big discharge into the Tur created a totally new situation for the flood control management, because it generally happens the other way round. The management of the flood on the Tur had to face an unexpected, serious situation because instead of the forecasted 3rd grade flood alert water stages, the water stages exceeded the highest ever-measured level. Due to this, on both sides of the River Tur and along 5.9km on the right side dike of the Palád Creek the height of the dike had to be increased by building emergency dikes in an extremely short time. We have to note, that without the intrusion of water from the Palád, with the forecasted peaks the construction of only a few hundred meters of emergency dikes would have been necessary, for which the flood management was fully prepared….

'On the left bank of the Tur ….. causes of the dike breach: an unmanageable overtopping occurred, due to several unexpected factors, which hindered the transportation of the necessary material to the critical places, which let to the loosening of the crest.

About the flood management measures taken by the water directorate: On the whole, the Water Directorate organized and controlled the flood protection, focusing on gaining and keeping the possible lead-time. The Directorate perfectly kept to the regulations both national and foreign tasks concerned. "

Protection work on the levee section after the dike breach

Before the possible arrival of a new flood wave, which could be expected based on the volume of the precipitation forecasted, the reconstruction work on the badly damaged dikes had to be done to restore their protection capacity after the breach.

The dikes were so badly damaged at the breaches, slidings, overtoppings and at their vicinity, that the leader of the National Technical Flood Control Committee ordered their immediate reconstruction (8.05 km on the right bank of the Tisza, 1.9 km on the left bank of the Tur). The restoration of the protection capacity happened in order of importance in the following steps:

- – block openings from breaches and overtoppings, provisional supportation at slidings.
- – construct permanent earth structure.

The restoration of the earth structures took place after the cease of flood control, in the framework of separate contracts. During the construction the provisional structures were demolished according to the plans of the construction.

With the help of provisional structures (containers, sandbags) the overtoppings on the Tur were terminated at 8.00 on 9th March at 12+000 dike-km with 46 cm, and on 10th March at 12+400 dike-km with 56 cm water level difference. The blockage was made on 11th March at 12+000 dike-km by CS2M sheets on a length of 36 m and on 12th March at 12+400 on a length of 65 m by LARSEN sheets. The designs were made by VIZITERV Consult Ltd. Later the parts behind the sheet piling was supported by stone-bags.

At the Tarpa dike breaches the stabilization of the dike edges could begin on 8th and 9th March. By 12.00 and 16.30 they managed to block the pouring water by building in sandbags and containers filled with stones, which were delivered to the spot by helicopters. After the dike breaches happened, possible ways of blockage were considered immediately. The designs of the blockages were made by VIZITERV Consult Ltd., after consultations with several experts. The aim of the proposal was to find the possibly most efficient and most urgent way for the blockage. Its main point was to consider uncertainties caused by the weather, the condition of the dike, the approachability. Parallel operations started and they were designed to be useful for the final dike construction even if they may have proved to be unsuccessful at the moment.

- Cut down the top of the dike to 1.5 m height in the vicinity of the edges, fill the gap, and dry up the depression.
- Transport sheet piling to the location of the breach, prepare sheet-piling work.
- Examine the dike material and its condition, prepare borrow sites (Kisar).
- Transport and deposit other building material (TERFIL, sand-gravel, crushed stones).
- Construct approaching road. The construction of the road along the foot of the dike was done from two directions.

Completed blockage by sheet piling at 12+000 left bank section of the Tur

Completed blockage by sheet piling at 12+400 left bank section of the Tur

Sheet piling of the downstream dike breach

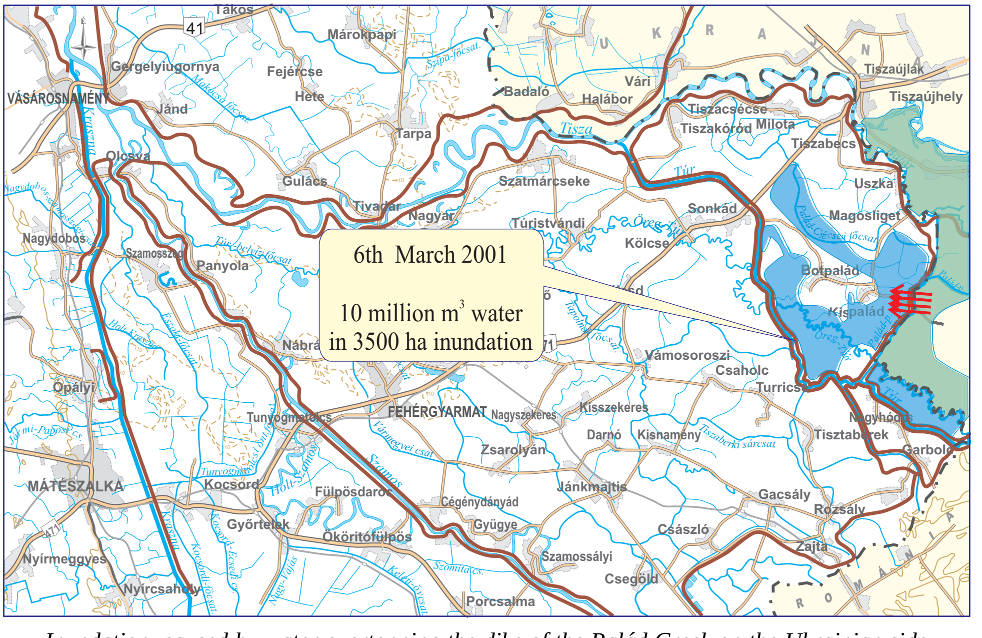
Efforts did not cease at night

The design was approved by the National Technical Flood Control Committee, the implementation immediately began. Sheet piling work commenced on 11th March and the provisional blockage of the breaches with LARSEN sheets was completed in record time thanks to hard and organized efforts of flood control squads ordered to the spot (ÁBKSZ, ÉDUVIZIG, KÖVIZIG). It was completed by 14.00 on 14th March and 16.00 on 15th March.

Besides the openings caused by breaches, at the time of the flood wave 14 slidings formed along the Tivadar-Tarpa section on the right bank of the Tisza. During the flood control there was no possibility for complete supporting so their reinforcement had to start immediately, could not wait until the final reconstruction of the section because it took a long time and in the meantime another flood wave was likely to form. The work was done by the FETIVIZIG flood control squad, with the help of army forces. The supporting work began on 10th March and ended on 17th March.

Confinement in the area between the Tisza and Szamos

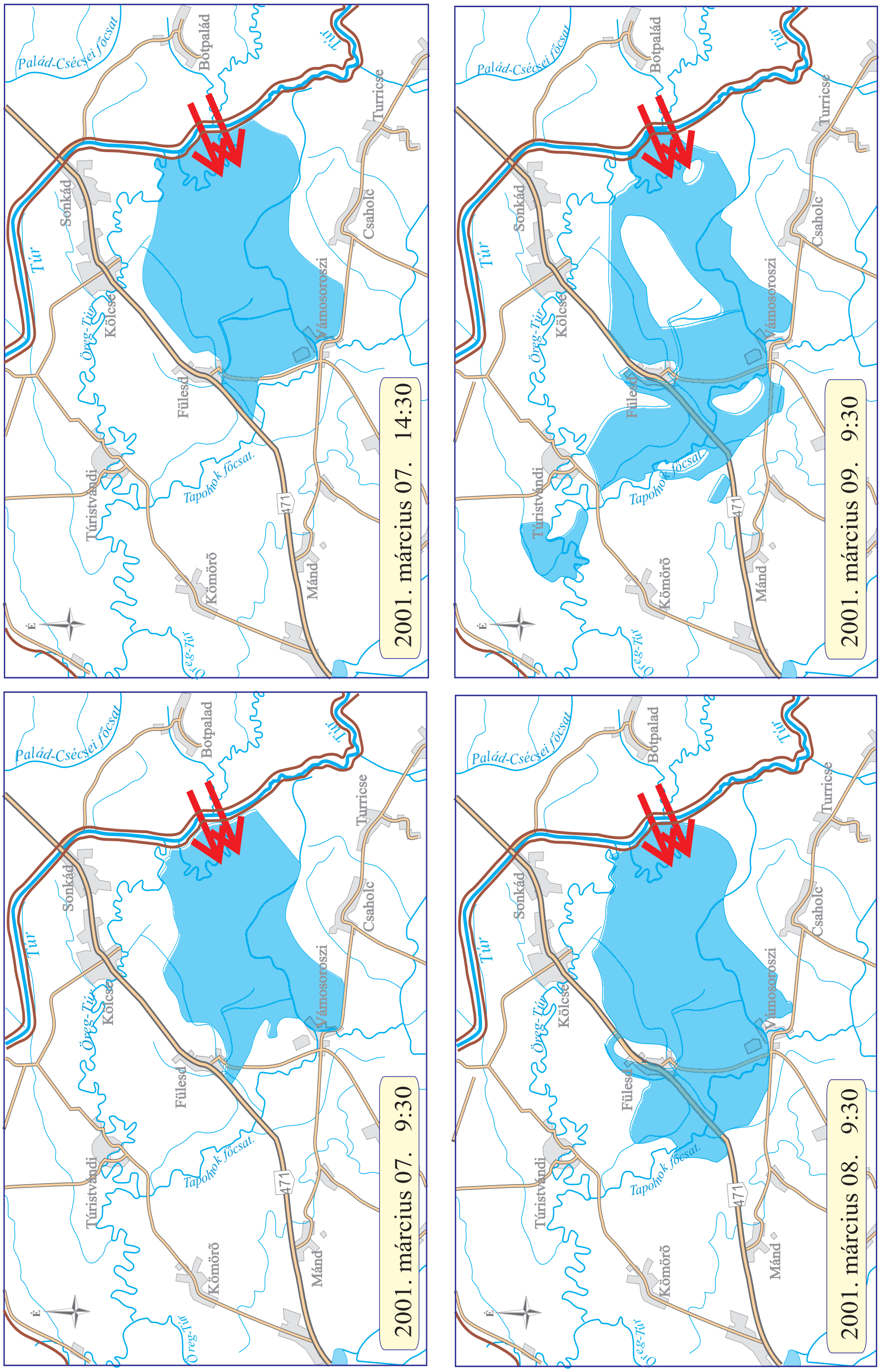
The water coming from the Ukrainian dike breaches broke into the Palád Basin and caused rapid water stage rise on the right side dike of the Palád. Then, making protection activities impossible at sections 5+100-6+423 the water overtopped the



Inundation, caused by water overtopping the dike of the Palád Creek on the Ukrainian side

Helicopters assisted at the construction of the excess weight stone band

Constructing excess weight stone band with the help of the army



Inundation due to dike subsidence on the left bank of the Tur at Sonkád crest and was pouring at heights of 10-50 cm for 50 hours, however, it did not breach the dike, only badly damaged it. Approximately 10 million m^3 poured over the dike, which later flooded an area of 3500 hectare. The returning of the pouring water at the mouth of the Lower-Old-Tur was done with 5 portable pumps until the wheel-sluice was opened and then from 10th March gravity drainage was done from 10th March through the Tiszakóród sluice and from 11th is through the wheel-sluice.

According to later calculations, 10-12 million m^3 water poured out through the two openings on the left bank of the Tur. Following the pouring, the water spread out in the flood region. Then, following the natural slope of the area, it started flowing towards the Tur-drainage-canal. The main direction of the spreading affected Fülesd and Vámosoroszi. Confinement structures were made here too. In lower areas confinement line was constructed to protect Túristvándi, Kömörő and Nagyar. The outpoured water reached the Tapolnok main canal, through which it got into the Tur-drainage-canal after flooding agricultural areas along the dike. From the Tur-drainage-canal the water could be directed to 'Petőfi-sluice' at Nagyar and to 'Kövessy Győző-sluice' at Olcsvaapáti. Because of the high water of the Tisza the sluices were closed, so 7 portable pumps with the capacity of 500 l/sec were installed at Olcsvaapáti, which were operating from 8th-10th March. On 10 March both sluices were opened, which made further pumping unnecessary, at the same time resulted in major recession on the main canals and in the inundated areas. Due to the recession, on 14th March they were able to begin demolishing the provisional dikes, protecting the villages.

Confinement in the Bereg Region

Following the dike breaches, the director of the Water Directorate initiated the evacuation of certain Bereg settlements. According to the resolutions of the president of the County Protection Committee, the evacuation of 20 settlements in two phases was ordered. Besides the evacuation arrangements, uncovered gas-pipes at the dike breaches had to be taken care of, arrangements had to be done for banning traffic other than flood control forces on highway 41, for preparations for disinfections, for saving valuable belongings from collapsed or badly damaged houses, for necessary vaccinations and for handling carcasses.

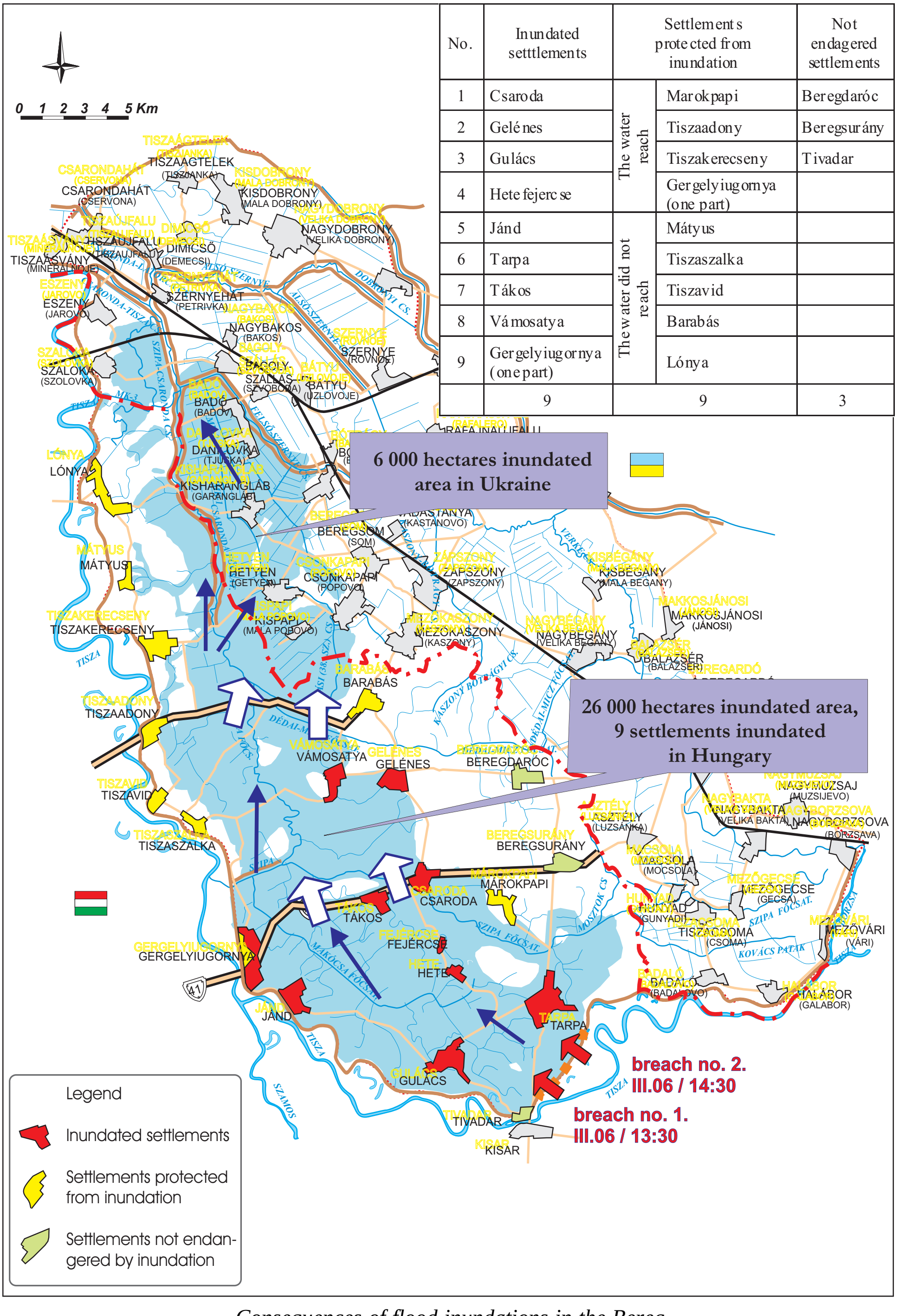
The Water Directorate made hydraulic calculations of the water pouring through the dike breach as a basis of the designs for technical activities. It was calculated, that a total of 120-140 million m3 water poured through the breaches. The outpouring water broke into Tarpa, Gulács, Hetefejércse and Jánd. Due to the lack of time it was impossible to carry out confinement in the above settlements. On 7th March, with the coordination of the Water Directorate material supply was organized, and with the help of the personnel that remained there, it was possible to prevent the water from getting into Márokpapi. The construction of confinement lines at Gergelyiugornya, Tiszaszalka, Tiszavid, Tiszaadony, Tiszakercseny, Mátyus and Lónya commenced.

The flood control squad of the FETIVIZIG established a central sandbag filling site in Vásárosnamény. Filling sandbags was continuously done, day and night, with the help of the military forces. They supplied sandbags for protection and confinement activities from this site. Installation of portable pumps at Tiszaszalka began in order to enable the returning of the water at the mouth of the Szipa Canal, prior to the opening of the sluice. Until the opening of the sluice on 11th March, the permanent pump-station and the portable pumps were in constant operation.
The water pouring through the breaches reached the second confinement line that is Highway 41 on 7th March in the morning. While the storage capacity of the confinement area upstream the road was about 70 m3, the volume of the pouring water was 120-140 m3. It was obvious, that the level of the water would be much higher than the road and would damage it along a long section, making transportation impossible. In order to keep the propagation of the water under control, the road was cut through on a length of 15 m each at the following locations: At both sides of Tákos Village, that is on the Csaroda side at 62+500 at 01.00 o'clock on 8th March, then along the Tákos-Gergelyiugornya road section at 58+200 at 02.30. Provisional bridges were constructed over the gaps, which secured sufficient access to the flood stricken settlements.

The water, which was pouring through Highway 41, followed the Makócsa-, Szipa- and Csaronda Canals to proceed towards the lower areas of the drainage basin. Then it followed the gradient of the terrain and the Csaronda and Dédai-Mitz Canals. The water started to flow on the terrain, over depressions and dead river beds across the frontier to Ukraine, where it accumulated in the area closed by the right side dike of the Csaronda and the left side dike of the Upper-Szernye, and caused remarkable flooding. The rest of the water poured over the Tiszakerecseny-Hetyen road and along the left side dike of the Csaronda and along low areas it reached Lónya, where it was blocked by the Lónya-haranglab road.

The water pouring from the dike breach flooded a maximum of 26 000 hectare area in Hungary and 6000 hectares in Ukraine. Out of the 20 settlements of Bereg 9 was inundated (Csaroda, Gelénes, Gulács, Hetefejércse, Jánd, Tarpa, Tákos, Vámosatya and parts of Gergelyiugornya). Four settlements (Márokpapi, Tiszaadony,

No.	Inundated setttlements		Settlements protected from inundation	Not endagered settlements
1	Csaroda	The water reach	Marokpapi	Beregdaróc
2	Gelénes		Tiszaadony	Beregsurány
3	Gulács		Tiszakerecseny	Tivadar
4	Hetefejercse		Gergelyiugornya (one part)	
5	Jánd	The water did not reach	Mátyus	
6	Tarpa		Tiszaszalka	
7	Tákos		Tiszavid	
8	Vámosatya		Barabás	
9	Gergelyiugornya (one part)		Lónya	
	9		9	3



Consequences of flood inundations in the Bereg

Tiszakerecseny and parts of Gergelyiugornya) were protected by provisional structures and the water reached them, 5 settlements (Mátyus, Tiszaszalka, Tiszavid, Barabás, Lónya), which were protected by provisional structures, were not reached by the water. Three settlements (Beregdaróc, Beregsurány, Tivadar) finally were not in danger of inundation.

During the flood, information exchange and technical assistance, beyond the regulations prescribed in the Frontier Water Agreement, was continuous between the Hungarian and Ukrainian authorities. Seeing the outstanding danger of flood the experts of the two countries joined their forces in their efforts. Lónya could be approached only from the direction of Ukraine, so the Water Management organizations there helped with the construction of the confinement line, by supplying machinery and material. The Hungarians assisted in decreasing the water-load in Ukrainian territory and in returning the water.

III.4 Summary of experiences

The official final report about flood control summarized *the most significant experiences and recommendations* as follows

- Despite the extremely short time, the Water Directorates were able to supply the commanding staff, the flood control squads and the necessary material.
- All the dike breaches occurred at placed that did not meet the regulated standard or were undeveloped.
- The flood information- and on-line sensing system operated well.
- The cooperation and the relationship with the experts of the neighbouring countries were exemplary.
- The well-organized staff and special equipment of the army is indispensable in case of flood control of this size.
- Flood risk in this area can only be reduced by constructing protecting structures that meet the regulated standard, and the entire infrastructure of flood management is updated in the near future.
- The forecasts were correct, so the flood control committee of the Water Directorate and the Protection Committee was able to take necessary steps, far before the flood wave reached the stipulated level.
- The flood protection dikes were in good condition from a maintenance point of view.

- In case of newly built dikes, traffic and transportation was impossible on the crest (even walking was difficult). There were no phenomena (seepage, etc) on such dikes.
- It is necessary to develop dikes with height deficiency at the mouth section of the Tur and construct emergency reservoirs. The dike of the Palád Creek was destroyed, so its development and extensive construction is necessary as well.
- The loading on the Lónyay main canal was lower than in the previous years due to flood wave attenuation, however, here too, extensive flood control was necessary. The construction of floodgate is still necessary.

Most important measures to be taken in the future

- Development of measuring, monitoring, data transfer, forecasting and alert systems
- Assessing effects and possibilities in connection with forest coverage and water storage.
- Development of forecasting methods
- Renovate damaged objects, continue development, and evaluate experiences.

IV. Flood management development programs on the Upper-Tisza after the 2001 Bereg flood

IV.1. Development of the flood protection dike system and its supplements

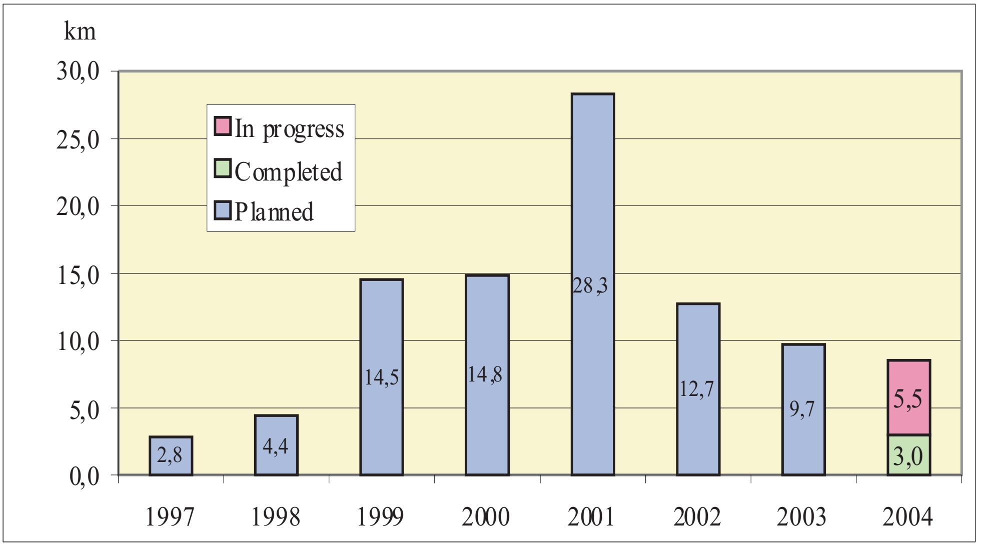
The dike system in the Tisza Basin together with its supplements, which were constructed during the past 150 years, still remain the most important tools of flood management. Levee reinforcement and raising have always been continuous activities. In the territory under the supervision of the Upper-Tisza Water Directorate there is altogether 544.0 km levee, out of which 544.1 km is earth dike, 0.1 km flood prevention wall and 3.0 km high bank.

During the past decade the general assessment of the Upper-Tisza dike system was done in 1996, following the 1993 and 1995 Christmas flood waves. Based on this the latest flood management development program began in 1997. Right at the beginning of the above program, in November 1998 a huge flood wave occurred, exceeding the highest ever measured water stage at several Hungarian and foreign gauges. Based on the observations of the November 1998 flood, the 1996 flood management concept was reviewed and modified as required. The 1998 and the present development programs are based on the above study.

The most important statements and recommendations of the study:
'The propagation of the 1998 flood practically proved the statements of the (original) 1996 study. It is remarkable, that at Tivadar, where the flood water stage exceeded the highest ever measured water stage by 99 cm, there would have been 66 cm left to the crest for safety if the dike had been built on the mentioned section The most important flood protection activities were necessary along those sections the reconstruction of which had been ranked as most urgent. Thus, our opinion is, that the flood management development plan be based on the previous plans, supported by overview of the November, 1998 flood.'

Results of the development program so far

As a result of the development that started in 1997, the condition of the flood management has improved. *From 1997-2004 the reinforcement of a total of 86.20 km dike was completed*, however, 44 km still remained urgently to be done. The reinforcement of the remaining 130 km is important as well. Presently (in 2004) 35% of the total flood protection dikes is lower than it is required. From the flood management point of view, river regulation is also important. There are 26 sections on the



Accomplished dike developments

Tisza and 4 sections on the Szamos with urgent need for construction or reconstruction of bank protection. From 1998-2004, 18 bands were fixed.

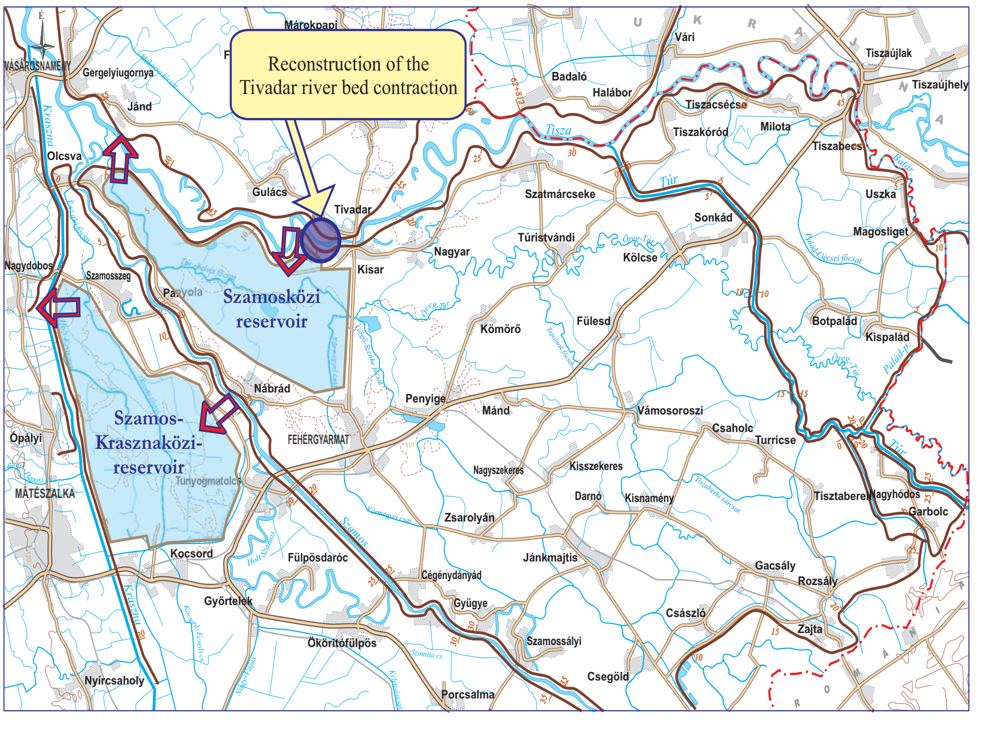
The targets of the flood management development program for the next 3 years (2004–2006) are summarized in the 3rd phase of the plan as follows:

- constructing the total flood protection system in the Bereg Basin between Jánd and Lónya (38 km),
- developing the Tur flood protection system, constructing the levee section at the mouth and the Upper-Tur reservoir,
- constructing 0.4 km dike at Tiszaszentmárton on the left bank of the Tisza,
- developing the flood protection system of the Lónya main canal by constructing the flood gate,
- updating all the elements of flood management infrastructure (sluices, flood management centres, information network, bank protection),
- preparing a study on the development of the flood protection section between Zsurk-Vásárosnamény.

For the implementation of the above from 2004-2006, 15-16 billion HUF is needed, (calculated on 2002 prices). For the completion of the program further 29 billion is necessary.

IV.2. Elaboration of Vásárhelyi Plan, element of the Plan concerning the Upper-Tisza (VTT)

The concept to increase the flood-safety in the Tisza Basin is based on the system, which was designed by Pál Vásárhelyi and was implemented in the 19th century. The present plan further develops the above by storing surpass water at certain places in the flood plain at exceedingly dangerous areas, providing opportunity for new development perspectives and a new type landscape management. Corresponding with the VTT national flood protection development, it focuses on two areas to improve the flood-safety along the Tisza: on the one hand *improving the discharge capacity of the high-water bed*, on the other hand *constructing floodway reservoirs*. In the plans of the 2004-2007 implementation program, the construction of the Cigánd-Tiszakarádi, Szamos-Krasznaközi, Nagykunsági, Hanyi-Tiszasülyi and Tiszaroffi floodway reservoirs, and the implementation of the 1st phase of the Nagykörü reservoir was recommended. At its 15th October 2003 session the Government made a decision on the territorial expansion of the 1st phase and the content of activities serving flood safety *[1107/2003.(09.05) Government Resolution].*



Elaboration of the Vásárhelyi Plan for the elements of the Upper-Tisza

Upper-Tisza elements of the elaboration of Vásárhelyi Plan

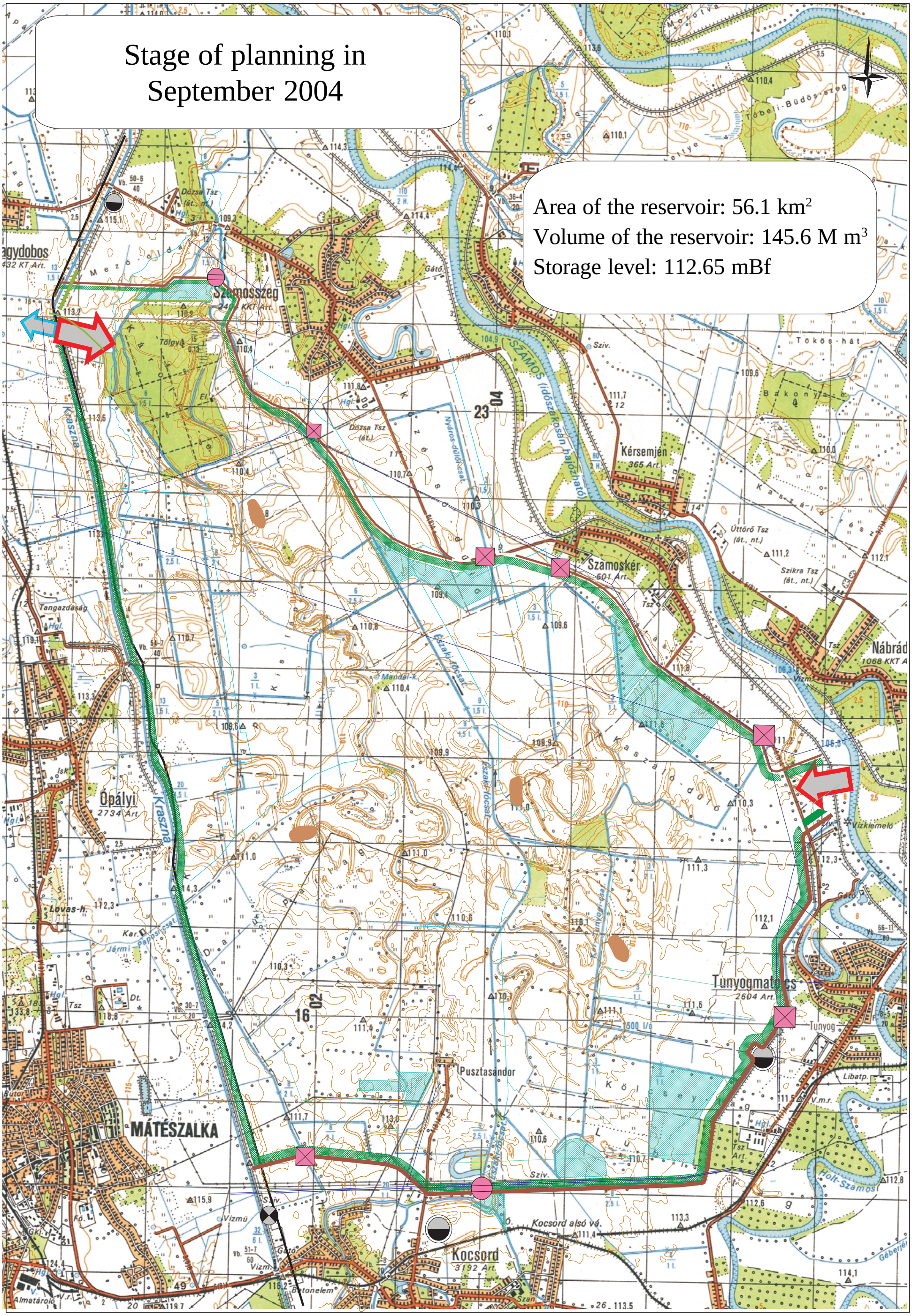
During the preparation work of the 'elaboration of the Vásárhelyi Plan' the possibility of the construction of three Upper-Tisza floodway reservoirs and the widening of narrow riverbed in the Tivadar region was examined. So far the feasibility of the implementation of Szamosközi and Szamos-Krasznaközi reservoirs has been evaluated, the possible Bereg storage was evaluated just as a concept. While the residents of the settlements in the Szamos-Krasznaköz welcomed and supported the construction of the reservoir, the residents in the Szamosköz rejected the idea. As a result of the above mentioned situation, only the construction of the Szamos-Krasznaközi floodway reservoir could be included in the 1st phase of the national program.

According to the plans of September 2004, from the west side the existing dike on the right bank of the Kraszna borders the Szamos-Krasznaközi floodway reservoir, while from the other directions it is bordered by the dikes in a distance from the settlements. The drainage structure is located in the right side dike of the Kraszna, opposite Nagydobos. Besides the drainage structure the construction of an emergency spillway is planned.

According to the September-October 2003 plans *(proposals for negotiations with the residents),* the borders of the Szamosközi reservoir would be: from the north direction the left side dike of the Tisza, from south-west and south the dike planned for the protection of Olcsvaapáti, Panyola, Kérsemjén, Nábrád and Fehérgyarmat. A fix opening place upstream Kisar, constructed into the left side dike of the Tisza would serve the filling up of the reservoir. Drainage to the Tisza would be done through the drainage structure, reconstructed from the existing sluice at Olcsvaapáti. Besides the drainage structure the construction of a spillway is planned.

From the *modelling experiments concerning* the Upper-Tisza, the following can be emphasized:

- The flood water stage decreasing effect of the Szamosközi and Szamos-Krasznaközi reservoirs (with approximately the same capacity) is approximately the same along the section of the Tisza downstream the Szamos mouth.
- The effect of the Szamosközi reservoir on the Tivadar contraction is significant. At the Tivadar bridge it exceeds 40 cm.
- The effect of the Szamos-Krasznaközi reservoir on the Tivadar contraction is far less significant, however, it is still more than 10 cm at the Tivadar bridge.
- The united effect of the Szamosközi-, Szamos-Krasznaközi-, Cigándi-, and Tiszakarádi reservoirs is about 60-70 cm along the Tivadar-Tokaj section.



General plan of the Szamos-Krasznaközi reservoir

Increasing the hydraulic conductivity of the Tivadar contraction

Due to the high-water contraction on the Tisza significant flood water level increase and unfavourable current conditions were observed in the vicinity of the Tivadar bridge. This has to be handled urgently. The results of modelling experiments show, that the water stage decreasing effect of the planned activities along the section at Tivadar reaches 20 cm (starting 7 km downstream the Tivadar bridge, it is gradually increasing as far as Tivadar). About 8 km upstream Tivadar it is as high as 30 cm and even 22 km far (near Tiszakóród) it is 17 cm. We can conclude, that the results of the calculations justify the implementation of the plans as soon as possible.

IV.3 Updating the confinement plans of the Bereg flood plain

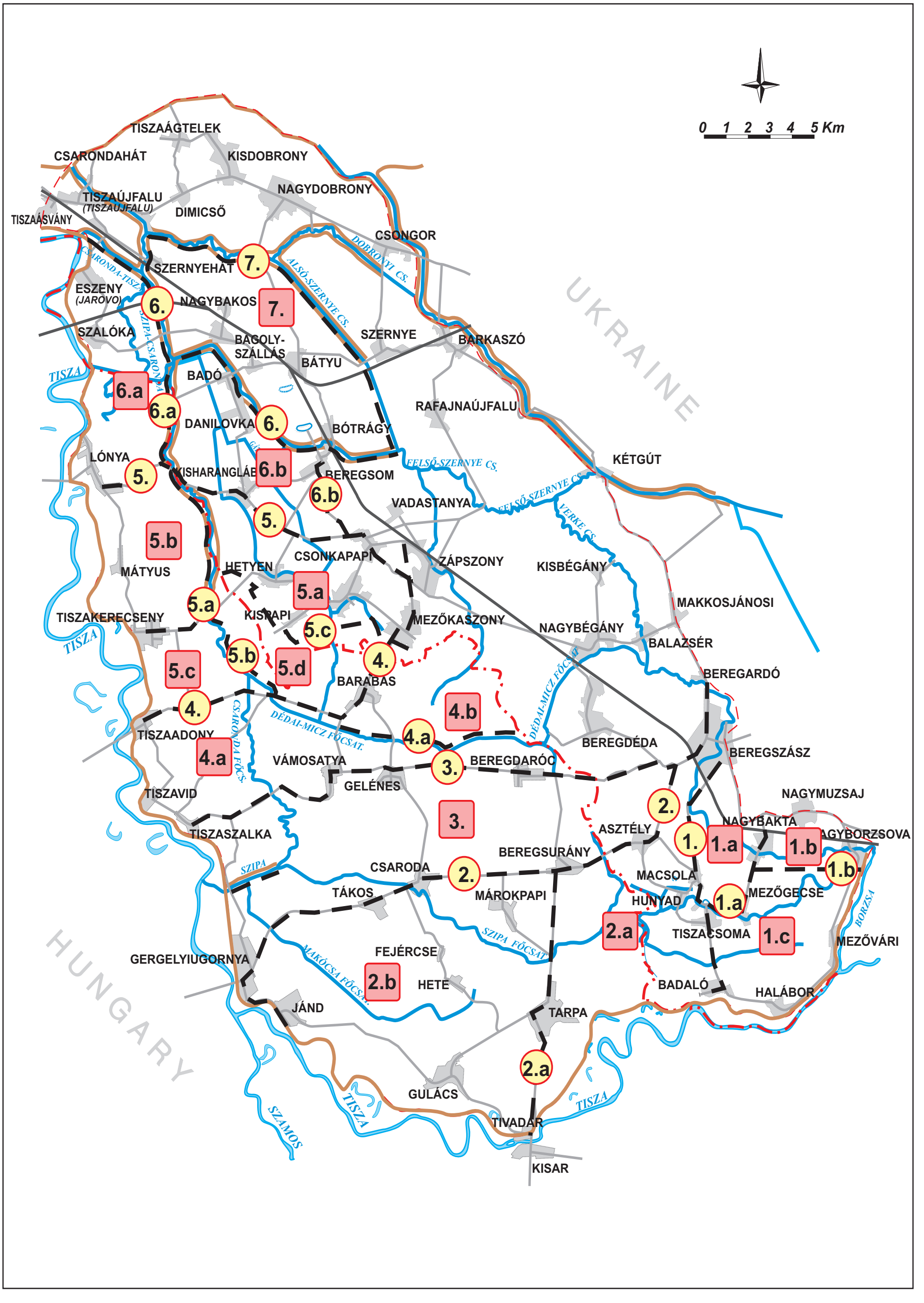
The observations of the confinement following the dike breaches in the Tarpa region in the Bereg flood plain at 13.30 and 14.30 respectively on 6th March 2001, clearly and repeatedly proved, that having confinement plans is essential for the water management service organizations.
Prior to the elaboration of the new plans a guide of methodology was prepared which during the planning activity was further developed in many aspects. The plan has three connecting parts:

- Technical description
- A set of appendices
- A data base of connecting documents helping the implementation (maps, detailed calculation of inundation modelling)

The plan was completed both in a printed and computerized way. *Mainly its computerized usage is effective.* The computerized usage of the plan can be done in two ways: it operates as a text oriented database; *or it can be used with ArcView GIS program.* The major basis of the inundation modelling plan was *the united Hungarian-Ukrainian M=1:10 000 rastered and vectorgraphical map library.*

The elaboration of concrete regional confinement variations was supported by two-dimension inundation models, which were made *based on 16 pre-written, characteristic dike breach-inundation scenarios.* The content of the scenarios included the experiences of previous confinements and the features of the area.

Having the plan, the definition of the tasks to be done about regional confinement and settlement protection can be done in two ways:



Possible confinement and detention lines in the shared Hungarian-Ukrainian flood plain in the Bereg

a. The dike breach-inundation scenario resembling most the real situation must be selected. After identifying the differences between the real situation and the scenario, *the recommendations from appendix VI.2.1 and VI.2.2 are to be followed.* So *the content of the action plan can be immediately defined:* actions to be taken about the confinement lines, order of possible evacuation, time given for evacuation in each settlement, possibilities for protecting the settlements, route of the evacuation, recommended location of returning water. The time required to prepare the action plan in this manner is 2-4 hours.
b. Having taken the steps detailed in point a), the previously elaborated and accepted action plan can be corrected (by immediate, further modelling), then the next step is to analyse the new data. Provided relevant information and software is available, the additional specifying model calculations, based on maps and the database of the plan, require 4-6 hours.

The new confinement will be efficient if it is continuously updated and if it is legally validated.

IV.4 Development of the Upper-Tisza region forecasting system

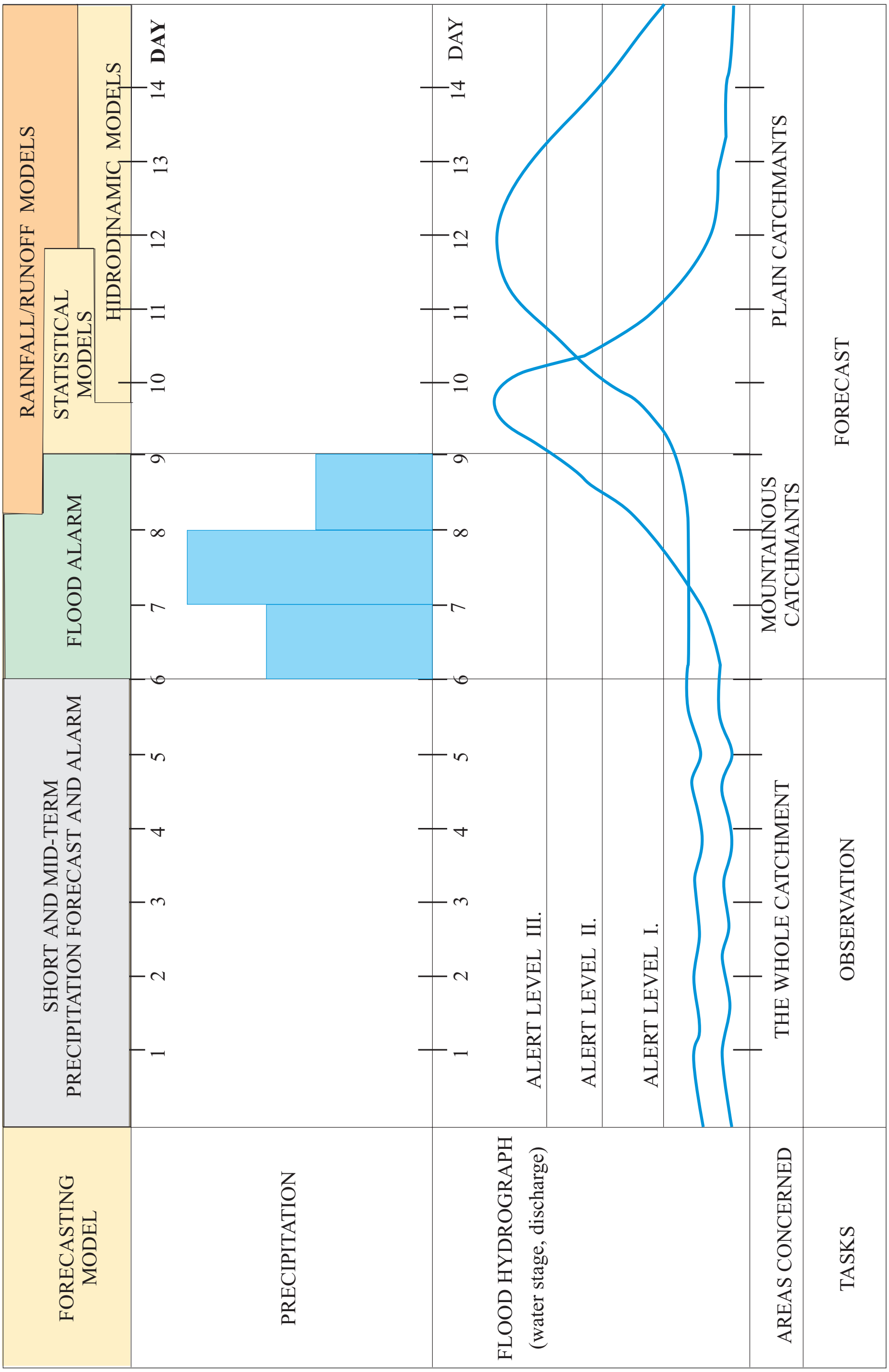
From 2001–2004 a comprehensive mid-term development plan was prepared for the entire catchment of the Upper-Tisza and various methodological development took place.

The mid-term development program recommends the coordinated developments of the element of the system and at the same rate. The core of the concept: reliable warning, alert and forecast with proper lead-time can be produced only by coordinated and complex development of all the elements of the information system. The content of development program concerning individual elements:

– The density of *manual stations* in Romania is satisfactory; there is no need to install new stations. At the same time, the content of hydrological data exchange must be extended. In Ukraine extensive extension of manual stations is necessary.
– *On-line stations* are required mainly for alert, warning, increasing the flood lead-time and for calibration of the precipitation field, measured by the meteorological radar. This means that most of the on-line stations have to be installed at mountainous part of the catchment and along up-

per river sections. Even spreading is important, according to the altitude of the region.

– *In connection with the meteorological radars* the concept recommends:
  - Creating a regional radar-meteorological network, which covers the entire catchment and its operation is coordinated.
  - Accelerating the change of the Nyíregyháza-Napkor radar and that the program is to cover hydrological usage development as well.
  - Using the domestic and foreign on-line precipitation network for continuous real-time calibration of radar precipitation fields.
– *Recommended development program* for remote sensing:
  - Obtaining the new version of the METEOSAT dealing with analogue pictures;
  - Overtake meteorological products from the National Meteorological Services, produced from MSG and NOAA digital broadcast.
– *Development of meteorological services:* during the years to come the National Hydrological Services are planning the following development of the ALADIN model linked to hydrological functions: further development of the non-hydrostatic version of the model, specification of the starting conditions of the model by developing and applying three-dimension variation analysis techniques (3D VAR).
– In the framework of methodology development two precipitation runoff forecasting models were tested and the EJEL regression model was further developed. The regression model performed very well in practical situations. The tested precipitation runoff models proved to be useful for preparation of water stage and discharge forecasts. The reliability of the forecasts met the expectations, however, did not meet the expectations of accuracy.
– The operation and supervision of the information system, the regular observation and analysis of the data on the Upper-Tisza requires 24 hour supervisory services. This has to be capable of continuous coordination of information technology sub-systems and issuing, receiving, and reading alerts and warnings.
– The development of the measuring network, information technology and methodology elaborated in the concept can only be efficient with international cooperation. The organisational framework of the implementation does not exist at the moment, those have to be created.



Methodological development concept of flood forecasting

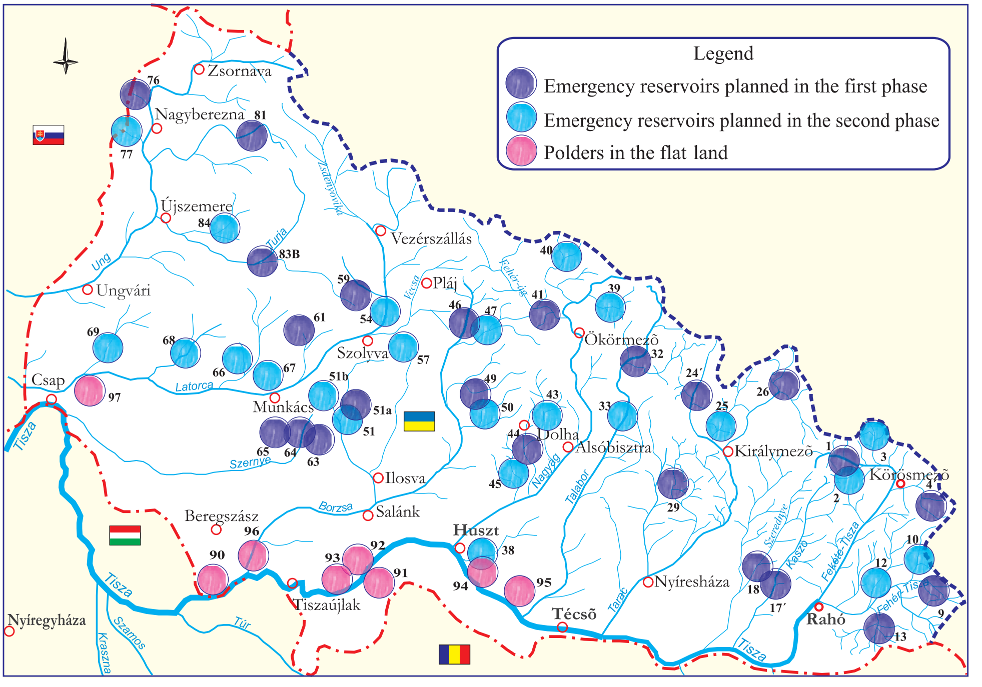
The content of the methodological work:
Two Hungarian developed rainfall-runoff forecast models capable of computer processing were included in the model: a lumped parameter model developed by the Water Resources Research Institute Corporation used for continuous forecasting and a model with distributed parameters developed by the research team of the Hungarian Scientific Institute. Both models proved to be useful for preparing water stage and discharge forecasts, based on rainfall. The forecasts met pervious expectations of the preparatory teams, however did not meet accuracy expectations. Both models are worth for further development. In the framework of modelling activities the applicability of the hydraulic model based on the Saint-Venant equation for forecasting was evaluated on the Tiszabecs-Tokaj section of the Tisza too.

In the framework of methodological activities the new Windows based regression forecasting model (WinEJEL), and new, graphical supplements were prepared. Actually these more traditional methods provided the most accurate forecasts for peaks.

IV.5 Other, non-Hungarian Upper-Tisza flood management development programs

As a result of the 1998-2001 huge Upper-Tisza floods flood control and disaster management development programs were accelerated in non-Hungarian catchments as well. A part of these are financed and arranged from international sources. Some of the more significant programs that can help the Hungarian Upper-Tisza flood management in the future are as follows:

- *New flood management development concept in Ukraine:* those who prepare the draft worked out a complex flood management strategy which emphasises up to date catchment management based on catchment. With the help of mountain and plain reservoirs the height of the flood wave peaks can be reduced both in the catchment and in the riverbed, by this the hydrologic load of flood protection dikes can be reduced. At the same time the flood protection dikes will be restored and their height will be increased, observing the design flood level and the volume of the 2001. flood.
- *The results of the NATO-Ukraine cooperation in the field of flood management:* After the catastrophic flood in 1998, the Ministry of Disaster Prevention turned to NATO for help with the mitigation of flood damage in the Sub-Carpathian region. The NATO reacted to the demand by



Planned emergency reservoirs in Trans-Carpathia

creating an expert taskforce in the framework of *the Partnership for Peace* program. The task of this expert task force was to make an assessment study and to submit feasible recommendations in the field of increasing the efficiency of flood management and disaster protection systems in the Sub-Carpathian region. The completed study has 6 chapters with recommendations.

– *In Romania* there are several monitoring development projects in progress. Financed by PHARE CBS sources, 38 online hydrologic stations are installed on the tributaries of the Upper-Tisza in Romania, that is on the Visó, the Iza and the Túr. The project includes GIS developments as well. Also financed by PHARE CBS, 19 hydro-meteorological and water quality online stations are being installed on the Kraszna. There is a DESWAT project (Destructive Water Abatement and Control of Water Disasters) in progress on the Szamos and Maros. In the catchment of Lápos (tributary of the Szamos) 5 online stations on the Maros, 86 online stations will be built until 2005, according to the plans. Important meteorological monitoring development is going on as part of the SIMIN project. According to the plans 6 complex online meteorological stations will be installed in the Romanian catchment of the Tisza.

- It is significant from Hungarian point of view that in the Rozsály moun–tains, above Nagybánya new meteorological radar was installed, which covers those areas of the Upper-Tisza region that are not covered by the Nyíregyháza-Napkor radar.
- *In Slovakia* a complex flood forecasting development program, called POVAPSYS, started in 2001. The planning of the development of monitoring began in 2003.
- In the Ukrainian part of the Upper-Tisza, in Sub-Carpathia several forecasting and monitoring projects were and are going on besides the Hungarian government projects. Financed by Danish government aid, there are forecasting model development projects (on MIKE 11 basis) for the catchments of the Ung, Latorca and Bodrog. By small TACIS projects an online station was installed on the Ung, at Ungvár. A 3 million Euro project, significant from a Hungarian point of view as well, began at the end of 2003, financed by TACIS. In this project new forecasting models are tested and further online hydrological stations installed. Coordination of the above projects would be extremely important, every country would benefit from this coordination, and the flood security of the border regions could improve.