WWF

HOW TO SAVE THE DANUBE FLOODPLAINS

The Impact of the Gabcikovo Hydro Dam System Over Five Years

WWF Statement
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GREEN
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PROGRAMME

WWF Statement

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Summary

The Gabcikovo hydro dam complex, located between Bratislava in Slovakia and Györ in Hungary is the largest engineering system built on the Danube. The construction of the dam, canals and reservoir system directly affected 3,900 hectares of fields and 3,400 ha of floodplain forests in Slovakia and another 2,000 ha in Hungary at the site of the original reservoir and Dunakiliti diversion weir - built before Hungary withdrew from the project.

The Gabcikovo dam system has been operating since the end of October 1992, diverting 80-90% of the Danube river water into the canal and reservoir. The remaining 10 to 20% of the water is allowed to pass through the Cunovo diversion weir and directly into the old river bed, the Hungarian branch system, and the Moson Danube. Some water from the Gabcikovo canal is diverted to recharge the Slovak branch system.

In addition to the direct impact of the building of the dam, major hydrological changes, including a loss of river water and a 2 to 4 m drop in the water table, pose a major threat to the remaining 8,000 ha of floodplain forests - 50% in each country. In addition, ground and drinking water reserves of the region are being reduced in both quantity and quality by the river diversions, the impoundment in the reservoir and canal, and the consequent loss of groundwater recharge.

Any cost-benefit interpretation of the Gabcikovo system has to take into account the enormous economic losses in environmental services (supply of products, recreation and water purification) in the affected wetland.

From the energy supply point of view, the Gabcikovo power system constitutes neither the best nor the only option for Slovakia, and the viable alternatives should be looked at.

In both Slovakia and Hungary efforts have been underway to monitor and mitigate the changes to the environment caused by the operations of Gabcikovo since 1992. Both states have responded to the negative impact by building and operating artificial recharge systems in attempt to provide a sufficient water supply to the floodplain system. Together with the favourable climatic conditions in most of past summers, this system was only able to limit and slow down the continued degradation. The available evidence monitored in the area, however, and international long-term experience with similar systems in Germany and Austria, shows that this small amount of water is not appropriate for restoring the original floodplain dynamics, neither hydrologically, morphologically nor ecologically.

Review of the 1993-1996 monitoring reveals:

- This artificial system provides no dynamic but only a small, constant flow of water , unable to produce the typical large-scale fluctuations and inundations crucial for the floodplain. In addition, the earlier variety of communication between the river and the floodplain is completely disrupted because the river drains the entire eco- and hydrosystems instead of regularly recharging them.
- The dropping of the groundwater table along the „old" river bed cannot be fully reversed. Large scale fluctuations in groundwater, needed for both moistening and aerating the soils and the forest root zone, have been lost.
- Forests, especially those along the river, are slowly dying from lack of moisture, or showing the severe stress symptoms of reduced growth rates, premature shedding of leaves, dry tree tops, etc. Damaged areas are being salvaged before their prime.
- The isolation and consequent drying out of the floodplain ecosystem in 1992 to1993 resulted in both immediate and long-term changes and losses to the typical fauna and flora. Floodplain specialist species are suppressed and replaced by drought-tolerant and alien species.

Based on the available evidence, WWF asserts that major negative changes are occuring to the floodplain forests, the groundwater system and the wetland biodiversity, as a result of the construction and operation of the Gabcikovo dam complex.

In future, neither a continuation of present mitigation measures, nor the building of new weirs in the old river bed, can stop or reverse this degradation. The discussed peak operation of the Gabcikovo system together with the subsequent installation of a second dam some 100 km downstream, would create additional and severe environmental damage to the Danube riverine landscape.

In order to protect the Danube floodplain system from further damage, WWF recommends that the previous water regime be significantly restored. At least two-thirds of the original Danube flow must be returned to the „old" river bed at Cunovo.

In addition, WWF is recommending the constricting and lifting of the river bed with gravel banks and islands, and reconnection of the side-arms with the river in a comprehensive and viable solution. This should be combined with restoration of the wetlands in the dam reservoir.

For any future solution, it is crucial to continue and extend the environmental monitoring and to regularly publish the results. For new mitigation measures, environmental impact assessments have to be conducted. A cost-benefit analysis of the Gabcikovo project is needed.

The decision of the International Court of Justice on 25 September 1997 prescribes a joint operation of the Gabcikovo system to serve both economic and environmental interests. A new solution requiring recognition of new environmental standards, including damage prevention, and agreement on more satisfactory volumes of water for the "old" river bed and the side-arms are needed and recommended by the Court.

Preface

In July 1988, Alexay Zoltan wrote a text to accompany his photographs in the book „Szigetköz" (Interpress, Budapest 1989). He wrote in his preface:

Obviously, the present work is not designed to give a full picture of Szigetköz. The photographs merely serve to immortalize the atmosphere and the rare moments of this land. This album should not be the requiem of Szigetköz, and I hope with all my heart that what is seen herein will not disappear after the putting into operation of the river barrage, and that the values of the landscape and the living world prevalent there could be preserved.

He concluded his introduction with the comment:

It should be borne in mind that if we change the environmental conditions of a region and later this step somehow proves to have been wrong, even a huge amount of money could not restore original conditions.

Elsewhere in „Szigetköz" Alex Zoltan had written:

There are some five hundred islands here, forming a wonderful water labyrinth where the stranger may easily lose his way. This insular world is continuously changing even today. During large floods the floodplain is filled up with water, sandbanks arise, at other places trees fall into the river because the banks are washed away. When inundation is over, these sandbanks are quickly occupied by vegetation, first by willow-scrub, followed by willow-poplar groves, thereby the sandbanks turn into small islands.

This process sometimes needs only a few years, this is why some of these islands have no names at all and are not marked even in the most detailed maps. The annual two floods - in the spring and in the early summer - and the persistent low water-level of the autumn and winter are fundamental factors in the formation of extreme conditions in the floodplain.

Danube side-arm (Slovak floodplains at Zitny ostrov) Photo: Zinke

1. Introduction

On the 25th of September 1997, the International Court of Justice in The Hague, Netherlands delivered their ruling on the dispute between Slovakia and Hungary over the building and operation of the Gabcikovo dam complex on the Danube River. The parties to the dispute and the ruling of the court itself have focused largely on legal arguments and questions of contract law. In their summary the judges ruled „that both Parties committed internationally wrongful acts“ and that the two parties must now negotiate a solution to the dispute including resolving such issues as compensation.

The dispute, however, involves not just issues of law but important consequences and implications for the Danube River and its floodplain ecosystem. These consequences and issues have in turn major economic and social implications for the people of the area and the entire Danube region. This paper tries on providing up-to-date information on the environmental aspects of the Gabcikovo dispute and proposes a solution to the conflict that protects to the minimum extent the Danube river and its floodplains. This information and the solution proposed here are especially relevant because the judges ordered both Slovakia and Hungary to „look afresh at the effects on the environment of the operation of the Gabcikovo power plant“ and to negotiate a settlement to the issue that involves „a satisfactory solution for the volume of water to be released into the old bed of the Danube“.

In producing this report, which focuses on examining the effects of the dam since it began operating in October 1992, WWF together with Slovak and Hungarian NGOs has attempted to obtain and review all the available information on the ecological changes in the Gabcikovo area, including the official monitoring data from both Hungary and Slovakia. It must be noted, however, that obtaining a comprehensive picture of the impacts of Gabcikovo has not been easy. This is in large part because of the political pressure on the scientific monitoring and the unwillingness of some parties to make such information in due time available to the public. Despite these difficulties, scientists and individuals have been very helpful in searching data and information for assessing the ecological impacts of the dam in the region. We are deeply indebted to these persons for their assistance.

The World Wide Fund for Nature (WWF) together with other NGOs has been an active participant in the discussions about Gabcikovo since 1986. Since that time WWF has published a number of studies and reports relating to the dam and the ecological implications of its operation. These reports in large part warned of serious negative ecological consequences for the floodplain forests, groundwater and fish and fauna as a result of dam operation. We are sorry to say that, based upon the evidence that exists, many of the earlier predictions of the damaging ecological consequences of the dam are already being realized. It is the sincere hope of WWF and the undersigning members of the NGO community that this clear evidence and proposed solutions of this report will help the parties to the Gabcikovo dispute to heed the recommendation of the judges in the Hague and to adopt a negotiated settlement that addresses these findings and truely saves the ecological integrity of the Danube river.

2. Some Background on the Gabcikovo Project

2.1. Review of Gabcikovo history

On 16 September 1977 Hungary and Czechoslovakia (CSSR) entered into a joint Treaty on the construction of the Gabcikovo-Nagymaros river dam complex. Construction started in 1978. During the 1980s rapid progress was made on the Slovak side, but Hungary built their Nagymaros dam only after a contract was signed with the Austrian Donaukraftwerke AG (Danube Powerplant Co.) in May 1986.

Starting in 1984 Hungary faced growing critisism and public protests against the environmental impacts of this project. This led in May 1989 to the suspension of works at Nagymaros and, on 31 October 1989, to the abandonment of the Nagymaros project. This was a few weeks after the Hungarian government had received a WWF consulting document (WWF 1989) which they had requested.

In October 1990 Hungary and the Donaukraft terminated their contract with a compensation of 2.8 billion Schillings (ca. 270 million US$) to Donaukraft.

Only after 1989 was the Czechoslovak opposition able to publicly campaign against the scheme. On 3 February 1990 it organised a human chain of over 50.000 people from Hainburg in Austria to Gabcikovo. In the summer of 1991, local people, with the help of international environmenal groups, held weeks-long demonstrations and occupations of the construction site. In April 1991, mayors from both states demanded that construction be stopped immediately, and insisted on transfrontier cooperation on environmental protection.

Hungary abandoned the bilateral Treaty on 25 May 1992., after years of unsuccessful bilateral negotiations, noting that, in November 1991, the Slovak authorities commenced construction on a new scheme, Variant C, for unilateral diversion of the Danube.

During October 1992, the European Commission tried to solve the growing bilateral conflict by asking that the announced start of operation on 20 October 1992 be postponed.

However, on 24 October, Slovak engineers started damming the Danube river bed at the new diversion weir of Cunovo and directed the river into the Gabcikovo canal.

In the London Protocol of 27 October 1992, Hungary and Czecho-Slovakia (CSFR) committed themselves to submit the dispute to the International Court of Justice in The Hague. The CSFR guaranteed to maintain 95% of the flow in the Danube, and to refrain from operating the power plant.

But CSFR continued to divert more than 80% of Danube water to Gabcikovo for power production, and in November 1992, WWF showed international media the nearly dry Danube river bed and drinking water wells on both sides of the river.

In a joint press conference with IUCN (World Conservation Union), Equipe Cousteau, Duna Kör (the Danube Circle from Hungary) and SZOPK (Slovak Union of Landscape and Nature Protectors), the WWF appealed to the European Commission to enforce the London Protocol.

Between 1991 and 1993, the European Parliament passed several resolutions emphasizing its critisism of the project.

On 1 January 1993 Slovakia became the legal successor of CSFR on the Gabcikovo- Nagymaros Treaty. The European Commission and their expert mission made successive mediation attempts to rescue a temporary flow of the Danube – suggesting 66% in January 1993 and 40% in December 1993. Both proposals were accepted by Hungary but rejected by Slovakia.

Between November 1992 and December 1993, the European Commission sent three expert missions to assess the effects of the operation of the Gabcikovo system, and to make recommendations for a temporary water management.

The Danube floodplains dried out completely in November 1992. Six months later, Slovakia started operating an artificial floodplain water supply system in its 4,000 hectares wetland. In July 1993, Hungary started a similar supply for its 4,000 ha side-arm system. Neither attempts had any marked ecological benefit.

In December 1993, WWF presented its „New Solution for the Danube“ (WWF 1994) giving its first assessment of the damage. It made some critisism of the EC expert reports – their underestimation of the environmental degradation and insufficient ecological remedial measures.

On 19 April 1995 Slovakia and Hungary reached an interim agreement on joint measures for a larger temporary water supply system for the 4,000 hectares of Hungarian floodplains in Szigetköz, and on a joint monitoring of the environmental impact of Gabcikovo. In this, Slovakia guaranteed a mean discharge of 400 m^3/sec, 20% of the river flow, into the "old" Danube bed below Cunovo, which, together with the construction of a new Hungarian weir near Dunakiliti, would allow a water supply into the Szigetköz side-arms.

On 3 March 1997, hearings on the Gabcikovo-Nagymaros dispute started at the International Court of Justice (ICJ). On 15 April the Court retired before presenting its decision on the 25 September 1997. The interim agreement ended 14 days after the ICJ decision, i.e. on 9 October 1997.

In October 1997, five years after commencement, the disputed construction at the Cunovo diversion weir still continued. A new 52 MW power plant will soon be powered by the remaining 20% of water discharged into the "old" Danube river bed.

2.2 Facts about Gabcikovo (see map 1 "status quo")

The affected Danube stretch has a length of approx. 50 km (river km 1,860-1,811).

The Gabcikovo dam complex includes

- The reservoir Cunovo (dikes of 25 km length, surface of 4,500 ha, volume of 196 mil. m^3).
- The diversion weir complex (see below).
- The completely sealed diversion canal (length: 17 km; capacity of 5,300 m^3/sec; width: up to 750 m; depth 6-13 m).
- The power plant and lock system (see below).
- The tail-race canal (length of 8 km).

The canal dissects the original landscape including the former vicinity of villages and people. With its huge dimension (canal dikes 11-18 m above surrounding landscape and width up to 737 m) it creates a new artificial horizon in the Danube lowlands.

The Gabcikovo Power Plant:
Installed capacity: 720 MW (8 turbines à 90 MW), built for peak operation but used today mainly for conventional operation.
Vertical drop of canal waters: 24 m.
Production: approx. 2,100 – 2,300 GWh/year (originally designed for 2,700 GWh/year peak power). 7,500 GWh during the first 4 years, as stated by the power plant operator.

The Gabcikovo Lock System:
2 lock chambers: 275 m long, 34 m wide.
Two major accidents in February/March 1994 resulted in the closure of all Danube navigation for five weeks and two years of repair works.

The Cunovo Diversion Weir: This is the main structure of „Variant C", replacing the Dunakiliti weir which was built by Hungary but not put into operation as planned. Construction of the Cunovo weir began only in November 1991. Although largely unfinished it was put into operation on 24 October 1992. An unexpected flood a few weeks later caused major destruction to the building site. The repairs, especially at the downstream side of the inundation weir, are still only provisional. Present construction work is concentrated on the new lock system and power station. Expected completion: end of 1997.
Here at river km 1,851.75 the Danube is being diverted into the Gabcikovo canal.

The huge Cunovo complex includes:
- Power plant (52 MW, predicted production: 170 GWh/year),
- Lock systems for canoes, sport boats and large ships (one lock is 24 m wide, 175 m long) and
- Three weir complexes with 27 gates providing the minimum flow into the "old" Danube and allowing the discharge of floods and ice blocks.

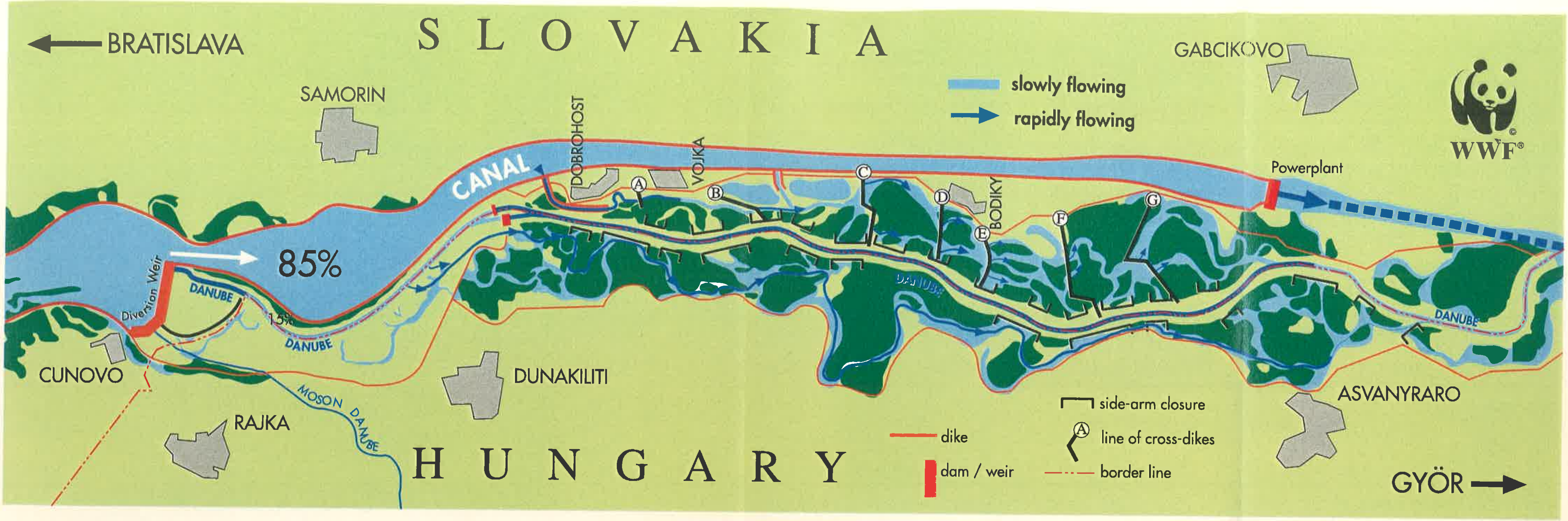
In addition, the weir provides the water supply for the Moson Danube (capacity of the connecting canal: 40 m^3/sec), including another small power plant (1 MW from 2 turbines).

Additional construction works during 1996 and 1997 at Cunovo are aimed at building large recreation facilities, including a kayak whitewater race area, swimming pools, camp sites and beaches on the „old" river bed. There are plans for a large yachting harbour, recreation parklands and an 18-hole golf course. The entire Gabcikovo-Cunovo recreation area is designed to attract 100.000 people.

Impact Area: Direct liquidation of 3,900 ha of fields and 3,400 ha of floodplain forests in Slovakia and ca. 2,000 ha of forests in Hungary. Another 8,000 ha (50% in each country) of existing floodplain forest, the third largest floodplain forest left on the Danube. A labyrint of side-arms and islands with high biodiversity is being damaged due to the river diversion in 1992. An artificial supply of water somewhat reduces the speed of degradation in the former extraordinarily rich, heterogeneous and rare flora and fauna.

Groundwater: Over 400 m deep layers of gravel and sand sediments, containing ca. 14 km^3 of water, the second largest drinking water reservoir in Europe. Around 1million people in Slovakia alone (Bratislava) are supplied from here which is only a fraction of the potential use of the reservoir.
The changed hydrology reduces the natural infiltration and the benefits of fluctuations – "breathing" of the soils. Some groundwater experts predict that the water quality will change because of reduced self-purification capacity, increased biochemical processes in the sedimentation area of the Cunovo reservoir, and activation of pollution sources along the Gabcikovo reservoir and canal.

Map 1: Status quo of the Gabcikovo dam system and the Danube floodplains



The map shows the situation created after October 1992 and valid in fall 1997: On average some 80-85% of Danube water is being diverted at the weir at Cunovo (left, river km 1,852) into the impoundment lake continuing as a sealed canal towards the Gabcikovo power plant and lock system (right). Only some 15-20% of the average Danube flow are let through the Cunovo system into the "old" river bed. At rkm 1,811, the Gabcikovo canal returns to the original Danube river bed. Therefore, the affected Danube section reaches from rkm 1,860 (upper end of the impounded waters near Bratislava) some 50 km downstream.

The Cunovo reservoir is limited to Slovak territory, the border starts right downstream between the villages of Cunovo and Raika and continues east through the „old" river bed, formerly the navigation route.

The Cunovo weir serves both to divert water into the canal, to supply water with average of 400 m^3/sec into the "old" river bed and of 40 m^3/sec into the Moson Danube, but also as emergency outlet for large floods (more than 6,000 m^3/sec) and for some power production.

The Hungarian part of the previously joint reservoir can be recognised between Cunovo and Dunakiliti.

The Gabcikovo canal and power plant system serves to secure river navigation and power production.

Since the construction of a new rock weir in the Danube north of Dunakiliti in May 1995, the old, adjacent Dunakiliti weir regained two functions: it regulates the downstream discharge in the „old" river bed and the discharge volume for the artificial recharge of the Hungarian side-arm system (see below).

In the floodplain areas adjacent to the Danube river bed, the following technical measures were undertaken:

- All connections between the side-arms and the Danube river bed were disconnected by concrete closures (exceptions: the inlet upstream of Dunakiliti and the two outlets into the Danube on Slovak and Hungarian side near Gabcikovo resp. Asvanyraro). Most of these connections were open (for exchange of waters and organisms) prior to October 1992 at least during Danube floods. Since November 1992, the Danube has a new water level of 2 to 5 meters lower than before (much below the historical record low water). Therefore, the former river can no longer play anymore its original role of steering the water levels (natural fluctuations between flood and low water periods of up to 7 meters) and of feeding the surface and groundwater bodies in the entire region between Bratislava and Györ. Today, the Danube in this section acts as a huge drainage system for the entire wetland: this impact is only reduced by the side-arm closures along the main river bed.

- In the side-arm systems on both river sides, technical installations for minimum water supply and control of water levels were constructed: on the Slovak side, an input structure near the village of Dobrohost supplies some 30 to 70 m^3/sec of water from the Gabcikovo canal via a one kilometer long sealed canal into the interconnceted side-arm system along the northern banks. A second input structure near the village of Vojka has apparently never been put into operation. Seven lines (A to G) of cross-dikes serve to permanently(!) impound and raise this artificial water to former average water levels, thus creating a chain of ponds and cascades. The cross-weirs have outlets of different character which result in faster water flows downstream of the cross-weirs. Due to infiltration effects, the discharge volume reduces from line A to G. The former large water dynamics (strong variations between discharge/water level and flow direction) resulting in the ecologically most essential morphological (sedimentation, erosion) and biological (migration) processes are most limited and stabilised today.

- On the Hungarian side, a similar system is operating: near the previous diversion weir at Dunakiliti, a new bottom weir made of rocks was built in the "old" Danube river bed in April/May 1995 which together with the Dunakiliti weir raises and impounds the Danube water levels. This made it possible to divert water (70 to 130 m^3/sec) from the Danube into a side-arm system, interconnected as far as Asvanyraro. In the Hungarian side-arm system, some single weirs were built in the main arms, however, not as concrete lines across the wetland, as on the Slovak side. Therefore, the water levels can vary more here. The morphological and biological processes are still limited.

In both side-arm systems a significant amount of the artificially recharged water infiltrates into the underground, thus the surface water volume gradually reduces during the passage. Even though this is a positive impact it should be kept in mind that the original infiltration rate in the area was much larger and that the impact on the underground water levels is smaller than required for the restoration of the former floodplain.

The high flows of the power canal create backwaters in the lower reach of the „old" river bed up to Asvanyraro: in this river section new intensive sedimentation of silt was monitored.

Graphical remark: The water and forest areas as well as the symbols used give rough descriptions of the real state of the area. This information is based on maps published by the Gabcikovo investor.

2.3. How much does Gabcikovo really cost?

To date there is no public statement on the cost-benefit ratio of the existing Gabcikovo hydrodam system. While an output of 7,500 GWh over the first four years (November 1992 to October 1996) was sold to the Slovak energy company SE (Slovenske Elektrarne), there are only very general, repeated statements by the investor company Vodohospodarska vystavba s.p. that Gabcikovo would cost 18 billion and Variant C would cost 8 billion (Czecho-)Slovak crowns. In addition, it was made public that credits on US$ 200 mio. plus a share of another US$ 200 mio. were obtained in 1995 and 1996 from J.P. Morgan Bank for finishing constructions at Variant C.

Apart from the investments and the (maintenance and repairing) costs of the Gabcikovo system, it is important to assess the economic damages to the riverine landscape, drinking water reservoir and other affected nature. Throughout history, floodplains have provided our societies with wood, fish, game, pure water and recreation facilities and other economic benefits. Their financial values are usually not included in the assessment of costs and benefits of development projects such as dams like Gabcikovo.

A WWF International (1995) Discussion Paper, „Economic Evaluation of Danube Floodplains“, was undertaken in order to calculate a general economic value of floodplains in monetary terms. Because no exact values of these wetland services yet existed, the study compared results of economic studies of the Danube floodplains elsewhere. The study distinguished between "input resources" (supply of wood and food for cattle and fish – each valued at their market prices); recreational services (value estimated by the cost of transportation to the recreation site); and nutrient retention (valued as nitrogen retention in the floodplains which would save the cost of conventional nitrogen abatement measures).

The estimated total annual value of the existing Danube floodplains amounts to ECU 383/ha. The total annual value of the entire actual area of Danube floodplains alone corresponds to ECU 666 million per year. The value of nutrient retention may account for about one-half of the total given value.

A change in the floodplain area (e.g. destruction), however, will not only change current benefits but also future values. The current and future benefits estimated are therefore based on a discount rate of 5%, amounting to ECU 7,660/ha. The current and future benefits from restored floodplains are lower than the values from natural, intact floodplains. When addressing the Danube floodplains affected by Gabcikovo, the economic benefits of power production, flood control and improved navigation should be compared to the values of the table below.

Changes in the economic assessment of the profitability of hydrodams have led to the conclusion that today many such projects would not be built: for example the general director of the Austrian "Verbund" power company Dr. Hans Haider made such a statement in an interview in October 1996 about the building of the Vienna-Freudenau power plan, which is to be completed in 1997.

When asssessing the future profitability of Gabcikovo, then the impact, maintenance and repairing costs on the river bed, navigation, water quality including potable water, and habitat and species diversity have to be included.

Table 1: Economic costs of the construction and operation of Gabcikovo for the environment

3,900 ha of fields destroyed (Gabcikovo canal)* x ECU 7,660 = ECU 29.874 mil.
3,400 ha of forests destroyed on the Slovak side x ECU 7,660 = ECU 26.044 mil.
2,000 ha of " " on the Hungarian side x ECU 7,660 = ECU 15.32 mil.
Sum of Economic Loss due to the realisation of the Gabcikovo system ECU 71,238 mil.

* While most of the fields affected by the Gabcikovo constructions are located outside the dikes, their destruction is an important economic loss. As the productivity of these fields is not known, it is assumed that they have the same economic value as the floodplain area.

4,000 ha of floodplains affected (Slovak side) x ECU 383/yr = ECU 1.532 mil./yr
4,000 ha of floodplains affected (Hungarian side) x ECU 383/yr = ECU 1.532 mil./yr
Sum of theoretical benefit of intact floodplains ECU 3.064 mil./yr

It can be estimated that during the first four years of Gabcikovo operations, these existing but damaged Danube floodplains would have produced a value of ECU 12.256 mil.. However, only a small part of this value could in fact be realised due to the river water diversion and consequent reduced wood growth, early clear-cuts of forests, much reduced fish catches, reduced water purification etc..

2.4. Energy: Does Slovakia really need Gabcikovo?

In the previous section we demonstrated that the loss of natural floodplains has a significant economic value which usually is overlooked when calculating the cost-benefit ratio of a hydropower plant. However, the proponents of Gabcikovo often cite how important it is for Slovak electricity supply.

The hydropower plant of Gabcikovo certainly constitutes a large electricity-producing facility for Slovakia, meeting the alleged main purpose of the entire Gabcikovo dam system: It is stated that Gabcikovo produces some 10% of the present Slovak power production. The power plant needed huge investment to start its operation, and its maintenance is also expensive, although concrete figures have not been published.

However, the high productivity of the power plant should be carefully interpreted: Apart from the direct and indirect production costs there are also the related environmental costs (see chapter 2.3.). And Slovakia's need for power should also be investigated. Another aspect is the overlying goal of the Gabcikovo promotors: the desired original peak-power operation system will need a second hydro dam downstream on the Danube (see chapter 5.3.). Recent river observations suggest that Gabcikovo is already being tested at peak-power output.

In one of its publications (VVsp 1994), the Slovak Gabcikovo investor states that each 100 m³/sec less water through the power plant reduces the energy production by 150 GWh/a. The decision of the International Court of Justice in The Hague stipulated that more water to be let into the „old“ river bed and into the side-arm system, rather than through the turbines of the Gabcikovo and Cunovo power plants.

If Slovakia were to divert only 35% of Danube water to Gabcikovo, electricity production would be reduced by some 50% (1,300 GWh).

Several Slovak energy studies, however, indicate that Gabcikovo – and even more its full operation – may not be necessary to meet Slovakia's electricity needs, or that at least it may not be the most cost-effective means of meeting those needs. It is not within the scope of this paper to examine this aspect in detail. However, we emphasize that viable alternatives exist at attractive costs for Slovakia's future energy sector: The well known options includes improved energy efficiency, installation of combined heat and power production (e.g. at Vojany and Novaky) and renewable energy sources.

It is also known that hydro power plants on the Danube have their lowest production in winter, i.e. at the time of highest energy needs, and that even during this, usually difficult, season Slovakia has large, unused reserves of installed power capacity. For example, in December 1995, the maximum load in Slovakia was 4,218 MW while the installed power capacity was 7,100 MW (Foundation for Alternative Energy 1996).

For a discussion about the need to keep Gabcikovo under full operation or to reduce its production, it can be concluded that Slovakia has alternative energy options, and that making use of them would reduce the negative environmental impacts of existing fossile, nuclear power plants and of Gabcikovo.

3. The Gabcikovo Case in The Hague

3.1. WWF legal study 1992

Summary of the Legal Study produced by Dr. Georg Berrisch in October 1992 for WWF on „Construction and Operation of Variant C of the Gabcikovo-Nagymaros Project under International Law“

The purpose of the study was to examine whether the unilateral construction and operation of Gabcikovo („Variant C“) is in accordance with international law. It first looked at Variant C under international customary law and the various boundary agreements in force between the two countries. Finally, it examined the status and implications of the joint CSSR-Hungarian Treaty of 1977.

Berrisch concludes that

- Variant C is in violation of the principle of good neighbourliness because it will cause significant or appreciable harm to Hungary, e.g. by endangering the huge drinking water reservoir below the affected area, by reducing the Danube water quality, and by lowering of the water table which will result in a loss to agriculture.
- Variant C violates the principle of equitable utilization which governs the use of the Danube as an international watercourse. The diversion has „*extremely negative impacts on the environment and on the traditional uses of the Danube*“[2], and CSFR and Slovakia have many alternatives available which would protect citizens from the danger of floods, prevent river bed erosion, meet their demand for energy and bring economic development to the area.
- Sufficient evidence of the negative environmental impacts of Variant C exists to support the conclusion that the project violates the above principles of international environmental law. International law does not require that the appreciable harm must be proven beyond any doubt. Even the Slovak constructors give no guarantee that the project has no negative environmental impacts. He also refers to the very critical report of the Canadian consultant Hydro Quebec International of December 1990, recommending a review and an investigation of many problems as well as the realisation of an environment impact assessment.
- The unilateral interference with the flow of the Danube, causing a change to the main navigation line („Talweg“), is a violation of several boundary agreements.
- CSFR cannot rely on the treaty of 1977 as a justification for Variant C because it is a unilateral project and not accepted by Hungary. It is not covered by the consent Hungary gave to the diversion of the Danube in the 1977 Treaty. This consent is limited to a joint diversion and a joint project.
- Variant C does not constitute a legitimate response by the CSFR or Slovakia to an alleged violation of the 1977 Treaty by Hungary. Even assuming Hungary has violated the Treaty, Variant C would be an out of proportion response, because it will cause irreversible damages to Hungary.

3.2. Summary of the „NGO Memorial on Legal and Scientific Issues

Introduction

The „NGO Memorial on Legal and Scientific Issues“ (Schwartz M. 1995 ed.) was prepared by various non-governmental organisations representing a broad range of expertise in environment and development issues. It was written to provide the International Court of Justice (ICJ) with an independent legal and technical ananlysis concerning the ecological and economical impacts of the Gabcikovo facilities, as well as specific informatin on the legal obligations of Slovakia under international law.

The significance of the issues before the ICJ cannot be overstated: This case involves the potential to shape multinational environmental rights and duties regarding shared national resources (i.e. watersheds) and the human impacts of development. This case also presents the first opportunity for the ICJ to clarify a state's obligation to protect the environment during the course of the development, use and allocation of a shared natural resource. And the Court's decision will have far-reaching implications for other regions of the world, in addition to those individuals and groups in the region. It also has the potential to articulate international environmental law that will have a permanent effect, guiding future developments in the field.

The Gabcikovo Facilities Will Cause Severe, Long-Term Environmental Damage as Demonstrated by the Global Experience of the Impacts of Large Dams

The Memorial contains research concerning the effects of large dams throughout the world. It reveals that the alleged benefits from these facilities can be eclipsed by widespread social and environmental degradation, especially in the cases of poorly constructed dams, and/or in the absence of a comprehensive environmental impact assessment („EIA“). Impounding water in a dam's reservoir and altering water flow downstream can indeed cause ground and surface water contamination, decimation of fisheries, lower agricultural yields, deforestation, and alteration of habitat necessary for native flora and fauna survival. The documented short-term impacts of the Gabcikovo facilities are consistent with those commonly experienced at other large dams. Furthermore, the future impacts of the project can be predicted from evaluating long-term effects of similar facilities, and are likely to be more severe on these resources, including probable serious groundwater contamination threatening drinking water wells, irrigation and other water supplies.

[1] Greenpeace, Slovakia; Human Rights Advocates, United States; International Rivers Network, United States; Natural Heritage Institute, United States; REFLEX Environment Protection Society, Hungary; Sierra Club Legal Defense Fund, United States; Slovak Rivers Network, Slovakia; SZOPK Central Danube, Slovakia; World Wide Fund for Nature.

[2] Environmental Assessment Sourcebook 53 (The World Bank, Washington D.C., 1991)

The anticipated impacts of the Gabcikovo operation, based on the impacts of large dams generally, include threats to sedimentation, surface water quality, groundwater aquifer and drinking water supply, agriculture, forestry, flora and fauna including endangered species, and fisheries.

International Customary Law Requires Slovakia to Undertake a Comprehensive Environmental Impact Assessment with Hungary Before Continued Operation of the Dam

The Memorial argues that in order to fulfill its obligations under established principles of customary law regarding the use of shared resources, a state undertaking development of a shared waterway, likely to cause significant impacts on the environment of the downstream state, must conduct a comprehensive environmental impact assessment in accordance with internationally accepted methodologies. This is the only effective way to determine the likely ecological, social and economic impacts and what alternatives or mitigation measures would be necessary to prevent the harm.

The Memorial further identifies that Slovakia's operation of the Gabcikovo facilities has and will continue to cause significant harm downstream to the people and natural ecosystems of both Slovakia and Hungary, and that these impacts, if not mitigated, will only become more severe and, in some cases irreversible, over time. If operations are allowed to continue, and comprehensive environmental impact assessment and the implementation of mitigation measures are not undertaken, these early signs of degradation will lead to further severe, irreversible environmental damage of Central Europe's last great natural floodplain system. While Slovakia asserts that it has conducted environmental studies on the facility, these are wholly insufficient to meet the generally accepted international criteria for an environmental impact assessment; thus, its failure to undertake a valid environmental impact assessment jointly with Hungary can be viewed as a breach of its international obligations under customary law on the equitable utilization of shared waterways and under the „no harm“ doctrine.

International Human Rights Doctrine Requires Slovakia to Undertake an Environmental Impact Report with the Participation of the Affected Communities

Further, the Memorial analyses international human rights doctrine in this regard, and suggests that governments are now obliged to take reasonable steps to prevent serious foreseeable environmental harm that can threaten human life and health. This approach is based on three points: first, the jus cogens obligation to protect life now extends to an obligation not to undertake acts which are likely to cause serious environmental harm threatening human life. Second, the potential consequences of environmental disasters on human health have led to a general principle of international law that those likely to be threatened with injury from proposed development activities must be given the knowledge of these foreseeable consequences and provided with the opportunity to participate in the government decision processes that could lead to the permitting of such activities. Third, the widespread recognition of the need to prevent this cause and effect relationship of ecological destruction and injury to life has led to the development of an emerging right to environmental protection. Yet Slovakia failed to undertake these required measures.

Conclusions and Recommendations

The Memorial, after examining the social and environmental impacts of the Gabcikovo operation and other large dams around the world, argues that it has become a general principle of international law that before constructing and operating this type of large facility, the government must conduct a comprehensive environmental impact assessment. Furthermore, when the dam affects a shared waterway, the customary laws of equitable utilization oblige a state to evaluate impacts and consider alternatives and mitigation measures to prevent harm to the downstream state. This is a duty which can only be effectively fulfilled by conducting an environmental impact assessment according to internationally accepted methodologies. Finally, human rights doctrine imposes similar obligations on Slovakia's operation of Gabcikovo to protect the right to life and to ensure its activities do not threaten human health, particularly by leading to contaminated drinking water and irrigation supplies.

Slovakia has failed to undertake theses obligations, particularly as its studies do not meet internationally accepted methodologies, and the public was not allowed to effectively participate in the decisions regarding the official development of the facility.

The Memorial recommends and urges the Court, regardless of which country it determines may have breached the 1977 Treaty, to decide that both Slovakia and Hungary must:

(1) Immediately adopt a process to comprehensively evaluate the existing and projected impacts of the entire Gabcikovo facilities through development of an environmental report that, utilising internationally accepted methodologies, analyses:
  - impacts on fisheries, wildlife, forests, agricultural lands, surface and groundwater supplies;
  - social, cultural, economic and other significant impacts of the project; and
  - a cost-benefit analysis to determine whether feasible, ecologically sound alternatives and mitigations to the project exist which would reduce the impacts.

(2) Maintain an average discharge of 1200 m³/sec (or 60 % of the average annual discharge of 2000 m³/sec) in the old Danube river bed.

(3) Incorporate within the process ways and means to foster effective participation by the affected communities in both Slovakia and Hungary in the environmental review process, including providing the public with environmental information on the project – whether already developed or yet to be developed – and allowing for consideration of public comment on the environmental reports.

3.3. The Judgment of the International Court of Justice from 25 September 1997: Extracts and comments

The Gabcikovo Dam did not only produce political tensions of international importance but it also had and has a serious impact on its natural environment. Unable to come to a negotiated conflict resolution, Hungary and Slovakia put the issue before the International Court of Justice in The Hague. Therefore, environmentalists expected that its decisions would solve the political conflict and bring an end to the struggle for survival of the Danube floodplains.

In the press communiqué no. 97/10 from 25 September 1997 on its judgment on the "Case concerning Gabcikovo-Nagymaros Project (Hungary/Slovakia), the International Court of Justice (ICJ) "*found both States in breach of their legal obligations. It called on both countries to carry out the relevant treaty between them while taking account of the factual situation that has developed since 1989.*"

The judgment refers principally to the binding Treaty obligations of both States ("*pacta sunt servanda*") which the Court considers adequate for resolving the conflict. It is of utmost importance, however, to stress that the first-ever environment judgment of the Court includes a series of very important environmental provisions.

In the **first part of the judgement** (§§ 49-129), the Court replies to the three questions in declaratory form. It found:

First, Hungary was not entitled to suspend and subsequently abandon, in 1989, its part of the works in the dam project.

Second, Czechoslovakia – and Slovakia as its Treaty successor- was not entitled to put the alternative provisional solution (called "Variant C") into operation in October 1992 as a unilateral measure.

Third, Hungary's notification of termination of the 1977 Treaty on 19 May 1992 did not legally terminate it.

The **second part of the Judgment** (§§ 130-154) is prescriptive rather than declaratory because it determines the rights and obligations of the Parties for the future.

1977 Treaty is not terminated

132. [...] *the 1977 Treaty is still in force and consequently governs the relationship betwen the Parties.* [...]

Present situation prevails for implementing the Treaty

133. *The Court, however, cannot disregard the fact that the Treaty has not been fully implemented by either party for years, and indeed that their acts of commission and omission have contributed to creating the factual situation that now exists. Nor can it overlook that factual situation* [...] *when deciding on the legal requirements for the future conduct of the Parties.*

[...] *What is essential, therefore, is that the factual situation as it has developed since 1989 shall be placed within the context of the preserved and developing treaty relationship* [...].

134. [...] *The Court cannot ignore the fact that the Gabcikovo power plant has been in operation for nearly five years, that the bypass canal which feeds the plant receives its water from a significantly smaller reservoir formed by a dam which is built not at Dunakiliti but at Cunovo, and that the plant is operated in a run-of-the-river mode and not in a peak hour mode as originally foreseen. Equally, the Court cannot ignore the fact that, not only has Nagymaros not been built, but that, with the effective discarding by both Parties of peak power operation, there is no longer any point in building it.*

With this prescription, the Court limits the barrage system to a run-of-the river mode for power production and to only one dam at Gabcikovo and a diversion weir at Cunovo. Therefore, reported bilateral political efforts since the fall of 1996, aimed at finding a future solution with a second dam downstream of Gabcikovo and with some kind of peak power operation, are actually contradicting the Court's judgment.

In the following paragraphs the Court gives its prescription for the priorities on how to operate the dam system:

The 1977 Treaty to serve more than power production

135. [...], *the 1977 Treaty was not only a joint investment project for the production of energy, but it was designed to serve other objectives as well: the improvement of the navigability of the Danube, flood control and regulation of ice-discharge, and the protection of the natural environment. None of these objectives has been given absolute priority over the other* [...]. *None of them has lost its importance* [...].

Gabcikovo to serve water quality and environment

136. [...] *the objectives of the Treaty can be adequately served by the existing structures.*

137. *Whether this is indeed the case is, first and foremost, for the Parties to decide.* [...] *The Joint Contractual Plan was* [...] *expressly described as the means to achieve the objectives of maintenance of water quality and protection of the environment.*

1977 Treaty was acknowledged to be negotiable

138. *The 1977 Treaty never laid down a rigid system* [...]. *Not only did Hungary insist on terminating construction at Nagymaros, but Czechoslovakia stated, on various occasions in the course of negotiations, that it was willing to consider a limitation or even exclusion of operation in peak hour mode.* [...] *The explicit terms of the Treaty itself were therefore in practice acknowledged by the parties to be negotiable.*

In negotiations all Treaty objectives to be fulfilled

139. *The Court is of the opinion that the Parties are under a legal obligation, during the negotiations to be held,* [...] *to consider, within the context of the 1977 Treaty, in what way the multiple objectives of the Treaty can best be served, keeping in mind that all of them should be fulfilled.*

Environment is a key issue; Environmental impacts of Gabcikovo are considerable

140. *It is clear that the Project's impact upon, and its implications for, the environment are of necessity a key issue. The numerous scientific reports* [...] *provide abundant evidence that*

this impact and these implications are considerable.

In order to evaluate the environmental risks, current standards must be taken into consideration. This is not only allowed by the wording of Articles 15 and 19, but even prescribed, to the extent that these articles impose a continuing – and thus necessarily evolving – obligation on the parties to maintain the quality of the water of the Danube and to protect nature.

Parties are required to prevent damage to environment

The Court is mindful that, in the field of environmental protection, vigilance and prevention are required on account of the often irreversible character of damage to the environment and of the limitations inherent in the very mechanism of reparation of this type of damage.

New environmental norms to receive proper weight for past and future activities

[...] *Owing to new scientific insights and to a growing awareness of the risks for mankind* [...] *new norms and standards have been developed* [...] *during the last two decades. Such new norms have to be taken into consideration, and such new standards given proper weight, not only when States contemplate new activities but also when continuing with activities begun in the past. This need to reconcile economic development with protection of the environment is aptly expressed in the concept of sustainable development.*

Environmental impacts to be re-examined; new satisfactory solution needed for the use of Danube waters

For the purpose of the present case, this means that the Parties together should look afresh at the effects on the environment of the operation of the Gabcikovo power plant. In particular they must find a satisfactory solution for the volume of water to be released into the old bed of the Danube and into the side-arms on both sides of the river.

Finally, the Court gives provisions for the new negotiations:

Obligation to conduct meaningful negotiations

141. *It is not for the Court to determine what shall be the final result of these negotiations to be conducted by the Parties. It is for the Parties themselves to find an agreed solution that takes account of the objectives of the Treaty, which must pursued in a joint and integrated way, as well as the norms of international environmental law and the principles of the law of international watercourses. The Court will recall in this context that:*

"(the Parties) are under an obligation so to conduct themselves that the negotiations are meaningful, which will not be the case when either of them insists upon its own position without contemplating any modification of it. "[...].

142. *What is required in the present case by the rule* pacta sunt servanda [...] *is that the Parties find an agreeed solution within the co-operative context of the Treaty.*

Accept assistance and expertise from a third party

143. *During this dispute both Parties have called upon the assistance of the Commission of the European Communities.* [...] *When, after the present Judgment is given, bilateral negotiations without pre-conditions are held, both Parties can profit from the assistance and expertise of a third party. The readiness of the parties to accept such assistance would be evidence of the good faith with which they conduct bilateral negotiations in order to give effect to the Judgment of the Court.*

Joint Regime at the System of Locks (Cunovo).

144. [...] *According to the Treaty, the main structures of the System of Locks are the joint property of the Parties;* [...] *the benefits of the project shall be equally shared. Since the Court has found that the Treaty is still in force and that* [...] *the joint regime is a basic element, it considers that, unless the Parties agree otherwise, such a regime should be restored.*

145. [...] *Works of the System of Locks* [...] *shall be operated* [...] *with jointly-agreed operating and operational procedures* [...].

The Court is of the opinion that the works at Cunovo should become a jointly operated unit [...].

Make Variant C compatible with the Treaty

146. *The Court also concludes that Variant C, which it considers operates in a manner incompatible with the Treaty, should be made to conform to it. By associating Hungary, on an equal footing, in its operation, management and benefits, Variant C will be transformed from a* de facto status *into a treaty-based regime.*

Variant C to satisfy both economy and environment

[...] *Variant C could be made to function in such a way as to accommodate both the economic operation of the system of electricity generation and the satisfaction of essential environmental concerns.* [...]

Common utilization of shared water resources

147. *Re-establishment of the joint regime will also reflect in an optimal way the concept of common utilization of shared water resources for the achievement of the several objectives mentioned in the Treaty, in concordance with* [...] *the Convention on the Law of the Non-Navigational Uses of International Watercourses::*

"Watercourse States shall participate in the use, development and protection of an international watercourse in an equitable and reasonable manner. Such participation includes both the right to utilize the watercourse and the duty to cooperate in the protection and development thereof [...]."

In summary it can be stated that the Court officially recognised international environmental standards which have to become a key objective of a future solution for Gabcikovo. The present illegal and environmentally damaging diversion of Danube waters into the Gabcikovo system has to be changed into a new satisfactory solution for the division of waters which must – following the 1977 Treaty – serve both economy and environment, i.e. secure protection of nature and prevention of further damage. This excludes a new dam or peak power operation. Both parties should newly examine the environmental impacts of the project, and, for the 6 months of negotiations, could benefit from the assistance of a third party.

4. Comments on Monitoring

4.1. Monitoring 1993-96

The public availability of recent monitoring proved to be quite difficult and limited (see page 31). The following comments mainly refer to the data from 1993-96 and, geographically, to the Danube section between river kilometers (rkm) 1,820 to 1,840. This stretch, with floodplain forests and side-arms, is not directly affected by the Gabcikovo construction works, but by the river diversion and the subsequent major hydrological changes. It is the object of various intensive mitigation efforts which will be also commented on.

4.1.1. Hydrology:

The floodplain region downstream of Bratislava is often called an „inland delta“. It was created after the Ice Age when large quantities of sediments from the Alps and Bohemian mountains were deposited downstream of the mountain gate, located at the western end of the Small Carpathians and at the entrance of the Great Hungarian Plain between Bratislava (Slovakia) and Györ (Hungary). The delta is formed by three main Danube river branches: the Small Danube in the north (Slovak territory), the Moson Danube in the south (Hungarian territory), both having only a very small amount of water discharge, and the main Danube, an artificially straightened river bed in the center, navigable until October 1992. This also forms the joint border between Slovakia (formerly Czechoslovakia) and Hungary. The floodplain area north of the Danube is called Zitny Ostrov (Great Wheat Island), the floodplain south of the Danube is known as the Szigetköz (Island Between).

This large deposit of sand and gravel layers is filled up by very large volumes of excellent quality groundwater, making it very attractive for drinking water production for millions of people. At present some 1 million people mainly from the Bratislava region, are supplied from here, all the Szigetköz communities use it, and some water is even transported to Budapest. It is estimated that the acquifer could produce three times more than is consumed in Budapest (Water Resources Resarch Hydrology Institute 1996).

The aquifer profits from a natural infiltration of Danube water, mainly along the banks of the river, but also in the floodplain. This process also leads to a reduction in Danube water pollution. The international importance of this natural purification system along the Danube and its side-arms has been almost ignored for a long time. However, the development of the „Environment Programme for the Danube

Danube river bed near Dobrohost/Dunakiliti in November 1992
Photo: Zinke

Danube river bed near Dobrohost/Dunakiliti in January 1997
Photo: Zinke

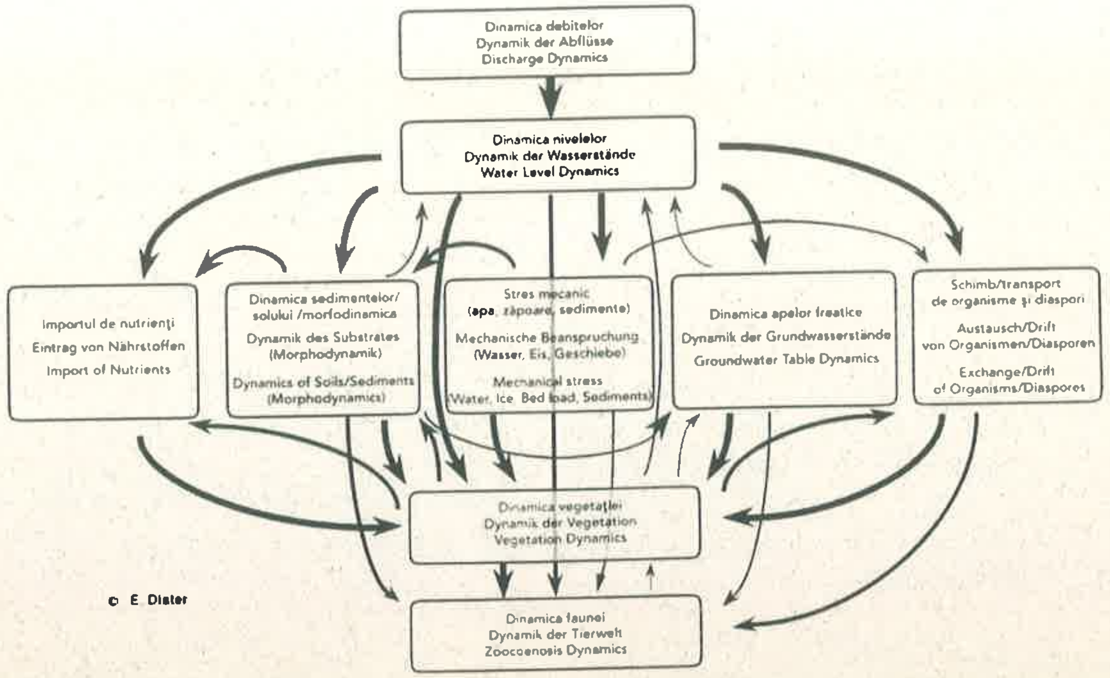


Figure 1: The main ecological factors characterising an intact floodplain ecosystem are dominated by the fluctuations of the river discharge which lead to a very dynamic interdependence. Dister 1996.

River Basin“, initiated in September 1991 by governments from the region and international financing institutions, meant official recognition of the need to restorate and protect the Danube river.

Furthermore, the Danube river basin countries and the European Union signed the "Convention on Cooperation for the Protection and Sustainable Use of the River Danube" on 29 June 1994 in Sofia. This Convention is aimed at achieving sustainable and equitable water management.

The „Strategic Action Plan“ (SAP), endorsed by the Danube country governments in December 1994 as a major result of the first phase of the „Danube Environment Programme, states in its introduction that

> *„a large number of dams, dikes, navigation locks and other hydraulic structures have been built (...) but such structures have caused changes in flow pattern and damage to the functions and biodiversity of the river system. (...) These changes have caused significant environment damage, such as reduced sediment transport, increased erosion and reduced self-purification capacity, including public health aspects in connection with drinking water supply of populations, recreation and bathing. (...) Nutrient and pollution loads coming from the river must be reduced if the health of the whole system (...) are to be restored. This can be helped by natural buffering systems such as wetlands and floodplains, which also contribute to biological diversity.“*

The „Short and Medium Term Priority Action" ‘conservation, restoration and management of riverine habitat and biodiversity’ which is important for maintaining the natural capital of the basin (its biodiversity) and re-establishment of its natural purification and assimilative capacity“, the SAP demands that

> *„measures must be based on the principle of ‘wise use’ of the Ramsar Convention, and should concentrate on priority sites. Integrated management and restoration plans should be prepared in collaboration with other concerned governments, local authorities, international organisations and NGOs.“*

For this SAP list of priority wetlands, Slovakia nominated in autumn 1994 the „Danube floodplain inland delta“ with 10,000 ha of floodplain area and a system of river branches, The „required action“ for this area reads as „land use management and biological restoration“. (SAP, p. 30).

The SAP talks about „Hydraulic Works“:

> *„The construction of dikes and reservoirs has greatly decreased floodplain zones with important loss or modification of habitats. One of the most important impacts is isolation of the larger parts of the floodplains by dikes creating „fossil“ floodplains which are no longer in contact with the surface waters of the river. Another impact of the reservoirs is in the modification of the Danube’s hydrological and sediment regimes. The major impact is the loss of self-purification capacity asnd hence of biodiversity and habitat diversity. Canalisation and hydraulic engineering works have modified the morphological patterns of many river courses.“*

There is a close connection between the fluctuations of river and groundwater: After a certain time lag, the raised or lowered river water level leads through infiltration or exfiltration to a subsequently raised or lowered groundwater table (see figures 1 and 2, from Dister 1996). This important relation also applies for the Danube river and the groundwater levels of Zitny Ostrov and the Szigetköz. High river water levels are reflected by raised groundwater levels even as far as several kilometers away from the river. Forestry and agriculture profit a lot from this moistening of the subsoil and from the subsequent aeration (a soaking in of air and oxygen). During the lowering of the groundwater level: this essential „breathing“ of the floodplain accelerates plant growth and the decomposition of organic material.

Ecologically, this sequence between dry periods and inundations (see figure 2) is the key factor characterising this ecosystem and its very high productivity. All other factors like morphodynamics, groundwater levels, exchange of organisms and biological dynamics depend on it. Therefore, these river fluctuations are essential for the whole ecosystem (figure 1, Dister 1996).

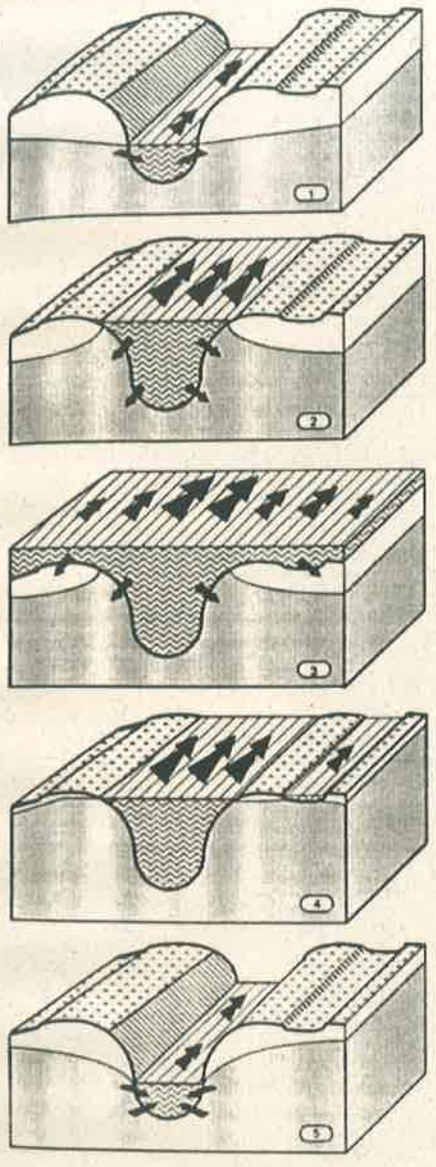


Figure 2: Typical changes of the river and groundwater levels starting from a rising river level (number 2 to 4) and continuing with a lowering river level (number 5 and 1). The groundwater follows the river with some delay, which causes infiltration of river water into the aquifer during the rise and exfiltration into the river during the lowering. The degradation of the hydrological system in the floodplain near Gabcikovo is given due to the constant exfiltration/ drainage into the Danube (number 5). Dister 1996.

4.1.1.1. Surface Water

The diversion of 80-90% of Danube water into the power canal since November 1992 has caused strong changes to the river hydrology. This is reflected in the monitored water discharge data (figure 3 above) . Both the volume and the morphological power of the Danube water were significantly reduced.

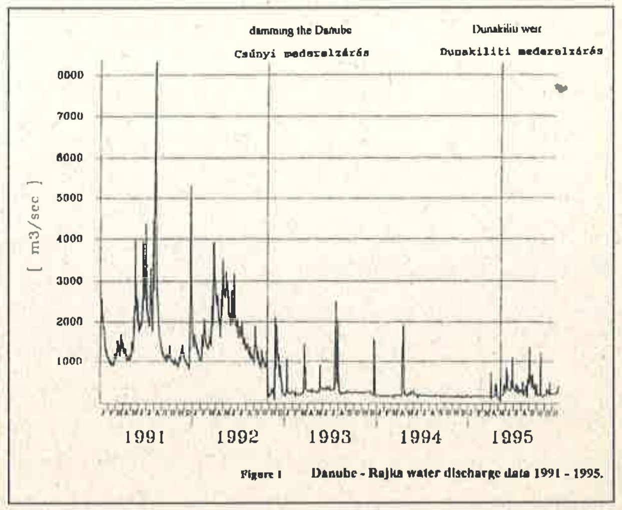


Figure 3: Danube -Rajka water discharge data 1991-1995. The curve shows the Danube discharge at the Hungarian monitoring station just downstream of Cunovo. It gives evidence of the important changes after the river diversion into the Gabcikovo canal: Water discharge in the river bed remained constantly low (mostly below historical marks).

The water volumes and levels are much below the historical minimum data (e.g. Horvath 1997). Below Dunakiliti, the river bed is filled only with shallow water, while the original banks and parts of the river bottom are usually dry. With a very few exceptions, all side-arms are disconnected from the river bed and water. Only during large floods (larger than approx. 5,000 m^3/sec) or during Slovak testing operations of the Cunovo weir, do more than the usual 100 to 600 m^3/sec of water run through this river stretch. The formerly typical large-scale penetration of Danube flood waters from the river bed into the side-arms will be very exceptional incidents in the future, because floods of up to 5,300 m^3/sec can be diverted at Cunovo into the Gabcikovo canal.

Formerly, the Danube side-arms were important for flood retention. Klucovska et Topolska (1995) calculated that at mean discharge (2,000 m^3/sec) only 8% of the Danube water was running through the left and right side-arm systems: while during floods the discharge of the river bed was gradually reduced. Previously, for a flood event of 5,740 m^3/sec in the Danube, up to 40% (= 2,300 m^3/sec) was gradually taken up by the side-arms, up to the mouth of the main Slovak side-arm.

Liebe (1997) states that, without diversion of the Danube, the active floodplain in the Szigetköz would have been inundated 32-36 days annually. However, no such water levels permitting inundation occurred after the river diversion. For 1993 and 1994, he calculated that, without the diversion, the side-arms would have received refreshing water supply from the „old" river bed for 63-70 days. Horvath (1997) states that this lack of water supply had a catastrophic effect on the floodplain side-arms. Artificial water supplements had only a damage-mitigating effect.

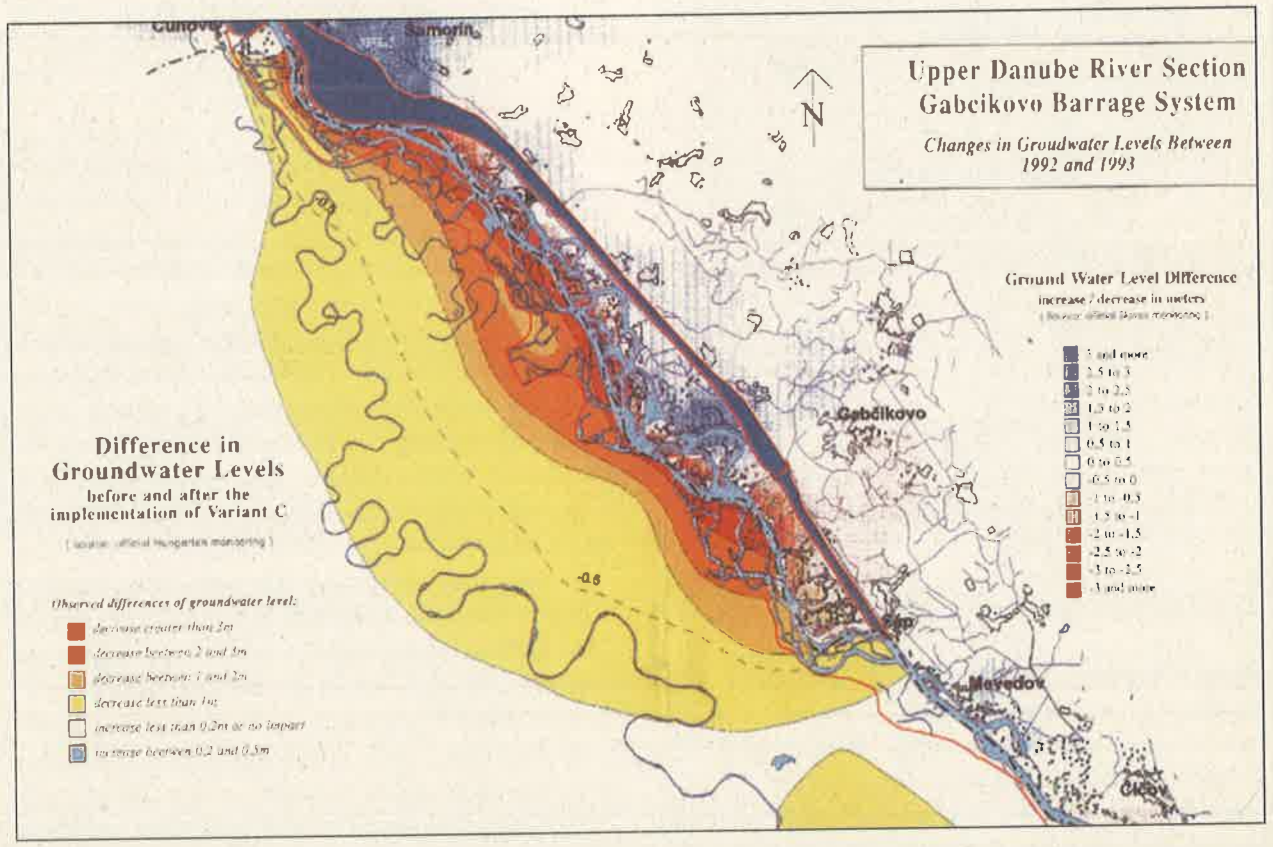
However, several engineering measures were undertaken in the main river bed after World War II, such as dredging gravel, building groynes, raising river banks and blocking side-arm openings during low water periods. This significantly reduced frequency of flows into the side-arms, with full flooding now only at discharges higher than 4,000 m^3/sec, and led to a regular and longer-lasting drying-up of floodplain branches (Holubova et al. 1995).

4.1.1.2. Groundwater

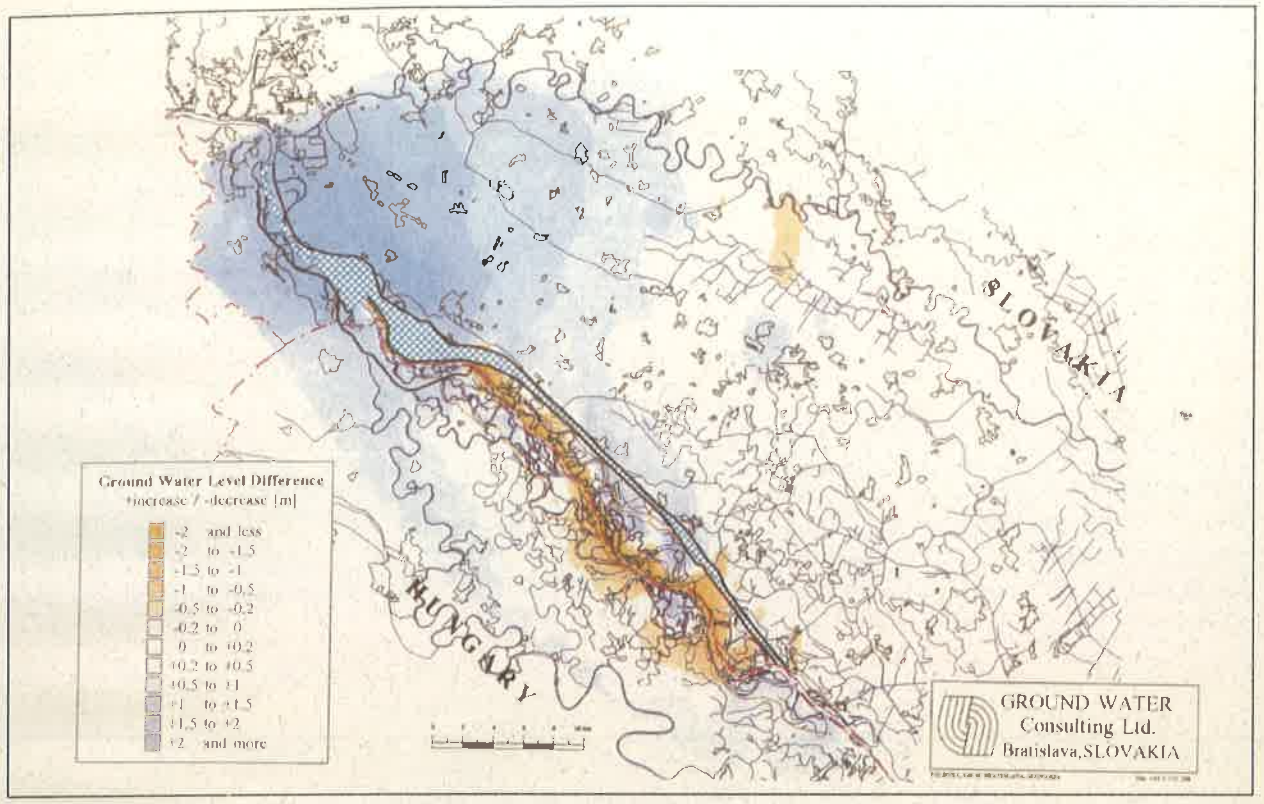
Before the diversion of the Danube, the Danube water infiltrated the underground even during low-flow conditions. This was caused by the relatively high elevation of the river bed above the floodplain, due to deposition of gravel and sand. Since the end of 1992, this process has been reversed in most parts of the area (Water Resources Research Hydrology Institute 1996). A general change in the groundwater level, fluctuations and flow direction was observed. Since then, the water table in the Danube floodplains has dropped by 2 to 4 meters; the seasonal, ecologically most important fluctuation of the surface and groundwater table was strongly reduced, and the former important infiltration of water into the aquifer was reversed, draining the „old" river bed. Tree roots lost contact with the water table especially in gravel layers where water cannot raise up to the top-soil.(MTA 1996)

Groundwater monitoring in both Slovakia and Hungary give evidence of the serious desiccation of the floodplains, the fall of the water table reaching up to more than 4 m along the river bed. This could only partly be reversed by artificial recharges over the last years (Maps 2, 3 and graphs 4a-c). It is in this area where the most severe "forest dying" can be observed and where many species well adapted to large water fluctuations are disappearing while untypical species, tolerant to permanently rather dry soil conditions, spread and destroy the original balance.

Another effect of this changed hydrology is the loss in purification capacity. The previous purifying effect on this Danube stretch is very limited in the sealed section of the Gabcikovo canal. At the same time, any impure water in the Cunovo reservoir penetrating into the aquifer poses a serious threat to the drinking water supply system. Pollution reaching the aquifer is hard to remove later on and tends to move on through the aquifer. Therefore, restoring the earlier self-purification system and limiting, or better even eliminating, potential pollution sources, like the development of sedimentation and undesired biochemical processes in the Cunovo reservoir, or the old waste deposits north of the Gabcikovo reservoir, are important measures for the protection of the future drinking water supply. Contrary to earlier promises by the Gabcikovo builders, the construction and operation of new sewage systems and treatment plants in villages along the canal on the Slovak side is still incomplete.



Map 2: Differences in groundwater levels between 1992 and 1993, i.e. before and in the first year of Gabcikovo operation. The two monitoring programmes on the Slovak and Hungarian sides offer evidence of the important changes in the wetland along the Danube between Cunovo (top left) and Sap (bottom right), as caused by the river diversion. WWF et Reflex 1995.



Map 3: Differences in groundwater levels between 1992 and 1995, i.e. between pre-dam situation and after the installation of artificial side-arm recharge systems also on the Hangarian side. It gives evidence of the prevailing water deficite in the floodplain. Lejon 1996.

It should also be stated that the area for some 30 years suffered from a considerable drop in groundwater levels. This was mainly caused by river training and huge gravel excavations in the Danube section at, and downstream from, Bratislava, and to a smaller extent also by the erosion process triggered by Austrian dams upstream (see WWF 1994). This has already led to degradation of the upper parts of the former wetland (upstream of Dobrohost up to Bratislava).

Slovak groundwater levels have been measured at more than 600 observation wells in the broad region of the Danubian Lowland between Bratislava and Komarno for many years. Part of the area has been influenced by the construction of the Gabcikovo structures since the damming of the Danube in October 1992. Based on a series of groundwater level data, in the last thirty years before damming the Danube and the two years after damming the Danube, the long-term changes in ground water level regime have been evaluated.

The differences between the groundwater level contours characterizing the pre-dam conditions in 1992 and post-dam in 1993, show the impact of putting the Gabcikovo part of the project into operation. The biggest impact is the general increase of groundwater levels in the upper part of the Zitny Ostrov as well as on the upper right side of the Danube, still on the Slovak territory. An even more damaging impact is the lowering of the groundwater level close to the Gabcikovo tail-race canal. A drop in the groundwater level is also seen in the area close to the Danube floodplain area, which is a result of the draining effect of the old river bed (Bansky et Mazariova 1996). In this area the decrease is up to more than 3 meters.

Slovak and Hungarian monitoring results reveal the expected drop in hydrological conditions in the aquifer: While the semi-penetrable Cunovo reservoir caused a rise in the groundwater table around it, the completely sealed Gabcikovo canal does not have any connection to the surrounding water table and to the very low Danube, which used to steer the groundwater fluctuations and the groundwater infiltration. The floodplain with its side-arms and large-scale forests is particularly affected by this intensive draining: Even with all side-arm openings to the Danube closed, a severe 3-4 m drop of water tables could not be prevented in a strip of 100-200 m along the „old" river bed. (e.g. Bansky et Mazariova 1995)

This impact is also well monitored in Hungarian monitoring maps which show that this situation is still prevailing (see figures 4a-c and 5 on pages 18 and 19).

The direction of groundwater flow between Rajka and Asvanyraro changed substantially from a S-SW direction into a Eastern direction towards to Danube. So, most of the infiltrating supplementary water for the floodplain was seeping back into the „old“ river bed (Liebe 1997).

In 1993 and 1994, an area of 4,200 ha of agricultural land (19% of area) in the Middle-Szigetkîz experienced a groundwater drop below the cover layer of soils. In consequence, agricultural yield was lower than usual whereas groundwater wetting of soils increased the yield in a dry year (Palkovits 1997).

Water level monitoring from wells in the village of Lipot revealed an average drop of between 0.7 and 1.3 m in 1993 and 1994 (Nemesi et Pattantyus-Abraham 1997), together with a reduction of water level fluctuations in the wells. In some cases this has resulted in a drying-up process of the „swelling“ clay layer in the underground, equivalent to a 5-20% decrease in volume and associated with a sinking of the surface. The authors guess that this process is the reason for the unsually high number of cracks in houses in some Szigetköz settlements.

Hlavaty et Cambel (1995) report that the overall drop in the groundwater level at the Slovak side-arm near Dobroshost by 1.5 m over the last 30 years was followed by another sudden decrease of 1-2 m at the end of October 1992, resulting in the complete loss of even capillary contact between the groundwater and the soil profile. In the side-arms near Bodiky and Gabcikovo/Istragov, similar data were observed. In a side-arm monitoring station further away from the river, the moisture conditions did not change .

The very occasional discharges of flood waves through the"old" river bed served to raise the groundwater levels in both floodplains. For instance at 1.400 m^3/sec, by 0.1 to 1.1 m, especially the narrow strip along the Danube(Monitoring 1996).

4.1.1.3. Artificial floodplain supply system

One of the most important negative impacts of the Danube diversion is the complete absence of regular inundations of the floodplain. Under natural conditions this is responsible for the morphological shaping of the riverine landscape through erosion and sedimentation processes, and for the repeated input of natural nutrients fertilising the floodplain. This fact is recognised by many experts, including the head of the Slovak monitoring team, Prof. Igor Mucha, who stated in the preface of his monitoring report (Mucha 1995): *„one of the most important events is for example flooding of the inundation area.“* Others, like Cambel (1995) and Uhercikova (1995), demand the complete flooding of the inundation area because *„previous analyses have confirmed that even a 1-2 m groundwater level increase would not mean a significant change for the majority of ecosystems in the former Danube inundation area.“*

There were a number of technical efforts to remedy the ecologically catastrophic state caused by the complete absence of natural water inflow and regular inundation into the Hungarian and Slovak side-arm systems since November 1992:

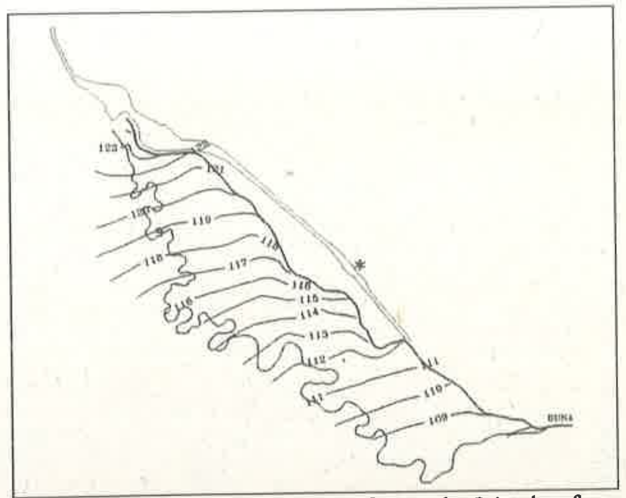


Fig.4a: Mean Groundwater level surface in the Szigetköz from 1 January 1991 to 23 October 1992, i.e. prior to Gabcikovo. Water Resources Research Hydrology Institute 1996.

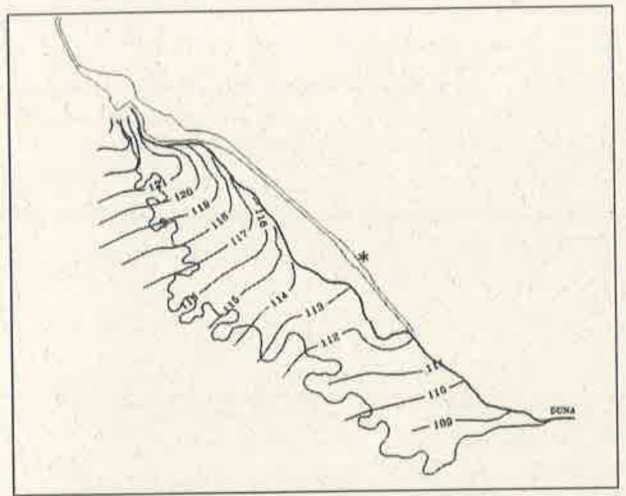


Figure 4b: Mean Groundwater level surface in the Szigetköz from 1 May to 19 May 1993, i.e. after the start of Gabcikovo. Mean discharge of the Danube at Bratislava is 2,002 m^3/sec, at Dunaremete in the Sziegtköz 302 m^3/sec. Water Resources Research Hydrology Institute 1996.

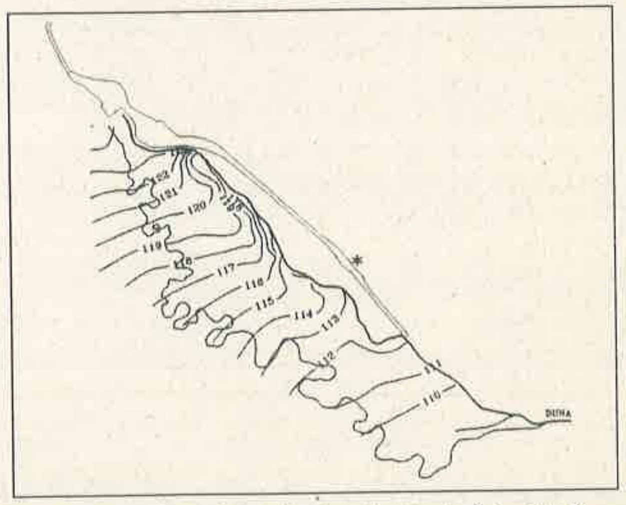


Fig.4c: Mean Groundwater level surface in the Szigetköz from 19 July to 4 August 1995, i.e. after the start of Gabcikovo and of the Hungarian recharge system. Mean discharge of the Danube at Bratislava is 1,938 m^3/sec, at Dunaremete in the Sziegtköz 312 m^3/sec. Wat. Res. Resh. Hydr. Inst. 1996.

NEW CROSS-DIKES
IN THE SLOVAK
SIDE-ARM SYSTEM

"Line D" (near Bodiky) dissecting a side-arm and a forest clear-cut; the "old" Danube in the left background.

Photo: Zinke

"Line G" cutting through a side-arm, nearby Gabcikovo power plant; several forest clear-cuts in the center and background.

Photo: Zinke

Typical Slovak side-arm in the of summer 1994. The water level is practically constant over the years. The impounded upstream section (right) promotes siltation (colmatation), the fast flowing downstream section leads to bed erosion.

Photo: Zinke

Slovak side-arm at "line G" in summer 1994: no water going over the weir. By the summer of 1996, the trees in the right background had disappeared.

Photo: Zinke

New cross-weir at the Danube near Dunakiliti (rkm 1,842) in July 1995. These rapids are hardly to overcome for most Danube fish.

Photo: Zinke

New cross-weir at the Danube near Dunakiliti in February 1996: all water in the "old" Danube was then diverted over the Dunakiliti weir (left background), acting as a perfect fish barrier).

Photo: Zinke

On the **Slovak side**, a number of technical installations were built in the side-arm system to allow simulations of former Danube floods but using only very small amounts of water. The works include, near the village of Dobrohost, an intake structure with a 1 km sealed canal, leading water from the diversion canal into the upper end of the main side-arm. Built mainly in the winter of 1992/93, it started in February 1993, i.e. 4 months after the start of Gabcikovo, with an interim pipeline irrigation system which was replaced in May 1993 with the start of operation of the Dobrohost intake structure and canal: From then on between approx. 5 and 120 m^3/sec (average ca. 30-40 m^3/sec; designed capacity: 234 m^3/sec) were diverted into the side-arms near Gabcikovo.

As a second technical measure, seven lines of small cross-dikes s were built in the side-arm system between Dobrohost and Gabcikovo, forming a cascade-like system, each locally lifting the water table and together allowing the input of small water volumes while creating the impression of high water levels („floods“) in the side-arm system.

A third important construction measure was the closure of all side-arm connections with the main river bed, securing a one-direction flow of surface waters to the lower end and preventing unwanted „losses“ into the main river bed.

Klucovska et Topolska (1995) report that field measurements supported by the Slovak EU-Phare project on hydrology concluded that up to 80% of the inlet discharge infiltrates into the groundwater while passing through the side-arm, particularly in the upper part. During WWF field visits it was observed that this effect meant that little or no water was going over the line G cross-dikes of the main side-arm branch (Map 1), in spite of a substantial inflow at Dobrohost. The quick infiltration of water in the upper section meant that the closing of cross-dike culverts – planned for raising the water table and for simulating a flood – could not be undertaken.

The authors further state that a flooding simulation in the central side-arms (lines G to D) of a pre-dam Danube flood event of 4,000 m^3/sec, could be arranged with a flow of 150 m^3/sec through the inlet structure. However, even the simulation of such a small flood has never been managed.

In addition, it was admitted that the pre-dam water fluctuations, which would be needed for raising the oxygen content of the groundwater, cannot be achieved with this artificial discharge system(Holubova 1995).

Contrary to earlier engineer plans and public announcements, the dam operators have not yet produced artificial inundations of the entire floodplain: Instead of producing several artificial inundations every year, there were, until the end of 1996, only two artificial events in 1995 and 1997. Lasting for 35 days (21 July to 26 August) and varying from 35 m^3/s to 119 m^3/s, a small flood filled the Slovak side-arms without overflowing the banks – insufficient to realise the announced crucial inundation. The second “flood” lasted from 24 April until 26 May 1997, starting from the average at 20 m^3/sec and peaking at 130 m^3/sec.

Vargha et Nesticky (1995) report some details of the impact of this first artificial flood event on the Slovak forest system. They found that in spite of the long period the actual „flood“ (water going beyond the banks of the side-arms and producing the desired inundation) lasted only three to five days. The upper and lowest parts and the stretch along the Danube (a 200 m wide „dry belt“) were hardly affected, while between the lines B to G the groundwater table rose up to 0.5 to 0.7 m below the soil surface. According to the Slovak forest experts the chosen period was unnatural and they regret that the recharge structure's capacity was only 50% used, thus limiting the announced „inundation“ to a few depressions („hardly detectable“). For future artificial floods the authors demand at least one event at an earlier date and following the natural dynamics of the Danube. For the „dry belt“ they recommend a seminar for the forest owners advising them how to „reconstruct“ their (impacted) forests.

Somsak et Kubicek (1995) call the relatively constant discharges (28 m^3/sec) a disadvantage with negative consequences for the vitality of the original trees, which are ecologically adapted to frequent water fluctuations. In addition, the experts consider the absence of nutrients and suspended sediments in the water coming from the canal (reservoir) at Dobrohost a mistake in the design of Variant C.

Nesticky (1995) interprets the permanent high water levels in the side-arms (higher than originally under 2,000 m^3/s Danube discharge conditions!) as a prolongation of the vegetation period which threatens the annual shoots from freezing and being infested by fungi. He therefore demands a lowering of the water levels in the side-arms from mid-August onwards.

On the **Hungarian side**, as well, no immediate measures were undertaken following the unexpected diversion of the river. As in the Slovak wetlands, this caused a sudden drying out of the side-arms in November 1992 and large-scale fish deaths. Further degradation could not be prevented by increasing the discharge into the Moson Danube on 20 m^3/sec. The next mitigation efforts, in the form of artificially pumping a few m^3/s of Danube water into the main side-arm channel, started in 1993 and were continued with increasing quantities (last in October 1994 to 25 m^3/sec). Its effect on the rise of the groundwater level in the floodplain was negligible (LIEBE 1997). Eventually in spring 1995 a new cross-weir was built in the Danube bed near Dunakiliti. Announced as an „underwater weir“, this scheme proved to be a quickly built-up and reversible rock barrier which, starting in late May 1995, raises the upstream water table for several kilometers allowing the diversion of river water at two upstream side-arm openings (just downstream of the Cunovo weir) into the Hungarian side-arm system.

As on the Slovak side, most other Hungarian openings of the side-arms along the Danube bed had to be closed in order to retain the supplied water in the side-arms and limit the draining to the Danube bed. Since June 1995, the average input volume is between 30 and 120 m^3/sec, i.e. higher than on the Slovak side. The inflow is steered through the nearby

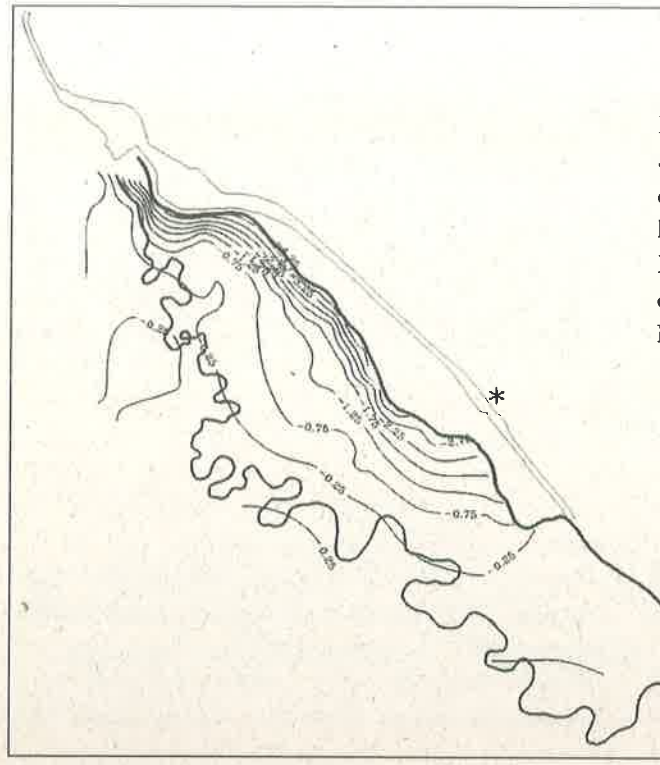


Figure 5a: Mean decrease of the groundwater level in the Szigetköz between 1 May and 19 May 1993 after the Danube diversion. The isolines (scale is one meter) indicate the much lowered groundwater level in the floodplain area along the Danube, as compared to the situation prior to the operation of Gabcikovo. Water Resources Research Hydrology Institute 1996.

Dunakiliti weir scheme which, in a politically heavily disputed decision, was put into operation in May 1995, thus fulfilling one of its original purposes as planned within the old Gabcikovo-Nagymaros project. With the halting of all construction work on Hungarian side in 1989, the already completed Dunakiliti weir, originally built to divert the Danube, lost its function and remained unused until May 1995.

Local field visits showed that, contrary to first announcements, Danube water does not always flow over the cross-weir but is largely going over the Dunakiliti weir. Thus, both weirs create a major, sometimes dry barrier for migrating fish and other river life.

As on the Slovak side, the impact on the groundwater table remained limited. While the main floodplain branch was continuously filled with rather fast flowing water, the ground water levels especially of the Central Szigetköz (active floodplain) were not considerably recharged. Computer model comparisons of the groundwater levels between the „natural“ hydrological situation as determined by the gauge station in Bratislava (using the 1992 values as a base line), and the field water levels measured in monitoring wells in the Szigetköz, showed the prevailing drastic change. Within the 2-3 km wide floodplain zone, the groundwater levels remained significantly lower during the artificial water recharge, as compared to the situation without the river diversion. While in the model, the seepage from the Danube would be the natural process, in reality the almost empty river bed continuously drains water from the aquifer, in spite of the artificial water recharge. A reduction of the water deficiency by only 0.5 m does not significantly improve the moisture conditions in the root zone of the floodplain soils (compare figures 5a,b and Map 3). (MTA 1996)

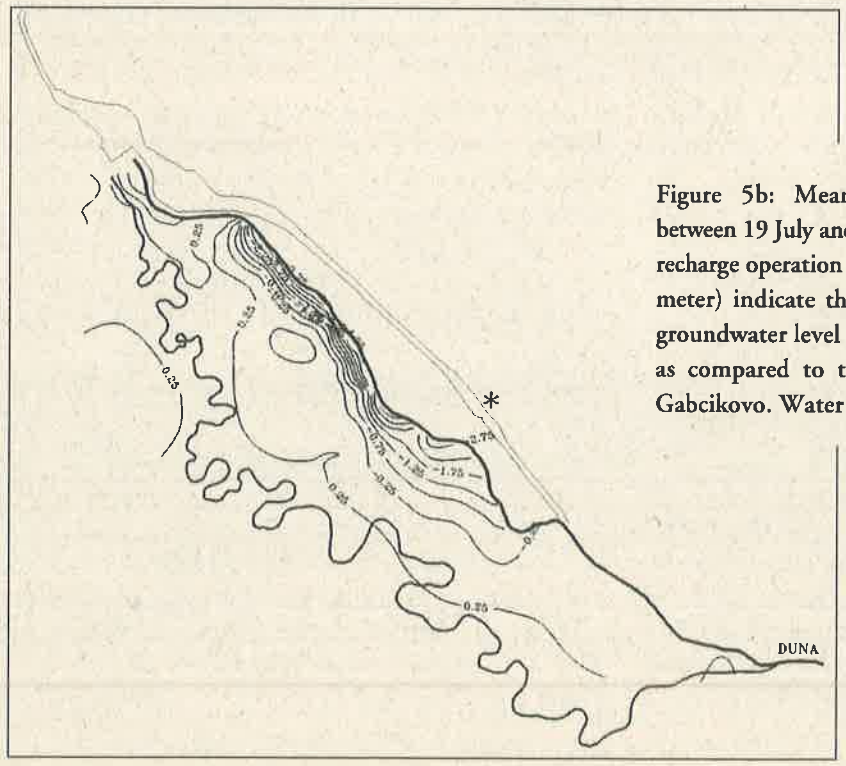


Figure 5b: Mean decrease of the groundwater level between 19 July and 4 August 1995 after the start of the water recharge operation in the Szigetköz. The isolines (scale is one meter) indicate the slightly raised but still much lowered groundwater level in the floodplain area along the Danube, as compared to the situation prior to the operation of Gabcikovo. Water Res. Resh. Hydr. Inst. 1996.

The Joint Annual Report from 1996 reports that groundwater fluctuations very much followed the surface water fluctuations, both at around 0.5 to 1.5 m. While this can be regarded as an improvement in hydro-dynamics, it cannot restore the pre-dam fluctuations which were more than 5 m.

The increase of groundwater caused by the cross-weir is limited to the Upper Szigetköz. For the critical and ecologically most valuable area this replenishment is insufficient. This is reflected in the graphs of the groundwater monitoring wells (e.g. well number 9503: see figure 6) which show the significant difference between the model curve (without Danube diversion) and the present situation (well curve) since 1991, continuing even after starting the artificial water input system (MTA 1996).

Hungarian scientists conclude that there is a need for flow dynamics in excess of the 1995 levels. In addition, they found that in various localities the water draining into the main river bed does not stem from the artificial recharge system (MTA 1996).

It is evident that the biological system suffers from these conditions. Water organisms as well as floodplain forests are under severe stress. The first trees began to die a few months after the Danube diversion, although large parts of the forests managed to survive the dry summers of 1993 and 1994 and obviously profited from relatively wet summers of 1995 and 1996. However, the monitored reduction of leaf surface and growth rates, early sheddings of leaves and dry tree tips are clear symptoms of the ongoing harmful and aggravating situation. It is only a question of a few years until, for exampl,e a hot summer season will mean large-scale forest dying. The forest localities along the main river bed are already severely damaged (see also chapter 4.1.3.2.).

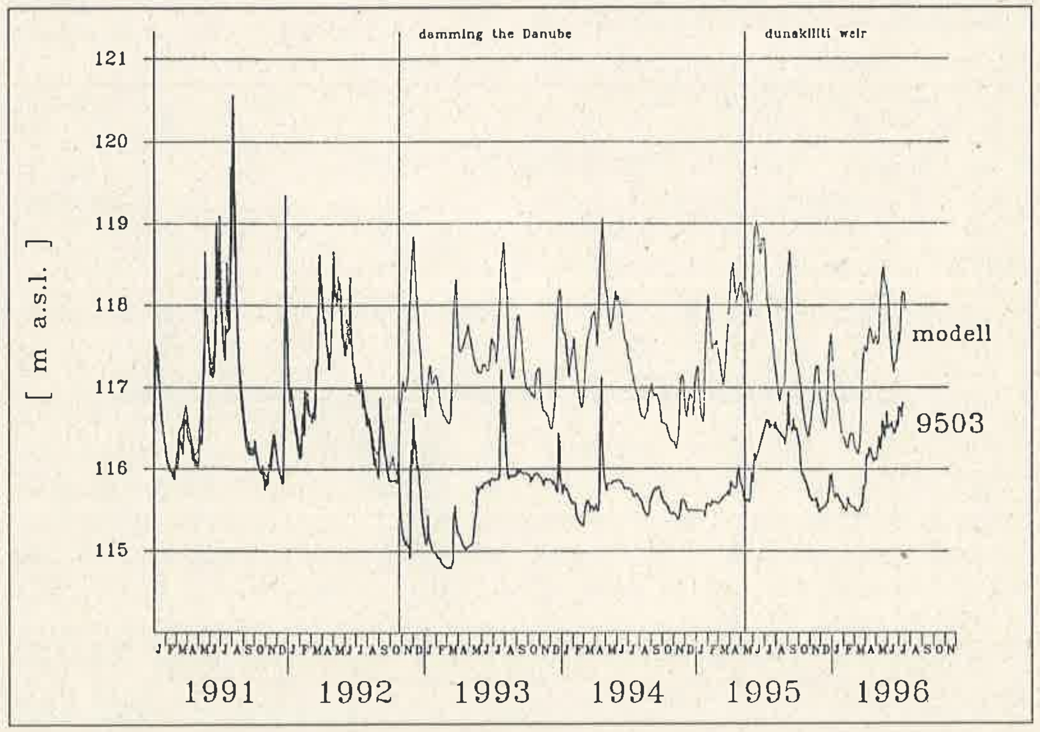


Figure 6: Changes of groundwater level in the monitoring well no. 9503 located in the central Szigetköz near the Danube between 1991 and 1996. The model curve shows the groundwater level if the Danube would not be diverted, the lower curve the reality. The vertical lines indicate the date of the river diversion and the start of the artificial floodplain recharge system through the operation of the new Danube cross-weir near Dunakiliti. Water Res. Res. Hydr. Inst. 1996

4.2.2. Morphology

Intervention in the river morphology has a long history and its first major impact occurred in the 19th century. One of, the most important single impacts in this river section has been the dredging of gravel since the 1960s: In 1965, for example, dredging of 1.9 million tons of sediment near Bratislava represented almost twice the volume of the annual bedload transport capacity. This major degradation of the dynamic morphological equilibrium caused upstream and downstream river bed degradation. At Bratislava the erosion amounted to 2 m in the last 30 years (Holubova et al. 1995). As a consequence, the floodplains were inundated only during high discharges.

Closing the Danube river bed at Cunovo has substantially transformed the channels in the reach of the Danube between Rajka and Szap and the arms of the Szigetköz (Rakoczi et Sass 1995). Quantitative channel measurements comparing the situation were taken from just before the Danube diversion in October 1992, to October 1995. This allowed further forecasting of channel changes. The data included particle size distribution analyses, indicating the velocity distribution of the river bed cross-section, measurement of deposition and erosion, and cross-sectional changes.

The changes in the "old" Danube channel indicate increasing sedimentation (see figure 7) as far as the return of the Gabcikovo canal (rkm 1.811), and again for approx. 10 km downstream. This pattern was interrupted by a abrupt and rapid erosion of several meters where the canal water fed back into the main river bed (MTA 1996).

Between October 1992 and May 1994, three Szigetköz side-arms experienced a substantial channel filling process, increasing downstream and amounting to: 33,000 m^3 in the Bodak arm, 72,000 m^3 in the Asvanyraro arms, and 434,000 m^3 in the already impounded backwater section 'of the Bagomer arms. In the Asvany Danube arm, the process of mud deposition rose to 40-50 cm from 1993 to 1995 (MTA 1996).

These data show the important impact of the Gabcikovo dam system on the morphology of the main river channel. According to measurements in 1996, this process continues.

The section in the" old" river bed upstream of the „underwater weir“ (rkm 1.843-1.851) changed from large clean gravel shallows into submerged, mud-covered areas (2.5 to 4.5 m higher water level) especially in the lower part. The conditions for infiltration and aquatic life deteriorated.

In the section downstream of the new weir (rkm 1.823 – 1.841), the former gravel bars are covered by a thick pioneer vegetation with a fine deposit of sand and rock powder coating in between.

The re-impounded river section (rkm 1.810-1.823) shows the highest mud-building effects. Here in the backwater reach above the conjunction with the power canal, the water flow ceased almost entirely and the water stagnanted. Fine sand and mud deposits of considerable thickness have been observed.

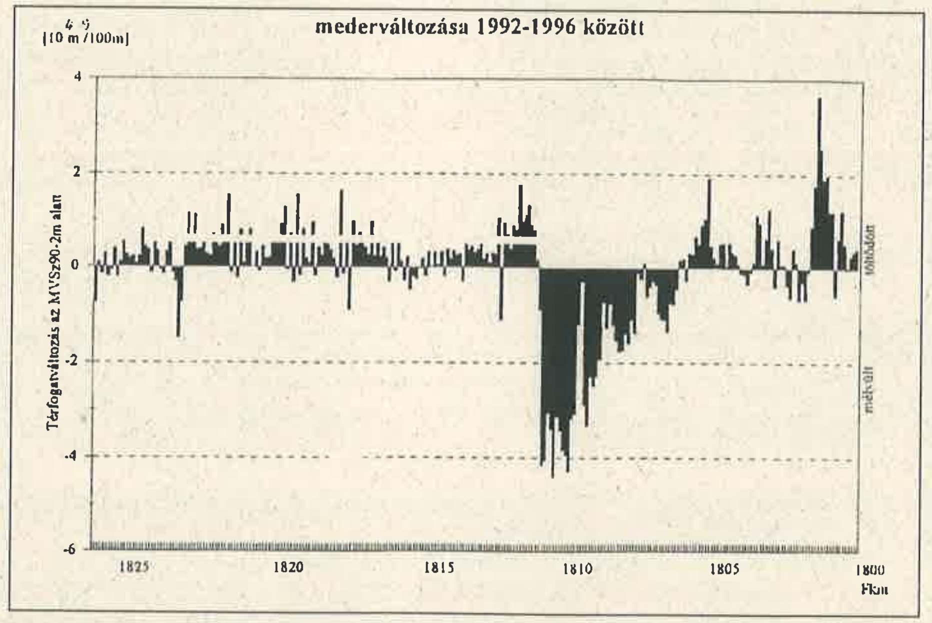


Figure 7: Relative change of river bed at the Danube river section rkm 1,800 – 1825 between 1992 and 1996, i.e. deposition above the "0"-line and erosion below it (from: Rakoczi et Sass 1996).

4.1.3. Ecology

4.1.3.1 General Comments on Slovak and Hungarian Monitoring

The environment monitoring activities in the impact area of Gabcikovo are and were of varying quality. While in 1992 and 1993 the results were used and commented upon by EC expert groups (EC Mission Reports November 1992, May 1993 and 1 December 1993, EC Mission Data Report 2 November 1993), the subsequent monitoring results were intended to support the countries positions before the International Court of Justice. A new monitoring process started in May 1995 with the signing of a new Slovak-Hungarian agreement, which required the production of Joint and National Annual Monitoring Reports. So far, the Reports for 1995 (May to December) and 1996 exists. Neither government publisiced these reports.

Hungarian monitoring seems to be comprehensive and detailed in certain sectors, but published documents are few and brief. This makes detailed independent evaluation difficult. There is only one published scientific overview of the impact of the Gabcikovo system on Hungarian territory in 1994 (Lang et al. 1997). A few other documents and publications present certain sectors of the overall monitoring activities and results. In this respect, the WWF critique from 1993 on the shortage of scientific results must be maintained.

Slovak monitoring is largely controlled by the Gabcikovo proponents who limit access to scientific details for the public. On the level of hydrology, in particular, there seem to be huge data bases. The Slovak „Environment Impact Review“ (Mucha, ed. 1995) is the biggest published monitoring report on Gabcikovo. It includes several critical, sometimes contradictary, expert findings on the impact of Gabcikovo, and some recommendations on how to mitigate this. This monitoring is largely dependent on the Gabcikovo proponents, Vodohospodarska vystavba s.p., but there is also some published critisism on the Slovak monitoring activities.

Lisicky (1995), for instance, saw some problems in the Slovak monitoring system of organisms:

- The 15 botanists participating in the monitoring in 1990-91 were later reduced to one or two.
- Only half of the 24 localities selected for monitoring were in fact monitored. Complex zoological and botanical monitoring was provided at only five localities.
- Only the forest vegetation is regularly monitored. The water and riparian vegetation was recorded only in 1990-1991, and the wet meadows only in 1990, and 1992. Hydrophytes do not seem to have been monitored.
- The data has been incompletely evaluated with poor interconnection between observed biotic and abiotic data and poor statistical interpretation- evaluated mainly by tables and graphs.

Possibilities for improving the evaluation of monitoring data

A common problem in community ecology is to discover how a multitude of species respond to external factors such as environmental variables, pollutants and efforts to manage them. Data are collected on species composition and the external variables at a number of points in space and time. To analyse the generally non-linear, non-monotone response of a community of species, one has to resort to the data-analytic methods of ordination and cluster analysis. These are indirect methods that are generally less convincing than direct statistical method of regression analysis.

In the late eighties, regression and ordination were integrated into techniques of multivariate direct gradient analysis, called cannonical ordination. This technique greatly improves the power to detect the specific effects one is interested in. One of these techniques, cannonical correspondence analysis (Ter Braak 1996), escapes linearity and is able to detect unimodal relationships between species and external variables.

4.1.3.2. Forests

The macroclimate of the Danube floodplains can be classified as forest steppe climate which in itself is unfavourable for forests. They can exist only thanks to sufficient water disposal (precipitation, groundwater, inundations), connected with high evaporation from large open waterbodies. The trees stand on alluvial soils which are developed by repeated deposition of nutrient-rich sand and mud layers (some 2 cm per year) during frequent inundations. Below this upper soil there is, at 50 to 150 cm, a thick gravel layer, sometimes mixed with coarse sand. In the absence of inundations, there is no more capillary contact between the fertile upper soil and the groundwater. This limits or even stops tree growth.

Before Gabcikovo, most sites of these Danube floodplains were under constant effect of water, with inundations lasting 1 to 2 months per year and consequent high forest productivity (Csoka-Szabados et al. 1997)

Hungarian monitoring

Due to the complete missing of floods and forest inundations, and to the connected groundwater sinking since 1992, precipitation remained the main source of water. In the period 1993 to 1995, the expected general and disastrous degradation of tree stands did not occur, mainly due to the unsually wet summers from 1994 to 1996.

At certain places, especially along the main river bed, there were significant losses of willow stands, as these are very sensitive to the absence of floods. The overall growth pattern of poplars showed a significant decrease, but the pattern was uneven (Joint Annual Report 1996).

Oaks and ashes showed no significant growth differences. However, the growth curve characteristic for the years prior to the diversion changed. Increasingly, the annual growth was restricted to the first stage of development, up to the end of

Slovak floodplain forests in late April 1994: dry tree tips of white willows.
Photo: Zinke

Slovak floodplain forests in October 1994: dry tree tops of poplar hybrids.
Photo: Zinke

Slovak floodplain forests: Example of large-scale clear-cuts downstream of "line G" (visible in the background) in late April 1994
Photo: Zinke

May, after which it slowed down and sometimes almost stopped. The former seasonal growth peaks promoted by inundation disappeared.

An early fall of leaves caused by the drought could be observed mostly in higher localities and along the Danube bed.

Regular inundations previously prevented rapid growth of forest-damaging organisms.

The absence of inundations has led to top dryness of trees in the area Rajka – Dunakiliti (Varga 1997).

Szabo et al. (1997) report that at their forest monitoring site in Dunsziget the leaf area of oak and alder was in 1993-1994 21-27% lower than in 1989-1992. A similar trend, indicating a suboptimal water supply for trees, for ashes in 1993 changed in 1994 due to beneficially more rainfall.

These experts found this rapid drying of wet habitats more clearly shown with the monitored herbaceous species (*Nuphar lutea* – yellow water lily, *Phragmites australis* – common reed and *Plantago altissima* – tall plantain). The tendency of habitat degradation suppresses hygrophilous (wetland) specialists and supports species with wide tolerance range or even drought resistance. Original flora and plant communities are threatened and already disappearing at various sites in the Szigetköz.

The more abundant rainfall in 1995 and 1996 seems to have replenished the lack of moisture in the soil: the average leaf surface is similar to the size before the diversion. But the floodplain forests are still in sub-optimal conditions with regard to water supply.

In the hardwood groves, the species spectrum is shifting towards the drought tolerant species and away from the water demanding species.

Already in spring 1993 the river bed and side-arm surfaces, previously covered by water but left dry after the diversion, became overgrown by terrestrial vegetation. Willows and poplars have quickly overgrown the pioneer weed communities from spring 1993. An oxbow-lake near Dunaremete, once permanently covered with water and hosting a lush auqatic macrophyte vegetation with dominance of the yellow water lily, dried up and, within two years, became 80% covered by weed communities (*Polygonum, Rumex*). Reed stands are expected to completely cover the former oxbow-lake floor in the future (Hahn et al. 1997).

Csoka-Szabados et al. (1997) emphasise that the health deterioration of trees can only be restored by uneven temporal occurence of wet conditions, but not by steady water levels.

Slovak monitoring

The first negative consequences of the building of the hydropower structures of Gabcikovo-Nagymaros was the removal of the floodplain forest to an extent of 3.267 ha (Somsak et Kubicek 1995).

After the Gabcikovo system started, further serious degradation was observed. Areas with negative trends in vegetation development, like Dobrohost, Istragov, Bodicka brana and Ostrovne lucky, are either directly and markedly influenced by hydrodam structures, or they show strong changes in the hydrological conditions – absence of floods, a decrease in surface and ground water level.

As the groundwater could no longer have its impact on vegetation, the climatic conditions started to affect the floodplain forests, especially those near Dobrohost (Cambel 1995). The dry spell from 1993 to 1994 increased this detrimental impact, while the wet phase from 1995 and 1996 only slowed it down.

At present, the limiting factor at a number of localities, especially Istragov, Dobrohost and Ostrovne-lucky, appears to be the absence of floods since the last in 1991, which in the summer months would compensate for the moisture deficit (Uhercikova 1995). The monitoring of the ground water level and the volume of soil moisture revealed that the soil water was

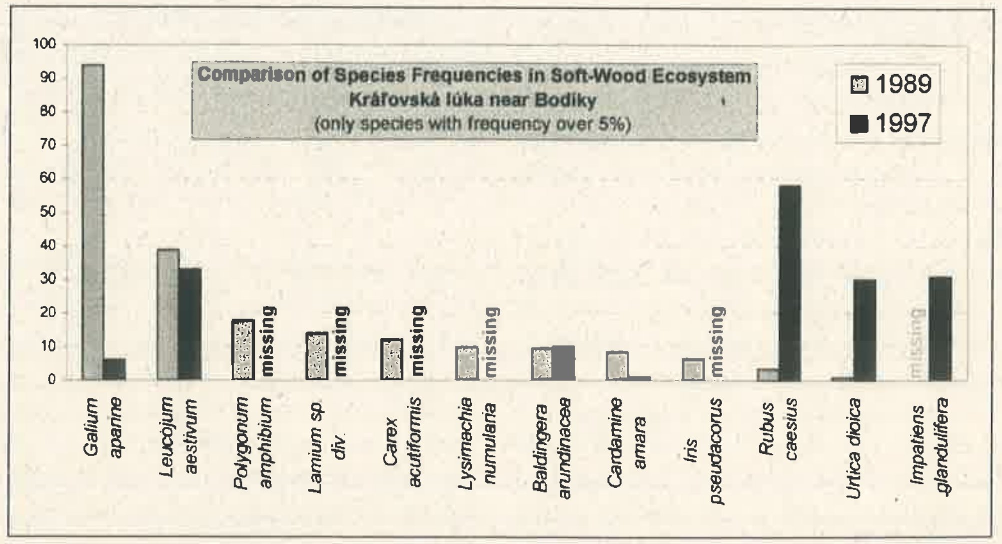
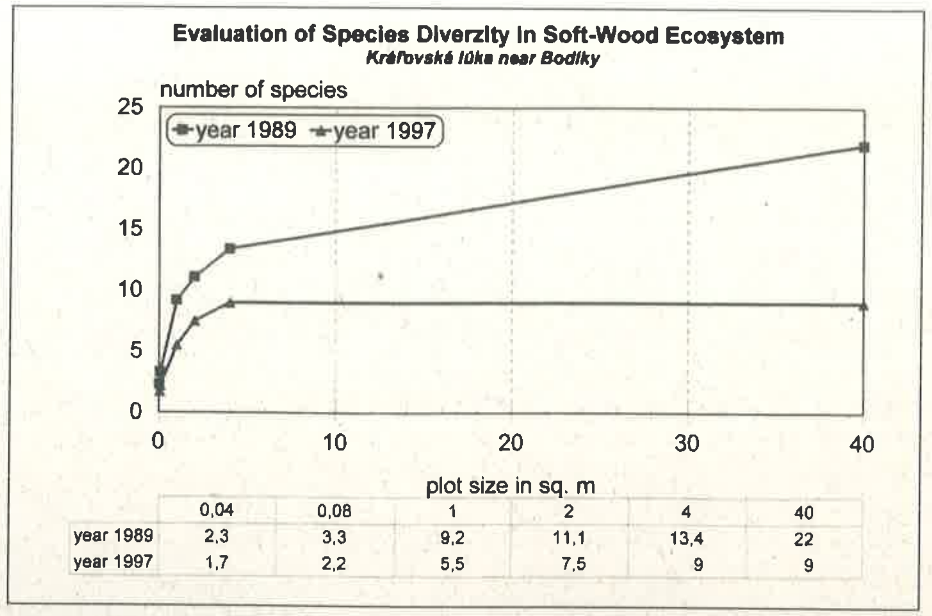


Figure 8a: Change of plant species frequencies from 1989 to 1997. From: Seffer et Stanova (in prep.)



	0,04	0,08	1	2	4	40
year 1989	2,3	3,3	9,2	11,1	13,4	22
year 1997	1,7	2,2	5,5	7,5	9	9

Figure 8b: Change of plant species diversity from 1989 to 1997. From: Seffer et Stanova (in prep.)

now hardly accessible for vegetation, and that even filling up the river arm system did not improve moisture conditions in areas close to the Danube which are influenced by the drainage effect of the old river-bed. The spectrum of species changed. For instance individual numbers of typical flood indicators like *Leucojum aestivum* decreased, while nitrophiles and neophytes become dominant. Oszlanyi (1995) found negative changes along the river bed, reflected by a significantly reduced (20-30%) leaf area index. Uhercikova (1995) concluded that if this situation did not change in 1995, an increased mortality among woody plants, further cover enlightement and continuation in successive alterations could be expected in these areas.

The Joint Annual Monitoring from 1996 reports that the wood yield data in five out of ten examined sites showed a decrease in growth.

Somsak et Kubicek (1995) state that along the whole river bed „the given situation excludes a natural reforestation of the original floodplain trees. It will probably only comply to cultivar poplars planted by 'deep drought'". Willows lost up to 80% of their leaves and are being replaced by shrub species such as *Cornus sanguinea*.

On the other hand, a substantial increase in the groundwater level above the Cunovo dam was not significantly demonstrated in phytocenoses at Kopac, Rusovske ostrovy and Topolove hony. Emissions from Bratislava constitute a substantial stress factor in these areas. This factor and its effect is not evaluated in this monitoring. Only the next few years will show whether the vegetation alterations are irreversible with respect to their age, or whether they are still capable of recovering. Furthermore, a gauge for measuring the ground water level has not been installed at the locality of interest (Uhercikova 1995).

Anthropogenic intervention, in the form of the selection of poplars, appears to have had a dominating effect on the areas Horna vrbina and partially also Klucovec. Since there is no way of differentiating between the effect of forestry and water engineering work, these localities became less valuable, or even useless from the point of view of monitoring (Uhercikova 1995).

Loss of original biodiversity

Another important sign of ecosystem degradation is the invasion of alien species. Invasive aliens can have a number of impacts upon a natural area. When they become established, they displace some of the existing native plants. In the case of an extreme infestation, there may be a loss of most of the original vegetation. This original vegetation would have supported a complex of animals that fed upon or reproduced within it. The species displaced may include rare native flora and fauna which can be seriously threatened by alien invasion.

There are many reasons why there are considerable problems with invasive species in natural areas. Most are adapted to somehow disturbed habitats. This disturbance in a wetland could be changes of water level fluctuations as a result of flood control measures (White et al. 1993).

Changes in the regime of floods and water tables stress the wetland's ecosystem. Decimation of woody plants and a thinning canopy enlightenment, leads to an invasion by non-indigenous species in the former floodplain areas. Some of these non-natives were already present in small patches in the Danube area before, but after 1992 the invasion took off. The neophytes *Aster novi-belgii, Impatiens parviflora, Impatiens glandulifera* and *Solidago gigantea,* which also indicate drier conditions, dominate in the monitored localities – Stary les, Kralovska luka, Horna vrbina, Klucovec and Istragov (Uhercikova 1995). Invasion of *Impatiens glandulifera* in Kralovska luka displaced the original vegetation in large areas.

An acceleratation of alien invasion in the left side arm system is expected in the near future because the artificial water supply of the side-arm system did not improve the situation regarding alien infestation. Such degradation of the community structure was also observed by Seffer et Jarolimek (1988) and Seffer et Stanova (in prep.) at the locality of Kralovsky luka near Bodiky, which is relatively far away from the most affected river stretch. In monitoring a plot of 40 m^2 in a softwood community they recorded, between 1988 and 1997, a reduction from 22 down to 9 plant species (figure 8b). The strong changes in the community structure includes the disappearance of five native species – all of which indicate wet conditions – the strong increase of *Rubus caesius* and *Urtica dioica* – indicating drier conditions – and the invasion of *Impatiens glandulifera* up to a frequency of 30% (see figure 8a). The comparison of species diversity in increasing space scale shows the significant change in average species number over different plot sizes. The diversity coefficient declines by over 50% – from 2.8 to 1.2. This indicates the far-reaching loss of typical dynamic conditions and the connected impact to the original biodiversity.

The 1996 Joint Annual Monitoring Report states that "on Slovak side in spite of good soil moisture conditions, the dominance of neophyte, invasive and nitraphylous species is slowly increasing."

Similar changes are also reported from the Szigetköz. Szabo et al. (1997) found that the invasion of weeds caused by intensive agriculture and silviculture has amplified follwing the Danube diversion. The partly exposed Danube bed, and the dried-up side-arms and oxbow-lakes, provided optimal conditions for weeds and adventive species. They conclude that the values of rich and protected flora is threatened most seriously or has already disappeared in the Middle Szigetköz.

4.1.3.3. Fauna

Faunistic research characterised the Szigetköz to have high species richness, special associations of species and a high degree of special mosaicity (Meszaros et Bertalan 1997). The same can be said about the neighboring Slovak floodplains in Zitny ostrov. The original list of species from 1993 included: 250 bird species (145 breeding), 41 mammals, 68 fish species (out of 70 species altogether in Slovakia; representing 80% of the Hungarian fish fauna), bald eagle, white and black stork, cormorant, several heron species, beaver and river otter. All fauna might include much more than 5,000 species.

The Szigetköz, called „the fish-crib of the Danube" (Koltai 1997), includes species having very different ecological demands, like the trout*Salmo gairdneri* from clean mountain rivers and the loachs (*Cobitidae*), typical for marshes.

The variety of very different living places allows a unique biodiversity to strive in a relatively small area.

Terrestrial animals

These negative hydrological and phytocoenological processes are also reflected in the fauna. Stepanovicova (1995) reports that, especially in the Dobrohost area, gradual changes in the species composition of almost all epigean and edaphic communities of edaphic evertebrates have taken place. Typical hygrophilous species retreat, while less pretentious mesohygrophilous species and those associated with soil desiccation increase e.g. Malacocoenoses, Chilopoda, Arachnocoenoses, Collembola, Coleoptera, Heteroptera. Only edaphic Curculionidae showed no changes. In this area, the zoocenoses lost their floodplain forest character.

In the area influenced by the Danube drainage effect, there are expressive changes of the mollusc community towards less hygrophilous species. This proves the necessity of flooding and raising of groundwater levels in the former inundation areas (Joint Annual Monitoring Report 1996).

For various groups, such as small mammals, macrozoobenthos or Cladocera, the monitoring period was too short to isolate the evaluation of present population changes from other impacts, such as pre-dam degradation and annual weather variations. Their development will remain unstable and incomplete for several more years.

Some specimens of butterflies (Lepidoptera) which are usually restricted to their habitats were detected far from their typical sites. This is interpreted as a local migration to discover new, potentially more suitable habitat as a result of environmental disturbances (Meszaros et Bertalan 1997).

Aquatic animals

Meszaros et Bertalan (1997) estimated that due to the drying-out of side-arms, lakes, Danube banks and meadows, some 50% of the bigger mussels *(Unio* ssp., *Anodonta* ssp.)and probably 70-80% of smaller mussels *(Pisidium* ssp., *Dreissena* ssp.) vanished. With the disappearance of the water plant *Stratoides aloides* from the Lipot dead arm, two dragonfly species (*Aeshna viridis* and *Leucorrhinia p.*), listed in the Berne Convention, also became extinct. There is a clear trend of species decline in many Szigetköz habitats. Drought tolerating, warmth preferring or xerophilous species appeared in higher numbers and abundance, while the same figures for aquatic and semiaquatic species decreased by 1994.

Vranovsky (1995) examined the structure of the plankton copepod taxocoenoses in the water bodies of the affected Slovak area. He concludes that as a consequence of the damming of the Danube, the disconections of the branch system, and the substitution of water solely from the headrace canal, the previously typical zooplankton had been practically eliminated. Vranovsky found changes in the Slovak side-arms such as a dessication of the biotopes, a decrease in euplanktonic species, and a parallel increase in tychoplanktonic (benthic and phytophilous) species. He also noted a significant decrease in the summer values of zooplankton biomass (fish food!) as well as some changes in the free-water zone of the Danube channel. Only the control monitoring site downstream of Gabcikovo remained rich in its copepod cenosis.

Halgos (1995) found important changes in the mosquito communities: the changes in groundwater levels affected both the quantity, by significant decrease in dried-out localities and in forest stands near the Danube, and quality. The species number dropped from 9 in 1991 to 4 in 1994 – a change to communities typical for stabilised waters.

Birds

Slovak ornithologists report a shift of water fowl from the old river bed into the reservoir, and a considerable increase in individual numbers. Kovacovsky et Rychlik (1995) for example found that wild duck (*Anas platyrhynchos*) numbers decreased in the old river bed between 1991 and 1994 from 653 to 168, which they attribute to the effect of construction activities near the Danube bed. At the same time, the changing water level in the reservoir affected those birds starting to breed on the artificial island of the reservoir just before the water levels increase in spring.

In addition, the island was planted with pines and black locust trees (*Robinia pseudacacia*) instead of allowing natural vegetation succession to take place in this area.

Darolova (1995) critisizes the improved public access to the side-arm system. This results in enormous disturbances and threats to breeding birds and sensitive species from tourists, anglers and poachers. In various localities the species number decreased gradually. The forest management system of expanding poplar plantations is a second cause of depletion of the bird communities. The seemingly higher number of waterfowl in the Cunovo reservoir and in the canal, has to be looked at in light of how many birds used to be dispersed in the many side-arms. These arms offered much more suitable food and shelter than the canal and reservoir. Darolova does not see a positive influence of the Gabcikovo system (referred to by the engineers as "bird's paradise") on the number of wintering waterfowl either. She emphasizes that the slower water flow in the side-arms leads to longer and more widespread freezing, forcing the birds to concentrate in the reservoir and canal.

Fish

The quantity and structure of Danube fish species largely depends on the size of waters and durability of linkage to the floodplain. The diversion of the Danube and the subsequent new hydrological condition had a highly negative effect on the chances of feeding and reproduction.

As a consequence of the Danube diversion, fish lost about 50% of their habitat in the Szigetköz and directly 200 tons of their biomass, without the loss in reproductive output. In 1993, 20% less fish were caught than in 1992. Many of the former 53 nurseries of the Szigetköz were either dry or degraded. Spawning conditions were disturbed due to unpredictable water levels (Meszaros et Bertalan 1997).

Berczik (1997) states that the previously 120 tons per year annual catch in the Szigetköz has gradually declined and the species composition of the fish communities changed. Only the Moson Danube arm, now receives more water than before, has become better for fish (e.g. more successful spawning).

Hungarian monitoring found that in 1996 the Danube and the side-arm system still had a low quality for fry-breeding and fish movement, even though the water levels and the flow velocity had become higher in many places. The number of young rheophilous fish, coming from the Danube, decreased while certain limnophilous species became abundant. In isolated water there is a substantial decrease in the number of species (MTA 1996).

The number of fish species increased after the starting of artificial water supply through a re-connection of two side-arm openings upstream of the new weir near Dunakiliti – which itself limits fish migration (Joint Annual Monitoring Report 1996).

Slovak ichthyologists state that significant changes for all hydrocenoses had already happened in the '60s and '70s with the cutting off of river branches, river bed erosion through gravel excavation and shortened floods. However, the diversion of the Danube water into the canal interrupted all natural processes essential for fish development. While the reduced „old" river bed offers much less natural shelter for fish, affecting both their abundanace and diversity, the side-branches are characterised by a change in dominance from rheophile to the phytophile species which have a wider ecological tolerance. Economically valuable species decreased considerably, partly because of the increased pressure from anglers and poachers. The absence of floods reduced the number of spawning habitats, which also changes the structure and productivity of fish cenoses. A prerequisite for any restoration is connection with the original river bed (Cerny 1995).

Holcik (1996) therefore predicts a further decline in fish diversity for the forthcoming years: „*The extinction of the resident form of Russian sturgeon and the wild form of carp is expected within a decade, because of damming of the Danube at Gabcikovo in 1992 and the subsequent interruption of migration routes and access to spawning grounds.*"

He states that the field data agree with the knowledge gained from similar hydropower works, and with Holcik's prognosis from 1981 of the development of ichthyofauna and fishery in the hydropower structure of Gabcikovo. The decrease in the total catch in 1993 was at 84.1%, as compared to a formerly predicted decrease of 78-89%.

The cause is the loss of the inland delta of the Danube and the subsequent loss of spawning, feeding and wintering grounds on a substantial part of this and adjacent stretches of the Danube. The decrease in the total catch will not stop but will continue unless a system providing inundation of the floodplain and bilateral connections between the old river bed and the river branches is established. The stocking of juveniles into the remnants of the branch system is not reasonable because the hydrological conditions in the branches do not allow the development of the zooplankton – the main food of juveniles. Moreover, the strong currents in the openings of the concrete weirs built across branches allows only downstream fish migration, but not upstream. Therefore, the dams at Gabcikovo, Cunovo and in the side-arm system create insurmountable obstacles for fish. Aside from that, the navigation locks at Gabcikovo *[editor:* and presumably also those at Dunakiliti and Cunovo] cannot be regarded as a sort of „biocorridor" between the separated stretches of the river (Holcik 1995).

Amphibians

Even in the pre-dam period, the amphibian habitat was under strong pressure in the surroundings of Gabcikovo. After the river diversion, Kminiak (1995) could not find any amphibian at one monitoring site near Dobrohost, which had become unsuitable for reproduction. In all eight monitoring sites 11 species were found, exhibiting strong yearly differences in species diversity. This was caused by floods (1991), long-lasting droughts (1992 and 1993) and by the decrease of groundwater near the river bed.

4.2. WWF Conclusion on Impacts

It can be summarised that the various mitigation measures that have been undertaken to date to prevent or reduce the many detrimental environmental impacts of the Gabcikovo dam system have largely failed for the following reasons:

- **Disruption of former hydrodynamics and lack of moisture**

The earlier hydrological dynamics of both surface and groundwater could not be restored. Various monitoring results reflect that the entire system is suffering from both limited and un-varying moisture and nutrient supplies. The artificial water supply system has led to a degradation in hydrodynamics on both sides of the river: the imposed „year-round continuously secured discharge" in the side-arms (Mucha 1995) prevents the ecologically necessary extreme conditions such as both dry and inundation periods in this floodplain ecosystem. The original diversity of species and habitats strongly depends on these fluctuations. Instead of improving conditions, the present largely monotonous flow of water has led to the disappearance of typical habitats, like gravel and sand bars and mud areas, and it does not provide the essential moistening of soils by nutrient-rich inundations.

- **Fragmentation of formerly interconnected wetlands**

Practically all previous connections between the side-arms and the river are disrupted. The once, mostly open interconnected system, is permanently divided into three isolated and severely degraded parts: the river bed, the Hungarian side-arms system and the Slovak side-arm system.

- **Degradation of morpho-dynamics**

Due to the small amount of water allowed to flow through limited parts of the wetland area, the many artificial barriers, especially on the Slovak side, and the rather flushing discharge in the main stream especially on the Hungarian side, the morphodynamics are limited and altered into non-natural forms: e.g. the cross-dikes in the side-arms prevent downstream sediment transport, the system of ponds and cascades fixes these restricted processes to specific localities instead of supporting dynamic morphological processes typical for the ecosystem.

- **Suspension of the natural purification system**

The natural, desirable decomposition of organic material and nutrient uptake is mainly activated during changes of flowing and standing water, inundation and dry periods.

However today, infiltration and self-purification processes are considerably restricted along the former river bed and floodplain. Only 10-20% is led through this area: As opposed to the former dynamics, there is constant flow velocity and water level, lack of intermittent water bodies, lack of large-scale inundations and dry periods. The 80 to 90% of the river water running through the reservoir and sealed canal, are dominantly impounded with very weak purification capacity, and especially at the bottom, with increasing toxic processes.

WWF therefore considers the present situation for the floodplain ecosystem as a serious ecological degradation. It is apparent that much irreversible damage has already occurred in the floodplain ecosystem and that the area is losing much of its Europe-wide renowned genetic and habitat diversity and previously unique floodplain character.

In the publication „A New Solution for the Danube" (1994), WWF has set quality benchmarks for a solution to the hydrological and ecological problems triggered by the operation of the Gabcikovo dam system. If the Danube floodplains, or more precisely its remnants, really are to be saved, the following priority objectives have to be fulfilled:

1. Re-establishment of the hydrological dynamics both:
in the old river bed,
in the side-arm system, and
in the floodplains.

This means it is essential to reestablish the crucial water level fluctuations in their amplitude, number and duration in the channels and in the floodplain. Because the pre-dam conditions were already causing significant degradation, the benchmark for re-establishing the wetland is the river conditions of the 1960s.

2. The restoration of the groundwater table dynamics.

This is only possible with an unrestricted connection between the surface water and the aquifer, and with discharge volumes and changes close to the earlier state. See also 5.

3. The reestablishment of a direct and un-inhibited connection between the river and the floodplain, including the side-arms.

This measure is essential for the exchange of water and for the migration of organisms and diaspores.

4. The enhancement of the morphodynamics.

Any future solution must allow erosion and sedimentation processes to take place, without interference from artificial cross-barriers. This is a prerequisite for promoting the natural habitat and biological dynamics of the floodplains. This means that morphodynamics would be allowed to occur throughout the entire area, while flood control could still be maintained.

5. The restoration of self-purification processes.

Infiltration of river water along the banks of the river bed and the side-arms, as well as during inundations of floodplain soils, activates the important filtering and water-cleansing system of the Danube floodplains near Gabcikovo, and helps to secure the future drinking water supply. Every effort should be made to re-activate this "natural sewage treatment plant" and to prevent further degradation of the huge aquifer.

SLOW DEGRADATION OF ONE SITE IN THE SZIGETKÖZ DUE TO THE DANUBE DIVERSION

Szigetköz side-arm and forests between Tejfalusziget and Cikolasziget ...

... June 1991

Photo: Bardos-Déak

.. May 1993

Photo: Bardos-Déak

... July 1995

Photo: Bardos-Déak

... October 1996

Photo: Bardos-Déak

SLOW DEGRADATION OF ONE SITE IN THE SZIGETKÖZ DUE TO THE DANUBE DIVERSION

Szigetköz: Danube side-arm near Cikolasziget...

... July 1988

Photo: Bardos-Déak

... May 1993

Photo: Bardos-Déak

... July 1995

Photo: Bardos-Déak

... August 1996

Photo: Bardos-Déak

SLOW DEGRADATION OF ONE SITE IN THE SZIGETKÖZ DUE TO THE DANUBE DIVERSION

Danube side-arm near Asvanyraro

... November 1991

Photo: Bardos-Déak

... November 1993

Photo: Bardos-Déak

... October 1994

Photo: Bardos-Déak

5. Future Perspective

During the five years of Gabcikovos operation enough data and results have been obtained to evaluate the situation and to assess the pros and cons of power production, navigation conditions, impact on the floodplain and river ecosystems and on surface and groundwater resources. The decision of the International Court of Justice will probably make it easier for both governments to solve the bilateral legal and environmental conflict.

Still, there are various questions and options for the future development of the Danube region which have to be tackled in the near future and on which WWF wishes to state its position:

5.1. Continuation of status quo

It is evident that the present mitigation measures are insufficient to secure the survival of the former floodplain ecosystem, let alone „improve" it, as is alleged. It can be expected that the present seriously degraded floodplain will sooner or later change into a stable state of a semi-dry parkland with drier forests and a diversity of wetland species typical for disturbed water habitats. The species diversity will be dominated by more ordinary elements, including those from steppe and agricultural habitats, while typical floodplain specialities will have vanished.

Various scientists, including ecologists, recommend some technical measures to prevent complete degradation. There are two contradictary solutions: one is building so-called „underwater weirs", the other is to restore the pre-dam situation by reconnecting the side-arms and the river bed, associated with the increased water discharge. WWF commented on this in 1994 („A New Solution for the Danube") and now wants to update the evaluation of the alternatives:

5.2. New Weirs in the „Old" River Bed?

In the original Gabcikovo-Nagymaros project the planned remedial measures included a recharge system for the side-arms and the regulation of the „old" Danube to protect some ford sections against erosion. The new idea, however, is to build a chain of some three to twelve new „underwater weirs" downstream of the Cunovo dam in order to raise water levels. Some Slovak engineers and monitoring experts (Bansky et Mazariova 1995, Hlavaty et Cambel 1995), are of the opinion that with the installation of a series of these „underwater weirs" in the „old" river bed, the present hydrological problems in the Danube floodplain and the river bed could be solved.

A first new cross-weir was built in April - May 1995 by Hungarian authorities in order to divert water into the side-arm system. Its local and regional impact is being studied and first results confirm the critical predictions regarding its limited benefits for the floodplain, and its detrimental impact on the aquatic habitats in the main river.

The experience that WWF and various hydro-engineers have gained with such weirs, especially in the Upper Rhine, implies that these would only lead to new problems. Arguments were already presented in earlier WWF publications (WWF 1994, Reflex et WWF 1995) and are updated here:

- The so-called „underwater weirs" will be in fact large lateral barriers on the river bed, raising the water level and thus creating a big impounded reach with negative consequences for aquatic habitats.
- These weirs will effectively block the natural migration routes, even if some fish passages were built. Experience has shown that these structures are used only by very few fish species, while most prefer to follow the main current, which goes over the weir step.
- Slovak ideas include the „improvement" of these weirs with boat passages, and even small hydro power plants, thus causing more obstructions in the river bed.

Lobbyists for these weirs usually refer to the „positive example" of the Upper Rhine, where such schemes allegedly *„created optimum conditions for nature conservation as well as for the preservation of branches and woods, for the advancement of farming and pisciculture and sustaining underground water resources supplying virtually all towns and communities in the Alsatian lowland*" (VVsp 1993 p. 16).

However in reality, the Upper Rhine schemes proved to be very damaging over the last decades. For instance, with regard to underground water management, Hügin (1981) and Kalkowski (1977) investigated the impact of artificial recharge systems on the Upper Rhine which were trying to mitigate damages by simulating earlier riverine hydrology. They found that only large-scale and long inundations can effectively raise the groundwater table, while raising the surface water by impounding side-arms or river sections and short-term inundations had only a marginal impact on the groundwater levels and on infiltration. The groundwater oriented towards the draining river bed, while the recharged side-arms colmatated, thus limiting the impact on the surrounding vegetation. The reduction in water fluctuations from this loss of dry and flood periods in the disconnected river and side-arm sections had the physical effect that 60 to 80% of the vegetation lost contact with the groundwater, and, on the whole, changed in nature over the years. Kalkowski concludes that more Rhine floods should be redirected into the floodplain area because the natural inundation, with its large-scale impact, cannot be replaced by any artificial measure.

The ecosystem study on the hydrodam at Altenwörth (Hary et Nachtnebel 1989) investigated similar mitigation activities near the Altenwörth power dam on the Austrian Danube. It found that even longer and more frequent artificial recharges into the side-arm system did not prevent the levelling of biotopes, biocenoses and groundwater curves. The reduced nutrient input, oxygen level and soil ventilation affected biological processes, and the water started to drain only in one direction.

A further comparison is given in the table 2:

Table 2 "Underwater Weir" compared to WWF Solution

Criteria for Water Supplement Solution	Submerged Weir	WWF Gravel Bars
Financial Considerations	Acceptable	Not yet calculated
Discharge into the Old Danube	Constant flow of 400 m³/s	Dynamic flow of 600–1500 m³/s
Technical state of the Cunova weirs to allow increased discharge into the Danube	Sufficient	Sufficient
Economic profit in Gabcikovo	High	Limited
Maintenance of river continuum (migration routes for water organisms)	Minimal	Yes
Re-establishment of the surface water hydrological dynamics and compensation for discharge deficits: in the old river bed	No	Yes
in the side-arm system	Partially	Yes
Restoration of ground water table dynamics	No	Largely
Re-establishment of a direct and uninhibited connection between the river and the side-arms of the flood plain	To a certain extent	Yes
Enhancement of natural processes of sedimantation and erosion and nutrient flow	No (technically undesired in the vicinity of the weir)	Yes
Restoration of natural self-purification processes	No	Largely
Limitation of ecological degradation	Very little	Yes
Transition to a restoration and an ecologically acceptable long-term solution	No	Yes

5.3. The Dam Alternative for Nagymaros

On 17 March 1995, the dike surrounding the previous Nagymaros dam construction site was re-opened and the Danube water returned to its old river bed. This physical ending of the Gabcikovo's sister dam did not end the efforts of dam lobbyists to find alternative sites for building a second dam downstream of Gabcikovo with its main purpose being to catch the flood wave originating twice a day from the peak power operation of Gabcikovo.

In its critical report of 16 November 1996, the Hungarian economic week magazine „Heti Vilaggazdasag" deals with the new and secret bilateral negotiations of governmental delegations on a potential agreement on the Gabcikovo-Nagymaros dispute. Here for the first time, a new dam site is mentioned as an alternative to the politically sensitive old dam locality of Nagymaros: the *Helemba islands* (the Slovak locality is called *Chlaba*).

The Helemba islands are river shallows located in the middle of the Danube at rkm 1.711 to 1.714 (depending on the water level), a few kilometers downstream of Esztergom and Sturovo along the joint border section of the Danube, and only 16 rkm upstream of Nagymaros. Danube navigation is hampered in this section: its channel is restricted both in depth and width (at the eastern end of island = rkm 1.711 these are 1.90 m, at MVSZ 90, and 100 m). In order to improve this situation, a VITUKI study (1996) suggested dredging the navigation channel, constructing groynes downstream of Helemba, or constructing a parallel training wall in the middle of the river over a distance of 2.5 to 5 km.

Ecologically, the Helemba island is a favourite nesting and resting site of birds like cormorants and herons. Intact riverine dynamics shape the island and support the growth of natural stands of willows and poplars.

The construction of a new dam is, of course, not only a politically heated proposal in Hungary, it is also a bad proposal from the point of view of ecology and the environment. The following arguments have to be raised against this proposal, most of which are identical to the arguments against Nagymaros:

- Helemba, one of the last untouched islands in Hungary and on the Upper and Central Danube, would be completely destroyed. A series of other side-arm systems and nature reserves upstream of Sturovo and Esztergom would be damaged.
- Any change to the river dynamics, such as impoundment, in this river stretch will have a negative effect on the riverine ecology and hydrology:
  + the drinking water supply from bank-filtered wells between Györ and Esztergom could be seriously affected
  + all banks upstream on the river and the lower parts of tributaries would be affected by the construction of high lateral dikes
  + thousands of hectares of agricultural soils on the lower reaches of tributary river could be water-logged.

  The traditional riverine landscape would be degraded into a monotonous canalised stretch of ca. 100 km. Many such examples exist on the Austrian and Bavarian Danube.
- As in the Gabcikovo impoundment lake - the Cunovo reservoir - sedimentation, silting and colmatation will be increased. Most river bed material, which eroded after the occasional opening of the Cunovo weir during the discharge of big Danube floods into the „old“ river bed, will be filling the Helemba reservoir. After some years, this will raise the question of how to remove this material: usually, hydrodam operators simply open the gates and spill it downstream, in this case towards Budapest. A more sophisticated method is excavating and depositing these mostly toxic sediments, thus demanding a suitable damp.

- Downstream of the new dam, increased river bed erosion will be triggered. This will lead to the next "necessary" technical measure, either a fortification of the river bed, like downstream of the Vienna-Freudenau hydrodam, or, the conventional way of constructing another dam. The resulting knock-on effect could produce a chain of dams as far as the Iron Gate, as was admitted by the Slovak engineer Miroslav Liska in the „New Scientist“, 17 September 1994.

In addition, there is the general question of a cost-benefit analysis for such new investments. The Danube hydro dams have their lowest productivity period in the winter (= low water) when actually energy needs are the highest.

Peak Operation of Gabcikovo

One of the main arguments for the "need" for a second dam downstream of Gabcikovo is the original plan, and also the present structure/capacity of the Gabcikovo system, to produce peak power. This means that once or twice a day (within only 4 to 6 hours) most of the water from the Cunovo/Dunakiliti reservoir will be let through the power plant. This would result in a downstream flood wave starting with a height of 4 m, which, due to the braking effect of the downstream reservoir of Nagymaros/Helemba, would level off its height at 1,5 to 2 m at Györ, located in the backwater reach of the lower Moson Danube) and to less than 1 m at Komarno (model calculations by Karadi et Nagy 1993).

It is evident that such an operation, which is unique for the Danube, would tremendously effect the downstream river biology: The flood waves will flush out the water and all non-attached water organisms from the first river kilometers. The riparian zone will also be emptied - large-scale erosion and sedimentation are the logical consequences (Bernhart 1989). The impact of such strong water fluctuations on navigation or the effluent of the Györ sewage treatment plant will hardly be an environmental improvement. It sounds quite cynical when peak operation promotors state that "environmental protection should have priority over energy production" (Karadi et Nagy 1993). It would be quite useful to make a first assessment of the impact of the present modest peak operation of Gabcikovo, which, as a surprising fact, was monitored over the last two years downstream of the power plant.

5.4. WWF recommendations: How to save the Danube floodplains

Based on the existing data and its own international experiences, WWF has no reason to change its former position. Today there are two options:

- to fully operate the Gabcikovo system and to artificially irrigate the degraded wetland, or
- to effectively change the existing economic exploitation of river waters in order to save one of the most valuable floodplain ecosystems in Europe, while allowing limited use of waters for the Gabcikovo system and navigation.

The second option follows the recent prescriptions of the International Court of Justice and leads to the following solution that WWF first presented in 1994 („A New Solution for the Danube“) and which is visualised in the following maps 4 a,b:

- a river discharge below Cunovo starting with a minimum of 600 m^3/sec and continuing with
- a dynamic flow of at least 65% of Danube waters (measured at the Devin gauge) into the „old“ river bed, and of no more than 35% into the Gabcikovo canal. This would be fulfilling the Slovak legal standards, as stated in the „19 Conditions“ of June 1991, § 14 Slovak water law, and the EC proposal of February 1993, accepted then by Hungary. In addition,
- compensation for the discharge deficit of 35% by raising and constricting the present river bed through new gravel bars and islands - at best of local material - on a stretch of approx. 20-30 km downstream of Cunovo.

Such a solution would not only be ecologically acceptable but could even restore the Danube floodplains to a degree typical several decades ago. Today, there is the chance of setting aside a large section of a big European river without any large-scale human interferences, such as navigation or hydro power. This option should be even acceptable under the condition that only a minimum of 65% of the overall discharge is available, as the remaining 35% can still be used by the new Cunovo power plant.

It is evident that due to the advanced ecological degradation throughout the affected area such measures must start immediately. Even though this ecosystem is generally able to recover relatively and overcome damage much better than most others, the ongoing loss of many specialised species and typical habitats is irreversible and must be stopped. The question of whether such a restored area could qualify for a national park – as demanded in April 1991 by the Hungarian Parliament – can be investigated only when these crucial changes have resulted in some measurable impact.

In addition, WWF maintains its former recommendation to

- reduce the existing Gabcikovo reservoir to the size of the navigation route and the discharge needs for the 35% river water volumes. This will help to reduce undesired sedimentation and biogeochemical processes in the surface and groundwaters of the artificial lake. The then „unsued“ area in between the river bed and the new dike-lines on the navigation canal could become an important wetland restoration area.

The planning and implementation of these measures should be done by an independent, international water engineering institute, local experts and an ecological institute experienced in river management.

The financing should come primarily from domestic sources in both Slovakia and Hungary, supported by international organisations.

Finally, **for any future solution it is most important** to

- continue and extend environmental monitoring in the affected area, and to regularly publish the annual results to the general public.
- conduct environmental impact assessments - following the EU standard - on any technical or mitigation work in the area.
- realise an independent cost-benefit analysis of the Gabcikovo project.

Concerning the planning and development of new recreation areas in the vicinity of the Gabcikovo scheme, an environment impact assessment with full public participation would be required. Potential sites should be located outside the floodplain area where some kind of organised and state-supervised restoration is needed anyway. Even at sites like those around the Cunovo complex or north of the Gabcikovo lock system, there is the question of, for example, a public transport system to move the expected 100,000 visitor people. It is illogical that such unplanned development as those around the two gravel lakes between Bodiky and Vojka has still not been controlled. Here, where the Gabcikovo investor hoped to turn the floodplain into a profitable recreation area, a rather unplanned development of hundreds of week-end facilities pose serious and growing environmental problems, such as water pollution by sewage, disturbance and destruction of adjacent floodplain biotopes.

Environmentally sound recreation facilities could eventually provide the long-promised new jobs and income sources for local people who have so far mainly suffered from the various Gabcikovo impacts on their neighborhood.

However, facilitated, attractive access to the floodplain forest area over the improved forest roads and cross-dikes will continue to pose widespread disturbances in terms of noise, destruction and pollution of habitat. While it must be

Maps 4a, b: New Solution for Danube Floodplains

This suggested solution aims at restoring and supporting earlier natural floodplain processes in the river section between Cunovo (rkm 1852 and Palkovicovo (rkm 1811). The given maps try to visualise the changes which could be reached by realising the suggested restoration measures for the Danube wetlands affected by the Gabcikovo system. This solution does not need major technical changes and corresponding investments for the existing scheme, but would still allow important improvements in the hydrology and ecology of the affected region.

The following graphical information gives a rough description of the expected changes. The preparation and realisation of this solution will, of course, need more thorough planning and calculation.

This solution needs a dynamic discharge volume of at least 65% of Danube water, as measured at the upstream Devin gauge, and with a low water minimum of 600 m³/sec, let through the Cunovo weir complex into the "old" river bed. This will help to restore the typical morphological dynamics, essential for the original floodplain ecosystem and the species diversity, including many specialised organisms. The main navigation route continues to go through the Gabcikovo canal and still up to 35% of water would reach the Gabcikovo lock and power plant system.

The "old" river bed would be narrowed at various sites by the creation of some new islands (using mostly locally available gravel). Their precise number, size and location have not been calculated but these maps indicate possible sites. These islands would secure the open river continuum at least downstream of Cunovo. They would constrict the river bed on a stretch of some 30 km and lift the water table to the extent needed to allow open exchange of waters with nutrients, diaspores and organisms.

The closed side-arms would be reopened, allowing in- and outflow of water and organisms and resulting in stronger infiltration of water into the underground as well as enhanced surface and groundwater purification processes for much more Danube waters than today. The cross-dikes would be opened up, allowing larger water flows and fluctuations.

At low water

With the example here at approx. 800 m³/sec, typical for autumn or winter periods, the "old" Danube would already get much more water than today (see map „Status quo"), which is often less than 300 m³/sec. The main flow of water would go through the river bed, only some side-arms would still be connected with the Danube while large parts of the wetland would have stagnant/slowly flowing water or fall dry, i.e. this is a period of a soaking-in of oxygen into the soil. Sedimentation processes prevail at this period.

At high water

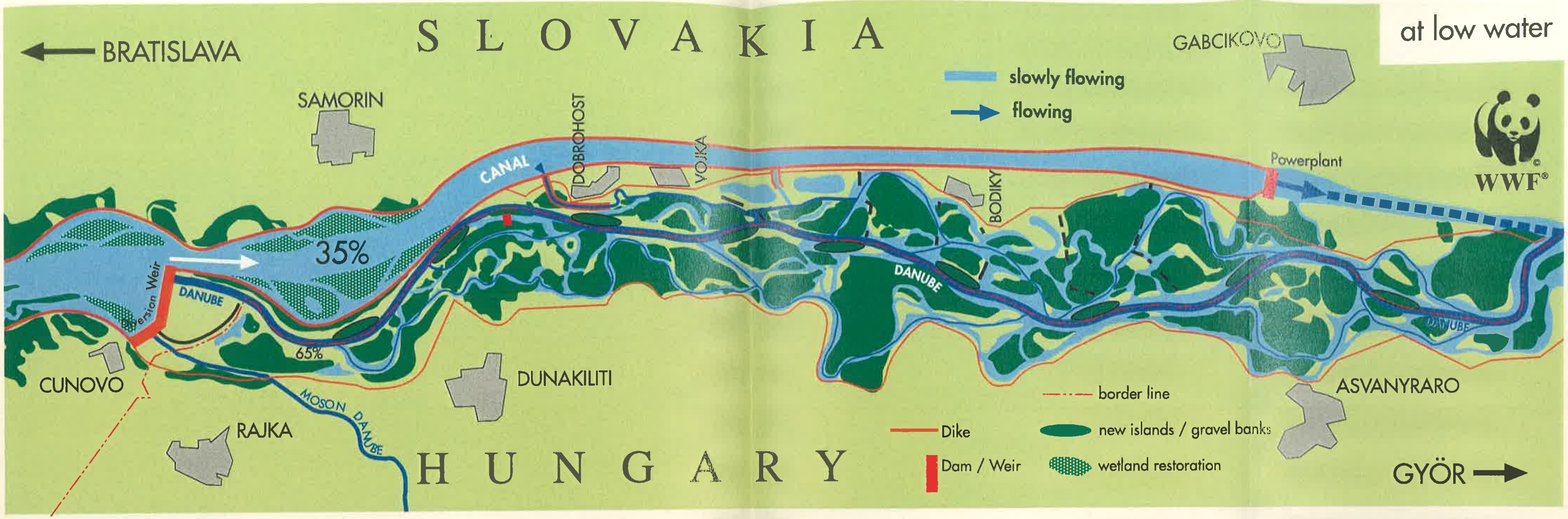
With the example given here at approx. 4,000 m³/sec, typical for spring or summer periods, Danube water is flowing through large parts of the wetland and inundating the low areas. A complete inundation requires a big flood event of more than 7,000 m³/sec. The river water forces enhance the further shaping of the bars and islands through increased erosion and sedimentation. New habitats and a high diversity of typical floodplain fauna and flora will develop within a few years.

Due to the fact that the **Cunovo weir** creates a barrier for downstream sediment transport it will be necessary in the long-term – for what ever future overall solution will be agreed upon for Gabcikovo – to work out a morphology-balancing solution for the downstrean section. This can be either a regular input of gravel downstream of Cunovo, a system used on the Upper Rhine, or a fortification (protection against bed erosion) of this section, a system presently being tested at the Danube east of Vienna, or a chain of new weirs, each having local and downstream detrimental impacts.

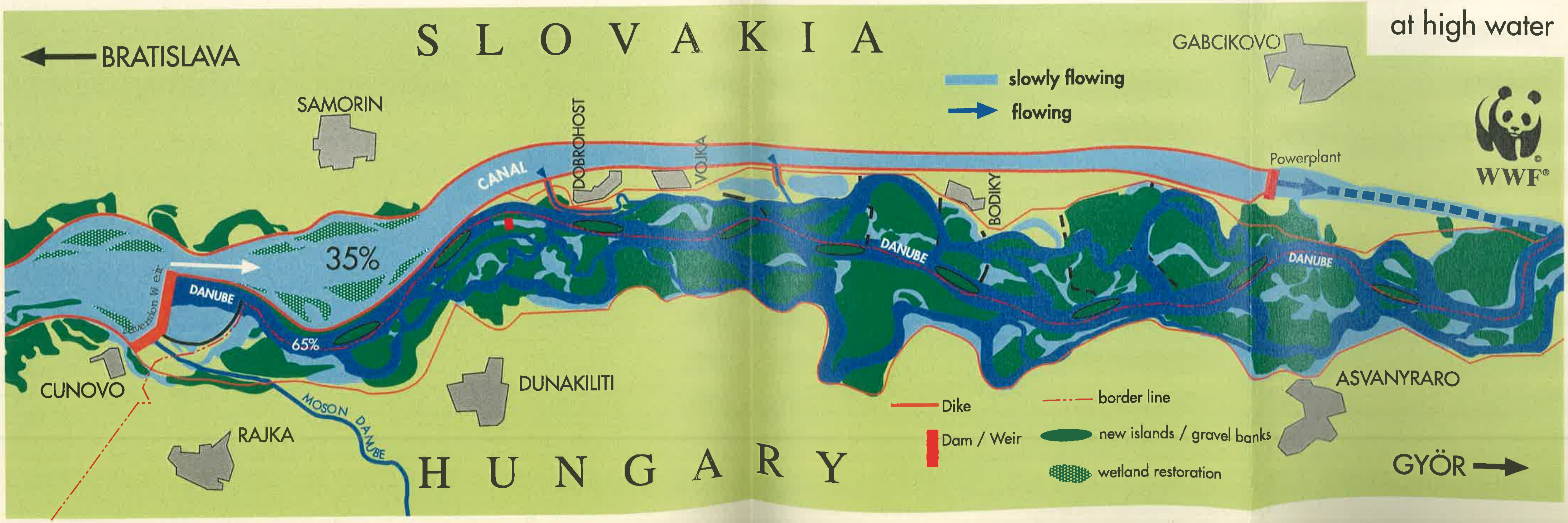
The construction of a fish migration device at the Cunovo weir complex could improve the present totally blocked upstream route for at least some organisms and would allow access into the Austrian floodplains and the Morava-Dyje river system. However, it should not be expected that this measure could fully replace the former open migration route.

It is evident that monitoring and improvement of any restoration measure will be necessary over a long-term period. This is necessary for any other future solution.

New solution for Danube floodplains and Gabcikovo dam system



at low water



at high water

stressed that the efforts of local authorities, in the form of closing the forest roads with barriers in 1994, helped to reduce the recreation pressure on the floodplain area, it did not stop the overall problem of highly increased disturbances. Urgent political decisions and respective measures are still necessary to limit and control this detrimental process.

Even though this problem has not been so prominent in the Szigetköz, this area is also subject to growing recreational interest and therefore needs more management.

Before the production of this Statement, there was consideration to write a "Requiem for the Danube Floodplains." However, in spite of the many serious changes that have taken place as a result of Gabcikovo, there is still a lot of natural values which can be lost if the present exploitation of nature continues. The International Court of Justice prescribed negotiations to achieve a more satisfactory solution for the Danube. WWF supports this view and produced this document to define the quality benchmarks for achieving this.

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