INTERNATIONAL COURT OF JUSTICE

CASE

CONCERNING THE GABČÍKOVO-NAGYMAROS

PROJECT

(HUNGARY/SLOVAKIA)

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Annex 1

Environmental Evaluation of the Gabčíkovo (Bős)-Nagymaros River Barrage System

submitted to OVIBER
National Investment Enterprise for Hydraulic Projects

prepared by
Bechtel Environmental, Inc.
February, 1990

(Appendices 2-5 omitted)

Environmental Evaluation of the Gabcikovo (Bös)-Nagymaros River Barrage System

Submitted to:

OVIBER
National Investment Enterprise
for Hydraulic Projects
H-1054 Budapest,
Alkotmany U. 27-29
Hungary

Prepared by:

Bechtel Environmental, Inc.
50 Beale Street • San Francisco, California 94105-1895

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INTRODUCTION

1.1 PURPOSE

Bechtel has independently reviewed the Gabcikovo (Bös)-Nagymaros Barrage (GNB) Project in terms of potential environmental impacts, operational considerations, and currently planned mitigation measures. We have examined the project from the standpoint of its stated goals of integrating and optimizing multiwater resources for the purposes of power production, navigation, flood control, regional development, water supply and water quality, agriculture and forestry, natural biological values (including fishery and wildlife), recreation, visual enhancement, and preservation of archaeological values.

Our approach to the environmental review was a multidisciplinary effort, which focused on:

- Defining significant impacts associated with the project that warrant evaluation and mitigation
- Determining additional baseline data needed for impact definition
- Reviewing planned mitigations to reduce impacts to insignificant levels or to enhance project benefits
- Identifying additional investigation measures that could reduce impacts further
- Assessing effectiveness of the monitoring program by defining preoperational environmental conditions and operational conditions

Where possible, the significance of potential project-related impacts were qualitatively defined in the context of construction and operation activities, and the expected duration of the impacts. Impact discussions in this evaluation reflect the amount of data and analyses available for the environmental review. For example, the hydrologic regime of the project area has been thoroughly studied and potentially significant impacts have been identified by VIZITERV and associated experts and Bechtel concurs with this assessment. More limited data and analyses are available regarding project-related impacts on biological resources. Therefore, a more detailed impact analysis was made for biology than that provided by VIZITERV. Our impact analysis considered the potential effects the project could have on the environment's social benefits to man, such as agriculture and regional development, and the impact of the project on the intrinsic values of environmental resources such as biology. Additional data collection and modeling is recommended where needed for either additional impact definition or determination of the adequacy of the proposed mitigation and monitoring program.

We have approached the environmental evaluation with the philosophy that impacts must be identified, appropriate mitigations must be in place prior to project operation, and the project monitoring program will be used to ensure the effectiveness of these mitigations.

1.2 BACKGROUND INFORMATION

Information used in the review of environmental effects related to the GNB project are based upon:

- A 3-day site visit to the project area
- Summary documents provided by VIZITERV (see Appendix 1 for detailed list)
- Selected publications and
- Interviews with VIZITERV professionals and other experts

The site visit included a review of construction sites at Dunakiliti weir, Gabcikovo power plant and navigation canal, Nagymaros barrage site, and selected intercept channels and sidearms in the Szigetköz. In addition, a general reconnaissance was conducted along accessible areas on the right side of the Danube River from Visegrád to Süttö and on the left side of the Danube River from Nagymaros to Szob. All impact evaluations in Section 2 are based upon data and analyses provided by VIZITERV and interviews with VIZITERV professionals and other experts. This information and a list of experts interviewed are summarized in Appendix 1.

1.3 PROJECT DESCRIPTION

The physical structures, planned water releases, and flow regimes of the GNB project used as the basis for evaluating environmental impacts associated with the project are described below. In this report, we have evaluated the complete GNB project, including the Gabcikovo and Nagymaros barrage systems and associated structures. The peak operating data used as design criteria for the original conception of the project and structures is used in this evaluation. However, it should be noted that studies are currently under way to revise those operational criteria.

1.3.1 Physical Structures

The GNB project will regulate Danube River flows over an approximate 160 km reach of the river from Bratislava to Visegrád. Principal components of the project in both the Hungarian and Czechoslovakian territories are:

- The upstream Hrusov-Dunakiliti reservoir formed by the Dunakiliti barrage and Gabcikovo power station
- The power navigation canal that transports water from the upstream reservoir to the Gabcikovo (Bös) power station
- The Gabcikovo (Bös) power station and shiplock
- The Nagymaros barrage, power station and shiplock which regulates releases from the lower reservoir

The Hrusov-Dunakiliti reservoir and Gabcikovo (Bös) power station, barrage, and shiplock are scheduled for completion and operation by 1990. Completion of the Nagymaros barrage, power plant, and shiplock has been delayed indefinitely.

The environmental evaluation presented in Section 2 is limited to impacts affecting Hungarian territories (right side of the Danube River), although we recognize that both sides of the Danube will be affected by the GNB project.

Barrages at Dunakiliti and Gabcikovo have created the Hrusov-Dunakiliti reservoir, which will provide an elevation drop needed for power generation at Gabcikovo. The reservoir will also provide sufficient depth for river navigation, and sufficient capacity for storing daily inflows for 15 to 19 hours and releasing the stored water over a 9-to 5-hour period for peak power production. Water diverted for power production and navigation purposes will reenter the Danube River downstream of the Szigetköz area. The power canal has a design capacity to continuously pass 4,000 m^3/s. Therefore, the peak flood flows in the Szigetköz can be reduced by 4,000 m^3/s. Studies are under way to reevaluate these design criteria.

1.3.2 Planned Water Releases and Flow Regimes

During normal daily operations, most of the stored water will be diverted through the Gabcikovo powerhouse. However, continuous flows will be released over the Dunakiliti weir into the old Danube River channel to reduce environmental impacts to the old Danube River channel area. The amount of river maintenance release is still being evaluated; however, the currently planned release is 100 m^3/s. The historical average annual river flow in the old Danube River channel is about 2,000 m^3/s.

The upper reservoir water level will range between elevations 129 and 131 m above sea level (asl). This impoundment level will raise the normal water surface elevation at Dunakiliti by 8 m. Further, the impoundment level will be between 2 to 6 m above the right bank ground level along 10 km of the reservoir right bank dike. To minimize seepage from the reservoir to the adjacent low land area, a clay blanket extends from under the dike 150 m into the reservoir. To control the reservoir seepage that passes under the dike, an interceptor/collection channel is constructed parallel to the dike. The estimated seepage water, of about 50 m^3/s, will be routed to the Danube side arm channel at the upstream end of the Szigetköz. These collected seepage flows together with supplemental releases from Dunakiliti weir/shiplock will be used to help maintain desired ground water and surface levels in the Szigetköz.

With the planned 100 m^3/s continuously released at the Dunakiliti weir, the average depth of flow in the upstream reach of, the old Danube River channel will be reduced from 6 to 2 m. The water level at the confluence with the power tailrace canal and the old Danube River channel will be controlled by the Nagymaros reservoir impoundment and will be near the prior GNB project average water surface level. However, in the old Danube River channel downstream water level will fluctuate daily according to the power releases at the Gabcikovo powerhouse. These daily fluctuations can be $\pm$ 2.5 m, at the tailrace confluence and $\pm$ 1.0 m, 10 km upstream of the tailrace confluence according to the original Joint Convention (KET) operation plan (the operational criteria that would produce these fluctuations are under study and revision to minimize daily fluctuations). These daily water level changes will require riverbank stabilization to control erosion. Such erosion control measures are planned for the GNB project.

The water level in the side arms of the Szigetköz is currently influenced by daily water level changes in the old Danube River channel. The southern border of the Szigetköz is delineated by the Mosoni Danube. This arm will also receive releases from the Hrusov-Dunakiliti reservoir. The forecasted release to the Mosoni is 20 m^3/s, which is greater than the previous average flow in the upstream reach. The previous 20-year average has been 5-15 m^3/s depending on the stage of the Danube River at Rajka.

The Nagymaros barrage will develop a 120 km long reservoir with a normal water surface elevation near 109 m/asl. This impoundment will provide a 9 m elevation drop for power generation, and sufficient depth to allow navigation up to the Gabcikovo shiplock. The reservoir will also act as an equalization pond by receiving the generation flows from Gabcikovo (about 4,000 m^3/s for 5 hours) and releasing these flows at an uniform rate to the natural flowing river downstream. Further, the Nagymaros weir and shiplock, with the gates fully open, will safely pass the 1,000-year flood event.

For the 40 km segment upstream of Nagymaros barrage, the new normal water level will be above the right bank ground elevation. Lowland areas will be either filled with local sandy soils, or diked. Drainage/seepage interception channels will be excavated parallel to the landward side of the dikes, in order to ensure that the surface waters are properly drained. In some cases, pumping stations will be added to the drainage channels to lift the collected landward water into the Danube.

Peak hydroelectric generation at the Gabcikovo powerhouse will significantly affect the flow regime in the Nagymaros reservoir. According to the KET operation plan for the design low-flow case, power releases will change from zero to 4,500 m^3/s and continue at $\pm$ 4,500 m^3/s for the 5-hour peaking duration and then reduce to a zero release. This changing inflow pattern can cause the water level upstream of the reservoir to rise and fall up to 4 m during daily operations. These operating criteria are also being revised. At the downstream end of the reservoir, the water level change will be attenuated to about 1 m. Riverbanks and levees are to be protected by geomembranes overlain with riprap to control potential erosion.

1.4 SUMMARY AND CONCLUSIONS

1.4.1 Summary

Bechtel has reviewed the GNB project to independently identify potential environmental impacts and benefits related to the project and assess the effectiveness of planned mitigation measures and the project monitoring system. This review is based upon data and analyses provided by VIZITERV, interviews with VIZITERV experts as well as other experts, and a site visit of the project area. A wide range of environmental issues have been examined by the Bechtel team, including potential impacts on surface and ground water hydrology, geology, archaeology, land use, biology, recreation, visual resources, and socioeconomics.

The GNB system is an ambitious project, combining water management goals of power production, navigation, and water supply with environmental protection measures. From an environmental viewpoint, the project is important because of the planned diversion of 30 km of the Danube River and the peaking mode of the Gabcikovo power plant.

The project has used a sound technical and scientific basis to identify impacts and appropriate mitigations. However, several areas should be considered for additional studies or mitigations. These include ensuring that (1) water quality is maintained along the Danube by completion of wastewater treatment plants; (2) archaeological resources that are affected by the project are thoroughly investigated; (3) additional studies are conducted to define biological baseline conditions and appropriate mitigations; and (4) sufficient flow releases into the old Danube River channel in the Szigetköz will maintain planned ground water levels.

Several benefits will come from the project, including increased archaeological research, creation of a new riverbank park, improved water quality in the Mosoni Danube, better flood protection, improved navigation, and the generation of electric power.

1.4.2 Conclusions

Our review has shown that potentially adverse impacts in hydrology, land use, visual resources, and recreation have received close attention by VIZITERV. Based on the data available, these impacts will be mitigated to minimize them sufficiently. However, potential impacts to biological and archaeological resources may be significant, and planned mitigations may not be sufficient to reduce impacts to an insignificant level. While the artificial recharge plan in the Szigetköz is well conceived and will be effective in protecting and enhancing forestry and agriculture in the Szigetköz, conflicts may be present with protecting biological resources. Additional baseline data and biologic modeling are needed to better define impacts to biological resources and plan effective mitigations. Additional data needed include information on the seasonal occurrence and habitat use of important wildlife species such as waterfowl and protected species in the Szigetköz area. Modeling of dissolved oxygen (DO) levels in the reservoirs is also recommended to quantify potential impacts to surface water quality and fisheries. Additional flows to the old Danube River channel and side arms may be necessary, to augment the benefits of the artificial recharge system and mitigate impacts to biological resources, but until more biological baseline conditions are established, this cannot be clearly determined.

The recommended studies for water quality and biology may result in identification of the need to modify the project's operational strategies. In addition to mitigation measures outlined by VIZITERV, alternate operational modes for the Gabcikovo power plant should be closely reviewed. Presently, alternate operational modes (including seasonal variations) are being studied to revise the original KET operation plan. Modified peaking schedules could help reduce potential significant impacts to biological and recreation resources caused by downstream fluctuations. Increased flow releases from the Hrusov-Dunakiliti reservoir to the main channel should be considered as a way of reducing signficant impacts expected downstream.

In comparison with U.S. hydropower monitoring systems, the proposed GNB monitoring system is unique because it monitors more parameters than the Columbia River Basin, Ohio River Basin, or Tennessee Valley Authority (TVA). Hydropower facilities on these rivers monitor water quality and/or minimum streamflows for fish and recreation, but do not monitor the array of environmental parameters sampled in the GNB monitoring system. With a few additions, this system will represent a state-of-the-art monitoring program for integrating environmental considerations with operations.

The monitoring program developed for the GNB project will assess changes in environmental resources affected by project operations and the effectiveness of project mitigation measures. Our review has identified aspects of the planned monitoring program that can be reduced, and recommended additional monitoring that would enhance the overall effectiveness of the program. However, mitigation measures should be in place (or clearly established, in the case of operational rules) prior to startups at either the Gabcikovo or Nagymaros power stations.

Benefits of the project as well as impacts and mitigations proposed by the project, or recommended by Bechtel are summarized below. Detailed discussions regarding impacts and mitigations measures are contained in Sections 2 and 3.

Hydrologic Regime. GNB surface and ground water conditions have been thoroughly studied by VIZITERV and other experts. The project's planned releases to the Mosoni Danube and the Szigetköz side arms will improve water quality in these surface waters. Project mitigations to minimize adverse impacts on the hydrologic regime have been incorporated into project design, including the artificial recharge system in the Szigetköz, and interceptor channel system at Dunakiliti reservoir, Esztergom, and Pilismarót. Potential problems that we believe require additional studies to quantify impacts and effectively develop mitigations are the water quality and water level fluctuations downstream of the Gabcikovo barrage. Revisions to the KET operation criteria are currently being studied. Reduction in water level fluctuations downstream of the Gabcikovo barrage will mitigate many of the impacts discussed below. Specifically:

- Water quality in both reservoirs could be possibly reduced below historical levels (DO below 6.0 mg/l) during summer months due to detention times, increased temperature, nutrient loads, and associated algal blooms

- Water quality during the summer months should be estimated using available computer models which simulate reservoir/powerhouse operations and changes in DO and water temperature

- If undesirable water quality is identified, alternative mitigation measures should be evaluated to determine the most cost-effective means to maintain the water quality at or above historic levels. Possible mitigation measures include continuous release through the Gabcikovo power plant to reduce detention time and releases over the Dunakiliti weir to promote more aeration

- Concern has been expressed by others that heavy metals accumulated in deposited sediments might be remobilized under anaerobic conditions and migrate into the ground water. The circumstances required to alter the bottom sediments are highly unlikely to occur, especially since the DO level will be tracked in the reservoirs and operational measures will be initiated to keep DO above minimum levels. However, it is recommended that sediment buildup be monitored, especially over ground water recharge areas, and heavy metal concentrations in these sediments be regularly measured. Should undesirable amounts of heavy metals accumulate over sensitive areas, this material can be removed. Alternatively, methods for controlling the reservoir bed DO levels should be investigated and implemented if found cost effective

- The original KET plan anticipated peaking operations at Gabcikovo for a minimum of 5 hours per day. The KET project operation would produce significant water level fluctuations at the upstream end of the Nagymaros reservoir. For example during summer months, peak power operations would produce 1.3 to 4.7 m^3/min rate of rise in water level and a 2.5 to 3.5 m change in water level over 24 hours. This is greater than current practices on the Columbia River in the U.S., where similar hydroelectric/navigation lock projects are operated. During the summer, the allowed water level changes on the Columbia River are 0.75 cm/min and 1.5 m over 24 hours. It is recommended that evaluation of modified Gabcikovo peaking operations be continued to assess possible reductions to project impacts associated with the large water level changes

Ground Water. The extensive mitigation measures planned by the project to control the impacts on ground water conditions appear adequate. To verify whether or not the mitigations are effective, the network of monitoring wells will provide a good measure, and allow modifications to be made to correct any deficiencies. To avoid the situation where unexpected conditions occur in sensitive areas, and because of the time required to make necessary corrections, vegetation and wildlife may be adversely affected and may not be able to recover, the following recommendations are suggested.

1. Detailed studies of critical areas in the Szigetköz should be conducted to determine if additional control measures are needed to mitigate impacts on the recharge of ground water. For example, the heron habitat area near Ásványráró may require close control of ground water fluctuations to maintain the proper environment for the breeding and feeding habitat. The hydrogeologic characteristics of a specific area will most likely differ from the homogeneous, isotropic conditions assigned in the analog modeling studies of the total area. Detailed studies of the critical areas can determine if the variations are significant, and the need for modifications in the general mitigation measures can be anticipated.

2. Mitigation measures to prevent waterlogging in the three major lowland areas adjacent to the Nagymaros reservoir have been provided. Within the intervening hill areas, where high natural banks are present, the raised ground water levels are expected to remain well below the ground surface. However, with the rise in base level, some seepage may occur in low areas not presently considered to be wetlands. Although such occurrences may not be widespread in the highlands, they could cause undesirable wet ground in

local areas. It is recommended that the hills be examined to identify potential areas where unwanted seepage may occur. Exploration and installation of monitoring wells should be carried out in those areas where seepage is possible, and where previous studies have not been adequate.

Biology. Biological resources in the project area are not entirely well defined and the amount of information varies. Specific biological information has been collected at the 12 biological monitoring stations, 9 of which are concentrated in the Szigetköz-Gönyü reach, 2 in the Gönyü-Nyergesújfalu reach at Tát and Almásneszmély, and 1 at Szentendre Island.

The floodplain vegetation along the Danube has experienced strong anthropogenic effects related to flood management, silviculture, and wild game management. Limited natural vegetation occurring in the project area includes a willow-poplar gallery forest, willow thicket, and ash-oak-elm gallery forest. These vegetative associations also provide diverse habitats for wildlife, especially in the Szigetköz portion of the project area. Important waterfowl species including grey herons, black storks, cormorants, night herons, and mute swans are known to utilize habitats near Ásványráró in the Szigetköz. Four protected bird species, the willow tit, treecreeper, little ringed plover, and penduline tit occur in habitats provided by natural vegetation along the Danube channel and side arms.

Construction of project facilities (including the Dunakiliti reservoir), and flood protection and bank stabilization structures will remove natural vegetation along the Danube. In addition, a zone approximately 250-300 m wide and reaching approximately 25 km along the Danube will be subject to aridification when flows are diverted from the Danube to the Gabcikovo navigation canal. Revegetation programs with native species in other areas and along dikes are recommended to mitigate loss of natural vegetation, wildlife, and associated wildlife habitats in these areas. Reestablishment of native forest along the Mosoni Danube, an objective of the Szigetköz Landscape Protection Area policy should be considered as a component of these revegetation programs.

Changes in ground water and surface water levels could also potentially impact the sensitive wildlife area near Ásványráró, the habitat of the four protected birds discussed above, as well as other wildlife resources. The most effective approach to mitigating impacts is to first determine occurrence and use of the area by these sensitive species and better assess impacts to these species and their habitats. If adverse effects are anticipated, it is recommended that water levels and water quality be closely monitored for at least 1 year in these areas to establish preproject conditions. Based on this information, water levels and water quality needed during operation to minimize impacts on the birds can then be determined and integrated into project operations. Also, establishment of a protected area near Ásványráró to protect these species could be considered.

Additional data are also needed for other wildlife species occurring in the Szigetköz and other portions of the project area before impacts can be determined or mitigations developed. A literature survey should be conducted to determine the potential occurrence of important species and then seasonal surveys could be done to determine the actual occurrence, abundance, and seasonal use in the project area.

Additional data are needed on fish species distribution, abundance, spawning locations, and spawning periods to enable accurate prediction of project-related impacts on fish resources. Seasonal baseline fish surveys over a 1-year period using multiple sampling techniques should be designed and conducted prior to project operations and used to better assess and mitigate potential impacts.

Changes in flow rates in the Dunakiliti reservoir and the main channel of the Danube River in the Szigetköz area are expected to result in fish stranding mortalities and changes in species composition (i.e., decreased numbers of those species adapted to fast-moving water conditions).

Operation of the barrage systems and power stations may result in decreased concentrations of DO and adverse effects on fish. The potential for oxygen deficiency effects should be evaluated by use of a system-wide DO modeling program and, if warranted, operational controls to mitigate DO decreases should be evaluated (e.g., alternating modes, spill flows, mechanical aeration).

Loss of migratory fish access to spawning grounds in the side channel system will result from blocking the outlets to the Danube and installating the weir at Ásványráró to maintain the water levels in the side arms. This is expected to result in a regionally significant, long-term impact on some fish species inhabiting the Danube. The ability to operate the Gabcikovo facilities while maintaining adequate flow to the main channel above Gönyü should be evaluated. Use of a control gate to allow fish passage at Ásványráró also should be considered in conjunction with baseline information on fish spawning migrations.

Entrainment and turbine-induced mortality of fish and lower order organisms will occur at the Gabcikovo and Nagymaros power stations. The significance of these effects should be assessed once baseline fish surveys have been conducted and, if warranted, an appropriate fish protection system should be developed.

The project has incorporated fish locks at Dunakiliti and Nagymaros to mitigate impacts on spawning fish due to blocked fish migration.

Land Use. The project impacts on land use in the project area were evaluated based upon anticipated changes in crop and forestry production and recompensation of losses of land or buildings.

The project will provide several benefits to agriculture and forestry production in the Szigetköz with installation of the artificial recharge system. These benefits include increases in arable land with more control of ground water levels and floods, as well as a more stabilized water supply for irrigation.

Changes in land use due to the project will not be significant. Reduction in agriculture and forestry production were recognized and compensation was made. Compensation has also been made for loss of residences and public buildings due to the reservoir or related projected facilities.

Some loss of forestry production will result from reduced flows along the Danube, even with the artificial recharge system, but this amounts to about 3 percent of the present forest and about one-third of the value of forest production in this area. This loss has also been compensated. Increased costs for transportation of forest products will occur. The artificial recharge system plans call for dikes across side arms of the Danube, further reducing water transportation. Compensation has been made through funding for new road construction to provide alternate transportation means.

Archaeology. The archaeological, historical, and monument resources within the study area represent relics both of Hungarian and European human civilization. The project has funded excavation of a number of important sites, and mitigation measures have been developed in conjunction with the Monument Plan Council of the National Committee for Technical Development to protect some of the most significant resources. However, significant impacts to archaeological and monument assets could potentially occur due to construction and operation of the proposed project.

Construction could damage or bury a number of known archaeological sites precluding future scientific study and excavation. Agreement was reached with archaeologists as to which archaeological sites were to be preserved by modification of project design, and what construction methods were to be utilized for specific sites.

Project operations will inundate the archaeological site on Helemba Szigetköz. The site on Helemba Szigetköz has been partially excavated. A possible mitigation for this could be that the entire site be excavated and significant artifacts and relics removed to the museum for preservation and public display.

Controlling the ground water levels at 103.5 m above sea level will reduce the accessibility of deep-lying archaeological artifacts in the Esztergom Royal Town area, but will also enhance accessibility to those artifacts presently buried above the mean ground water level. Current access to these artifacts is limited due to extensive surface development (buildings, roads, etc.). In the future, if and when excavation is desired, this impact could be mitigated by installation of a local dewatering system. Because of the limited surface access to these sites and the uncertainty of future excavation, it is not recommended that funding for a dewatering system be included as part of the project. It is recommended that ground water levels be monitored during project operations, to ensure that the ground water level does not rise about the predicted level of 103.5 m/asl. Future funding for excavation should include a dewatering system.

Visual Resources. The Danube River is the dominant visual feature within the project area. Construction and operation of the project will change the visual appearance of the Danube River and its riverbank throughout the project area. The significance of these changes is based on: the scenic quality of the landscape; the degree of visibility the project would have in the landscape; the ability of the project features to blend in or be visually absorbed by the surrounding landscape; and the potential population viewing these changes and the relative value they place on maintaining the present landscape character.

The following visual impacts are anticipated with project implementation:

- The substantial decrease in the flow in the old Danube channel will alter the existing appearance of the river. Additionally, riverside vegetation along the old riverbank will die or be removed, adding to the dry abandoned appearance of the channel. This impact could be mitigated by implementing a revegetation plan in the riverbed channel. However, the significance of this impact is not high due to low population exposure

- Introduction of new protective embankments along natural riverbanks will alter their appearance. This impact could be mitigated to an insignificant level by planting grass or lawn on the slopes of the embankments and vegetation at the foot of the embankment

- Clearance of forest and riverbank vegetation during construction reduces the natural appearance of the riverbanks, reducing their visual quality. Revegetation plans should be developed and implemented for all cleared areas along the river. This would reduce the adverse visual impact to a level of insignificance

- Construction of the barrage and auxiliary structures at Nagymaros would introduce new structures into a primarily natural and very scenic landscape. Extensive architectural design modifications (including underground structures and transmission lines) which have been incorporated into project design will substantially reduce the adverse visual impacts associated with the new structures

- Development of the proposed riverbank recreation area will provide new viewing opportunities to the population and proposed development of an attractive recreation area adjacent to the barrage site would substantially reduce the adverse visual impact associated with the project

Recreation. The project will create a new linear riverside recreation opportunity (a park) from Nagymaros to Györ, and possibly beyond. The park will provide new recreation opportunities for biking, hiking, sightseeing, and picnicking. A biking/hiking trail created along the protective embankments will also interlink the numerous small settlements along the river, dispersing some of the recreation/tourism away from the heavily concentrated recreation centers in the Danube bend to the less concentrated areas between Gönyü and Nyergesújfalu. The proposed riverside park will be a beneficial impact.

Water sports and riverside recreation (bathing) are two existing attractions of the study region. However, bathing conditions in the study area have deteriorated due to crowding and the Danube's poor water quality (downstream of Györ). Pleasure boating is also fairly limited along most of the Danube in the project area due to border protection restrictions. In general, the project would not improve or degrade these existing conditions. Specific impacts, both adverse and beneficial, are summarized below.

- Increased flows into the Mosoni Danube and Danube side arms in the Szigetköz area will improve and enhance recreation opportunities (bathing and boating) in this area due to controlled year-round flows and consequently improved water quality

- Decreased flows in the old Danube will adversely affect fishing and boating opportunities, but increased opportunities in the Mosoni Danube will help mitigate this impact

- Between Dunaremete and Nyergesújfalu, high fluctuations in water levels in the Danube resulting from peak power operations could adversely impact small boating and bathing opportunities. The impact on boating is not expected to be significant due to existing border restrictions. Bathing opportunities will be most adversely affected upstream from Gönyü, where water conditions are not degraded. Modified peak power operations which will reduce water level fluctuations are currently being evaluated by VIZITERV

- Tourism in the Szigetköz area is expected to increase due to improved recreation opportunities and the installation of a new sewage treatment facility. This could be either beneficial or adverse, depending on how well planners prepare for this growth

- Protective dikes and embankments built along the riverbank will eliminate existing boat landing sites, camp sites, picnic areas, and bathing places. These impacts will be offset in areas with concentrated recreation use (Visegrád-Dömös, Esztergom, and Pilismarót) by the development of new recreation areas

- Tourism in the Danube bend area is expected to increase due to construction of the new sewage treatment facility and the new bridge across the Danube. This could benefit local economies but could also have adverse effects if local planners do not carefully control future growth patterns

Socioeconomics. Construction and operation of the project will affect local, regional, national, and international social and economic conditions. Local effects in the Szigetköz area will include improved agricultural and forestry productivity due to water management (flood protection, controlled water supply, and a reduction in waterlogging). This will benefit the employment and income levels of the local population. The project will also improve recreation in the area and provide a new sewage treatment facility. These two factors are likely to contribute to an increased rate of community growth. Growth in this area will be beneficial to the local population if it is planned for and carefully regulated.

Development in the Danube bend area is currently limited by the lack of adequate sewage treatment and floodplain restrictions. The project will provide new sewage capacity and eliminate the need to restrict construction in the floodplain. This, coupled with planned improved roadway access, will foster regional growth. Growth in this area could be beneficial to local economies, but adverse impacts could occur if not properly regulated.

The need for electrical power in Hungary is increasing due to economic development. The possibilities of exploitating fossil fuels are limited and imported electrical energy is expensive and undependable. The project provides a clean, non-exhaustible source of energy, and does not rely on imported energy resources.

The implementation of the project is of international importance for Danube navigation. Anticipated improvement resulting from the project include: extended navigation time from 250 to 330 days annually; permanent nighttime navigation; increased freighter fleet cargo capacity of at least 20 percent; and decreased probability of navigation accidents. These benefits will be shared by the Danube countries, as well as other countries involved in navigation along this international waterway. It is anticipated that due to project construction, the tonnage of cargo shipped in the Danube will double in 10 years.

The project will provide protection against the 10,000-year flood in the region upstream of Palkovicovo/Szap. Along the downstream reaches, levees will provide protection against the 1,000-year flood. Over the life of the project, this should result in a significant protection to Danube River landowners and residents, who could experience agricultural and sylvicultural loss, structural damage to buildings, and even loss of life during large floods.

1.5 SUMMARY OF RECOMMENDATIONS

Detailed discussions of recommended mitigations and additions and changes to the monitoring program are included in Sections 2 and 3. Recommended mitigations are summarized below.

1.5.1 Mitigation Recommendations

1. VIZITERV should continue evaluating the peak operations (including seasonal changes) of the Gabcikovo plants with gradual load buildup. Variations in river levels due to peaking modes can significantly impact downstream resources including recreation and natural habitats.

2. Additional preoperational data are needed to define impacts to biological resources, especially fisheries, and develop effective mitigations. Additional data should include seasonal surveys for waterfowl, fish, other wildlife species, and four protected birds to determine distribution, abundance, and seasonal habitat use. Surveys should focus on the old Danube channel and side arm/oxbows in the Szigetköz. Consideration should be given to increasing the flow rates to the main channel. A system-wide DO modeling program should be conducted. Based on the modeling results, appropriate mitigation (e.g., spill flows, mechanical aeration, alternating operational modes) should be developed if warranted. The effectiveness of a control gate to allow fish passage at Ásványráró, to allow spawning fish access to the side channel system, should be evaluated. If warranted by a preproject fish survey, appropriate fish protection and guidance systems at the barrages should be developed.

3. Revegetation programs using native species should be considered for areas along the Danube. Restoration of area adjacent to existing remnant forests along the Mosoni Danube should also be considered. This would also meet goals of the Szigetköz Landscape Protection Area policy.

4. Modeling is needed to assess the possibility of reduced DO in the two reservoirs, and to develop any necessary water quality mitigation measures.

5. One of the most effective ways of improving the quality of both surface and ground water and its attendant effects on ecological conditions is to clean up the sources of the pollution. It is not the intent of this report to discuss such concerns, but some of the more critical areas of concern are the sewage discharge into the Mosoni at Györ; the leaching of bauxite red muds, and the asbestos cement plant, near Komárom; and the

excessive amounts of farm fertilizers seeping into the ground water in the Szigetköz and along the lower reaches of the project. We understand that construction of sewage treatment facilities at Györ has started and evaluation of industrial effluent treatment is under way. These and other effluent treatment plans should be pursued.

6. It is strongly recommended that sewage treatment facilities at Györ be operational before the Nagymaros reservoir is filled.

7. Local authorities should develop recreation and land use plans to enhance benefits of new tourism opportunities while limiting adverse impacts to existing land use and sensitive biological areas.

1.5.2 Monitoring Recommendations

Recommendations regarding the GNB project monitoring program are summarized as follows. Detailed discussions are presented in Section 3.

1. The project has expended substantial efforts to develop data to be used to implement mitigation of project-related environmental impacts. A program to educate the public about these efforts would do much to develop support for the project and to answer criticism developed by the opposition.

2. After project startup, the approximately 50 stream flow measuring stations (existing or planned) can be reduced for project operation purposes to about 10 stations, located at all project input sources. All measuring stations should be monitored until project operating rules for all ranges of input conditions (streamflow, sediment load, and pollutant load) have been verified.

3. After surface water levels versus ground water level correlations have been verified, the surface water level measuring stations can be reduced to those at headworks and tailraces of project structures, two locations along the old Danube River channel, and control structures for the seepage interception channels.

4. Cross section surveys should be conducted at 1 km intervals along the Hrusov-Dunakiliti reservoir to establish areas of major sediment deposition for the first 2 to 4 years of project operation. After major sites of sediment deposition are identified, the number of annual surveys can be reduced to four cross sections - one cross section should be located at the upstream end of the reservoir to check clearance in the navigation channel.

   During the first 2 to 4 years, annual cross section surveys should be conducted in Nagymaros reservoir at 3 km intervals and at reaches where bank filter wells are located. After areas of deposition are identified the annual surveys can be reduced to about five locations.

5. Annual analyses of bottom sediments should be conducted in both reservoirs to determine heavy metal content and to check that the bottom environment is conducive for keeping the metals in the stable adsorbed state.

6. During the first year of project operations, water quality sampling and analyses should also be conducted for the two reservoirs, Mosoni Danube, old Danube channel, and the Szigetköz side arm channel to check that the water quality model is properly calibrated and project operations are maintaining the required water quality level.

   Sampling and analysis should be increased during summer months when algal blooms are occurring. During the sample day, DO measurements should be taken twice (morning and evening) to record the diurnal DO changes. After the first year, sampling frequency can be reduced to monthly and the number of measuring stations may be reduced to selected key locations.

7. For project operations monitoring in the Szigetköz area, ground water level measurements should be reduced to three lines between the Mosoni Danube and the old Danube channel to track the ground water profile, and at areas of special concern. Continuous monitoring in these wells is recommended. Another 10-15 sites should be selected for long-term measurements and measured twice a year.

For project operation monitoring along the reach between Gönyü and Visegrád, monitoring should be conducted at potential areas of seepage from higher reservoir levels, critical biological and archeological sites, and between the river and the bank filter wells. The frequency of measurement should be based on the expected rate of change in water levels. Some sites may warrant continuous monitoring; others might be measured four times a year.

8. Ground water quality sampling and quality analysis should be conducted monthly for 2 years to establish baseline conditions. Vertical sampling of a few deep wells should also be conducted. During project operations, ground water quality testing should be conducted at critical sites and over a widely spaced grid along the right bank reach at 3-month intervals.

9. Ground water level data should be collected at all biological monitoring stations to monitor habitat changes. Stream gauging and water quality data should be collected at sensitive waterfowl locations such as Ásványráró.

10. Annual waterfowl surveys on the main Danube channel and side arms along the length of Szigetköz should be conducted. Data can be compared with preoperational survey results to determine changes in populations.

11. Seasonal surveys should be conducted for the four protected birds in the Szigetköz to detect changes in habitat use and abundance.

12. If protected mammal species are identified during preoperational surveys, seasonal surveys should be continued during monitoring.

13. Annual fish surveys including migration and spawning conditions should be conducted in the main channel and side arms of the Szigetköz and Mosoni to determine cumulative impacts.

14. DO levels should be monitored in both reservoirs.

15. Monitoring for forestry should only be considered if ground water levels cannot be maintained by the artificial recharge system as planned. No monitoring for agricultural crops or livestock is recommended.

2
Impact Evaluation and Mitigation Measures

Section 2

IMPACT EVALUATION AND MITIGATION MEASURES

To provide an independent review of the environmental consequences of the Gabcikovo (Bös)-Nagymaros Barrage (GNB) Project, the impact evaluation presented below focuses on identifying impacts that are beneficial or that are significantly adverse and warrant mitigation. We have followed the philosophy that significant impacts must be identified prior to project construction and operation, and qualified - or, where possible - quantified. Clear impact definition is needed to determine the extent to which adverse changes can be successfully mitigated, and to determine the effectiveness of planned and recommended mitigations.

To define impacts, a detailed preoperational (baseline) database must be available. Data collected during a preoperational monitoring program is used to assess the effectiveness of installed mitigations or planned operational rules for flow regimes, and to adjust mitigations as necessary during operation. The project preoperational monitoring system is very detailed in many resource areas, particularly hydrology and archaeology, and more general in other areas, particularly biology. We recognize that that variations in the preoperational monitoring system database is due to the evolutionary circumstances (social and political) surrounding the project since its inception. The delay in completing the Nagymaros barrage portion of the project affords an opportunity to further define the biological preoperational monitoring system, resulting in a better assessment of impacts and effective mitigations.

The impact evaluation and discussion of planned and proposed mitigations presented below begins with a discussion of the criteria considered in defining impact significance. These criteria are generally based on accepted U.S. standards and practices. Due to the variable database, quantification of significant impacts to high, medium, and low is not possible. Impacts have been defined qualitatively as being potentially significant (or not), beneficial, or adverse. Planned or recommended mitigation measures are discussed and the impacts evaluated. Table 2-2 in Section 2.8 summarizes the impact evaluation, planned project mitigations, and Bechtel's recommended mitigations.

2.1 HYDROLOGIC REGIME

2.1.1 Surface Water

The GNB project will regulate the daily Danube River flows over an approximate 160 km reach of the river. The potential significant project-related impacts to the area's hydrologic regime have been identified by VIZITERV in the summary documents outlined in Appendix 1. The significant project-related impacts are discussed in sufficient detail here to allow evaluation of planned and proposed mitigation measures and evaluation of the project monitoring system.

Significant impacts associated with the GNB project on the existing surface water distribution, sedimentation, and surface water quality throughout the Danube River reach of the project (from 1,696 to 1,860 river km) are evaluated according to the changes from historic averages and patterns described below. The historic average annual river flow through the Danube River project reach range from 2,000 - 2,400 m^3/s. The average streamflow velocity for this flow ranges from 0.9 to 1.1 m/s. The river depths for the average flows have been 5 to 6 m. The average annual suspended sediment inflow at Bratislava is estimated to be 7 million tons. The amount of this material annually deposited along the project river reach under preproject conditions has not been estimated. However, due to upstream barrage construction, the sediment inflow has shown a decreasing trend over the last 10 years.

Because of its importance to aquatic life and its role in the breakdown of pollutants, dissolved oxygen (DO) is a key water quality parameter considered in this evaluation. From 1984 to 1988, the DO content recorded at the Dunakiliti barrage site averaged 10.3 mg/l with minimum and maximum levels of 6.7 and 13.6 mg/l, respectively. The minimum DO level for Class I water (highest quality) in Hungary is 6.0 mg/l.

Hrusov-Dunakiliti Reservoir. Barrages at Dunakiliti and Gabcikovo will create the Hrusov-Dunakiliti reservoir. Surface water flowing into the reservoir will be stored and released through the Gabcikovo power plant for 5 hours per day. These power releases will be diverted from 30 km of the Danube River (from river station 1,800 km to 1,840 km). Average daily inflows, up to 4,000 m^3/s, will be diverted through the Gabcikovo power plant. However, project mitigation measures include continuous releases to the old Danube River channel, the adjacent side arms, and the Mosoni Danube to meet the Szigetköz's water demands for environmental preservation and agriculture. The current planned average diversions are 100 m^3/s to the old Danube River channel, 50 m^3/s each to the left and right side arm channels, and 20 m^3/s to the Mosoni Danube. The impacts to the old Danube River channel and Szigetköz area due to surface water redistribution will be discussed in the subsequent section.

The reservoir water level will range between elevations 129 and 131 m above sea level (asl). This impoundment level will raise the normal water surface elevation at Dunakiliti by 8 m. Further, the impoundment level will be between 2 to 6 m above the ground level along 10 km of the reservoir right bank dike. To minimize seepage from the reservoir to the adjacent low land area, a clay blanket will be installed under the dike, extending 150 m into the reservoir. To control the reservoir seepage that passes under this blanket, an interceptor/collection channel will be constructed parallel to the dike. The primary purpose of this channel is to drain the seepage water, thereby maintaining the local ground water level near the historic levels. Thus, the impact of saturating adjacent lands will be mitigated. This seepage water, estimated to be about 50 m^3/s, will be routed to the Danube side arm channel at the upstream end of the Szigetköz.

Sedimentation. The flow velocity in the Hrusov-Dunakiliti reservoir will range from almost zero to about 0.5 m/s during peak power production. The average flow velocity in this reach of the Danube without the GNB project is about 1.1 m/s. This reduced velocity in the new reservoir will induce settlement of suspended solids. According to VIZITERV studies, approximately 70 to 80 percent of the suspended sediment inflow will be deposited, primarily in the upstream portion of the reservoir where the inflows first encounter the reduced velocity regime. Deposition will also occur along the areas adjacent to the reservoir dikes. Sediment accumulation could fill the dead storage volume in the reservoir in about 60 years. However, during major floods, the gates at Dunakiliti weir will be lowered to allow safe passage of the flood flows. At these times some flushing of deposited sediments can be expected and therefore filling of the dead storage area will take more than 60 years.

Sediment accumulation in the upstream portion of the reservoir will have to be monitored to ensure that safe navigation depths are maintained. Periodic dredging of this area may be required. Sediment accumulation in the downstream portion of the reservoir will build up a less permeable bottom layer which will help reduce reservoir seepage.

Surface Water Quality. The impoundment of Danube River flows in the Hrusov-Dunakiliti reservoir will affect the quality of surface waters. Settlement of 70 percent of the suspended solids will clarify the water. The water surface area will be increased about four times. This larger surface area will increase oxygen gas absorption, and thereby improve the DO content of the water. The longer detention time will allow the natural biological process to reduce the organic load under favorable DO and temperature conditions. These three factors will improve the water quality. However, during the summer months, the clarified water depth will increase, allowing deeper light penetration. This, together with the already high nutrient load, will promote increased algae production. When the extra organic load from algae growth is mixed with the incoming organic load, a reduction in DO supply will occur. When DO is significantly reduced, the biological breakdown of the organic load will also be reduced. Reduction of the DO level below 6 mg/L, the limit for Class I water, would constitute an adverse impact. With a DO level at or above 6 mg/L, the Danube waters would maintain the project aerobic environment. Thus, there should be no significant impact to aquatic life or to downstream potable water works due to the GNB project.

To determine if there is a water quality impact due to the GNB project, a quantitative evaluation is recommended. This evaluation should first establish what conditions - organic load, water temperature, nutrient load, etc. - might produce undesirable water quality. If such conditions can be expected - even if they have a low probability of occurrence - then possible mitigation measures should be quantitatively assessed to determine the most likely cost-effective mitigation. Such analysis could be accomplished using existing water quality computer programs and the existing project database. The U.S. Environmental Protection Agency (EPA) computer program QUAL2E (see Appendix 2) can be used for this analysis.

If DO levels fall below acceptable levels, a proposed project mitigation measure is to temporarily pass flows over the Dunakiliti weir to reduce the detention period and thereby minimize oxygen depletion. This action would be initiated based on reduced DO levels detected by the project monitoring program. Other possible mitigation measures which could be considered would be to temporarily change the Gabcikovo power plant operation to a run-of-river plant, thereby reducing detention time and mechanical aeration (example is shown in Appendix 3).

A second potential water quality problem has been identified concerning heavy metals. Heavy metals tend to be adsorbed on suspended sediments. While Danube sediment sampling for heavy metals is limited, varying concentrations of Hg, As, Cd, Fe, Zn, and Mn have all been measured. Under GNB project conditions, the suspended sediments will be deposited in the reservoir as previously described. Deposited sediments with adsorbed heavy metals can remain in a stable state indefinitely. However, if the reservoir bed environment were to become anaerobic, either due to stratified conditions in the reservoir (which is unlikely), or deposition of organic material with the sediments, the heavy metals can be dissolved. For example, the insoluable ferric and manganic salts will be transformed to soluable ferrous and manganous form under anaerobic conditions. In the soluable state, the metals could pass into the underlying ground water regime adding an unwanted pollution load to the ground water.

There are measures which can be implemented to control this problem. The most positive measure is treatment of industrial effluent for removal of heavy metals. Industrial effluent is the major source of heavy metal load in the Danube. The second measure is to monitor reservoir deposition and to sample the sediments. Should sediments with undesirable metal concentrations be detected near ground water recharge areas, these sediments can be removed by dredging. The buildup of sediments is a slow process and remedial dredging could probably be accomplished at 3- to 5-year intervals. A third measure would be to monitor the reservoir bed environment to check that the adsorbed heavy metal state has not been altered. This will require testing representative sediment samples to determine what conditions will cause the metals to dissolve. Should an undesirable reservoir bed environment be detected, sediment removal by dredging can be initiated, or the anaerobic condition can be alleviated by forced vertical mixing using pumps or mechanical aerators.

Szigetköz. Reducing the flow in the old Danube River channel reach (about 30 km long) from the historic 2,000 m^3/s average to 100 m^3/s will significantly impact the adjacent environment. With the planned 100 m^3/s continuously released at Dunakiliti weir, the average depth of flow in the upstream reach of the old Danube River channel will be reduced from 6 to 2 m.

The water level at the confluence with the power tailrace canal and the old Danube River channel will be controlled by Nagymaros reservoir impoundment and will be near the prior GNB project average water surface level. However, the downstream portion of the old Danube River channel water levels will fluctuate daily according to the power releases at the Gabcikovo powerhouse. For the Joint Convention (KET) operation case with a 1,500 m^3/s average inflow into the upper reservoir and 700 MW peak power, the daily fluctuations will be $\pm$ 2.0 m, at the tailrace confluence and $\pm$ 1.0 m 10 km upstream of the tailrace confluence. These daily water level changes will require riverbank stabilization to control erosion. Such erosion control measures are planned for the GNB project. The operation of Gabcikovo powerhouse and the resulting downstream water level fluctuations are being evaluated. We understand that VIZITERV is evaluating alternate operation modes and that a modified operation plan will eventually be adopted which will yield smaller water level changes.

The water level in the side arms of the Szigetköz is currently controlled by the water level in the old Danube River channel up to 2,500 m^3/s as backwater effects. Beyond this flow rate the side arm dikes are overtopped and water flows directly into the side channels. Therefore, without additional water level controls, the water level depth in these side arms would be reduced up to 4 m, with flow diverted from the old Danube River channel. However, mitigation measures to control surface waters in the right bank side arms are planned to maintain the historical water levels in the Szigetköz area. Mitigation measures include improving the existing system of dikes which channelize the side arms waters and planned flow releases of approximately 50 m^3/s (more if needed) at the side arm headwaters. A rockfilled drop structure will be placed near the downstream end of the side arm channels. The purpose of this structure will be to maintain the desired upstream backwater level in the side arms and, most importantly, to keep this backwater level above the daily water level changes in the old Danube River channel induced by the Gabcikovo powerhouse operation.

The southern border of the Szigetköz is delineated by the Mosoni Danube. This arm will also receive releases from the Hrusov-Dunakiliti reservoir. The forecasted release to the Mosoni is 20 m^3/s which will be a benefit of the project. This release is greater than the previous average flow in the upstream reach of the Mosoni. The previous 20-year average has been 5 to 15 m^3/s depending on the stage of the Danube River at Rajka.

Sedimentation. The sediment load in the releases to the old Danube River channel and the side arms will be reduced due to sediment deposition in the upstream reservoir. Further, the flow velocities will generally be equal to or greater than the prior GNB project flow velocities in the same channels. Therefore, sediment deposition in the old Danube River channel and the Szigetköz area will be significantly reduced from historic levels. The amount of sediment deposition in the areas with the GNB project has not been estimated but is not anticipated to be a problem.

Water Quality. The old Danube River channel and the side arms will receive flows from the upstream reservoir. As previously discussed, the water quality in the Hrusov-Dunakiliti reservoir will be improved, except for possible seasonal degradation problems. Concerning flows released over the Dunakiliti weir, the water quality will be improved because of the aeration induced when the flow tumbles over the concrete energy dissipation blocks.

Water quality in the side arms will be improved. The currently stagnated side arms waters will be replaced by the steady 50 m^3/s or more flow released from the upstream reservoir.

The water quality in the Mosoni will be equal to or better than the past water quality, except for the downstream reach just above the confluence with the Danube. Here the daily water levels will fluctuate by $\pm$ 1.5 m, according to the KET operation plan. These fluctuations will alter backwater up to the city of Györ. At present there are a number of raw sewage water discharges into the Mosoni Danube at Györ. Except when major flows (greater than 3,000 m^3/s) occur in the Danube once or twice a year, the sewage effluent is passed into the Mosoni Danube and diluted. However, under GNB project conditions, the fluctuating backwater at Györ will hinder mixing of the raw sewage. We understand that a sewage collection and treatment plant for Györ is under construction and will be operational in 1993. It is strongly recommended that this treatment plant be in operation prior to impounding water in Nagymaros reservoir. This would eliminate what otherwise would become a health hazard if the current once- or twice-year sewage mixing problem were to be transformed into a daily problem.

Nagymaros Reservoir. The Nagymaros barrage will develop a 120 km long reservoir with a normal water surface elevation of 108 m. This impoundment will provide a 9 m elevation drop for power generation, and sufficient depth to pass navigation up to the Gabcikovo shiplock. The reservoir will also act as an equalization pond by receiving the generation flows from Gabcikovo (about 4,000 m^3/s for 5 hours) and releasing these flows at an uniform rate to the natural flowing river downstream. Further, the Nagymaros weir, with the radial gates lowered, will safely pass the 1,000-year flood event.

Along segments of the right bank, some dikes will be raised and the impounded water level will be raised above the right bank ground elevation. This will impact surface drainage from the right bank area, blocking normal drainage paths into the Danube River. To mitigate this impact, seepage/drainage interception channels will be constructed parallel to dikes where the reservoir water level will be above the adjacent ground level. The seepage/drainage flows collected in these channels will be lifted into the reservoir at a number of pump stations at the downstream reach of each interception channel. The water level in these channels will be maintained below the surrounding ground surface level, thereby mitigating the drainage problem.

Peak hydroelectric generation at the Gabcikovo powerhouse will significantly affect the flow regime in the Nagymaros reservoir. According to the KET operation plan for the design low flow case with 900 m^3/s inflow and 700 MW peak power production, daily peak power releases will change from zero to 4,500 m^3/s within one hour and continue at $\pm$ 4,500 m^3/s for 5 hours, then reduce to a zero release. This rapidly changing inflow pattern will cause the water level at the upstream of the reservoir to rise 4 to 5 m over a 5-hour period. At the downstream end of the reservoir this water level will be attenuated to a 1 m rise. This daily wave action will erode all exposed river banks and levels without mitigation. To control erosion, riverbanks and levees are to be fortified with riprap placed on geomembranes.

Current practice for the Columbia River in the U.S., where similar hydroelectric and shiplock facilities are in operation, require water level changes to be restricted to 0.5 m/hour and 1.1 m/24 hours during the months of April through September, and to 1 m/hour and 2 m/24 hours during the months of October through March. This practice has been established to accommodate the fish environment, recreational boating needs, and commercial navigation requirements.

As an example of actual river operation results, the recorded Columbia River water level changes for the reach of river downstream from the Bonneville Dam and Power Plant during a normal year (1980) were:

- o Maximum for 1 day - 1.9 m
- o Maximum for 1 month - 3.7 m
- o Maximum for 1 year - 5.4 m

Sedimentation. Except for short periods during major floods, the sediment load into Nagymaros reservoir will be reduced because of the retention of over 70 percent of the sediment load in the upstream reservoir. However, sediments will be received from runoff along the 120 km river reach of the Nagymaros reservoir and from the tributary rivers. In the upstream end of Nagymaros reservoir, little or no sediment deposition is expected along this reach because of anticipated velocity changes. Sediment deposition is expected in the 50 km downstream end of the reservoir, primarily along the shallow riverbanks where flow velocities are lowest. VIZITERV has estimated that sediment deposition in the lower reach river bank areas will be 4 to 5 cm annually. However, during major flood events, the radial gates at the Nagymaros weir will be lowered to the riverbed level and some flushing of bottom sediments is to be expected.

Some concern has been expressed regarding the potential for sediment deposition over the river gravel areas which link the Danube water to the filter bank water wells, primarily located along the river reach from Komárom to Nagymaros. Such deposition could form a more impermeable layer above the gravels and reduce seepage into the gravels and into the ground water wells. However, the deposition is expected only along the side banks, leaving the center channel section clear of sediments. Should this occur, the flow path to the water wells will be increased and the flow rate will be proportionately decreased. Because permeability of the river gravels is high, the increased flow path length is not expected to significantly reduce the flow to the ground water wells. However, it is recommended that the water level of these wells be monitored together with adjacent river water levels. Should a trend of reduced well water levels be seen together with relatively steady river water levels, blanketing of the river gravels with sediments may be occurring. This problem might be controlled by periodically lowering the weir gates at Nagymaros to flush deposited sediments or by selectively dredging the sediment deposits. Such dredging would be controlled to remove only the top sediment layer while leaving the underlying gravels largely intact.

Surface Water Quality. The quality of water in the Nagymaros reservoir will depend on the quality of the inflowing waters from:

Hrusov-Dunakiliti reservoir
Mosoni Danube tributary
Right bank communities and industries
Vag tributary, left bank
Garam tributary, left bank
Ipoly, left bank

Eighty-five percent of the inflow is from the upper Hrusov-Dunakiliti reservoir; therefore, the quality of these waters will control the water quality in Nagymaros reservoir.

The next largest pollution load is from the left bank triburary rivers Vag, Garam, and Ipoly. These combined inflows represent 10 percent of the inflow into Nagymaros reservoir. These tributaries exhibit water quality indices worse than those of the Danube.

The possible change in Danube River water quality due to impoundment in Nagymaros reservoir has not been evaluated. Water quality during some months of the year will likely improve due to settlement of suspended sediment and more biological breakdown in the upper reservoir, when the DO content is sufficient to continue this process. During summer months water quality is characteristically lower than average levels. Within the Nagymaros reservoir, water quality could decrease further than historic levels because of the combination of higher reservoir water temperature and longer detention time for algae production. The possibility of this impact needs to be studied and quantified to determine:

- o Combination of parameters, if any, that would cause water quality degradation over historic levels (i.e., flow rate, organic load, nutrient load, water temperature, and DO content)

- o Probability of critical combination of parameters occurring

- o Appropriate water quality control measures (i.e., treatment of source pollutant loads, reducing reservoir detention times during critical periods, passing more flows over the Dunakiliti Weir and energy dissipation blocks to aerate the water, etc.)

Such quantitative evaluations can be performed using the QUAL2E computer program which would model the two reservoirs together with the water quality processes (see Appendix 2).

The possibility that heavy metals may concentrate in settled sediments and later dissolve into waters drawn into the river bank water supply wells also exists for the Nagymaros reservoir. This is particularly likely because the Vag inflows have higher concentrations of heavy metals. Again, an analysis of representative sediments should be conducted to determine if there is any likely combination of events which could dissolve the adsorbed metals. If unacceptable conditions are determined to be possible, appropriate mitigation measures should be identified, tested quantitatively, and selected for later mitigation when required. Possible mitigation measures include temporarily stopping industrial discharges (the main source of metal contaminants), improving industrial effluent treatment, temporarily opening the gates at Nagymaros, flushing flows from the reservoir, selective dredging, or mechanical aeration.

2.1.2 Ground Water

Hr__ov-Dunakiliti Reservoir. The Hrusov-Dunakiliti reservoir and the Danube River down to the city of Gönyü overlay a large ground water basin which also ext_nds under most of the Small Hungarian Plain (Kisalföld). The Danube is the predominant source of recharge to this basin (reported estimate is 90 percent of total recharge). Downstream of the Small Hungarian Plain basin, below Gönyü, the Danube traverses a series of small ground water subbasins containing discontinuous aquifers extending to as much as 70 m depth. The uppermost aquifers in these subbasins are in direct contact with the Danube River.

Downstream from the Nagymaros barrage site, the very permeable and shallow gravels of the Danube River channel are the source of bank-filter water supply wells providing a major part of the supply to Budapest. Similar well fields provide water supply to communities upstream of Nagymaros. Concern has been expressed that operation of the project may impact those wells.

VIZITERV and its experts have conducted extensive and detailed subsurface investigations of these ground water basins and have established relationships between the aquifers and the Danube River. Based on the results of those studies, the impacts that GNB project facilities and operations will have on these resources is evaluated below.

Impacts the project may impose on the ground water hydrology are of four general categories:

- Changes in the ground water recharge characteristics of the Danube River
- Changes in the fluctuation and level of the water table
- Changes in the quality of ground water
- Changes in the filtering characteristics of the riverbanks

The significance of each impact is evaluated primarily with respect to ground water as a resource. Other impacts of immediate consequence, such as waterlogging of lowland areas, are also discussed. It should be recognized that some potential impacts associated with ground water changes described in this section may have significant consequences for other resource areas. Such effects will be discussed in specific sections addressing those resource areas. Potential project impacts on ground water hydrology are discussed by three subareas:

- o Dunakiliti reservoir to Gönyü
- o Gönyü to Nagymaros
- o Downstream of Nagymaros

Dunakiliti to Gönyü Subarea. From Bratislava/Pozsony to Vének/Gönyü, the Danube crosses a deep structural basin filled with very permeable sand and gravel layers of Quaternary or recent geologic age. Thicknesses of those deposits range from 10 to 12 m at the edges of the basin to more than 300 m in the central area near Ásványráró. Fine-grained, low-permeable layers are present, but are discontinuous. The full thickness of the deposits responds as one aquifer, which is referred to as the "gravel aquifer" of the Szigetköz.

From where the Danube first flows onto the basin, it is a source of recharge - that is, ground water flows away from the Danube River channel, southeastward beneath the Szigetköz to the Mosoni Danube. Ground water discharges to the Mosoni Danube and Raba-Hansag water system, which in turn flows back to the main Danube channel near Györ. The Mosoni is a drainage boundary within the basin. Ground water to the south migrates northeastward and also discharges to the Mosoni Danube.

The water table beneath the Szigetköz fluctuates in response to the rise and fall of the Danube stage. The response is progressively less with distance from the Danube River channel. Seasonal fluctuations, based on the 35 years of water level records in observation wells, range from 4.5 m near the Danube to 0.7 m at some distance from the river.

Impoundment of Danube River water in Hrusov-Dunakiliti reservoir and diversion of around 30 km of the Danube River channel will alter the recharge regime to the gravel aquifer. Recharge from the reservoir area will be increased because large portions of the reservoir are unlined and exposed to the gravel aquifer. The reservoir area open to the aquifer is over twice that of the bypassed old Danube channel. Recharge will also increase because the reservoir water level will be raised 4 to 8 m above the average river level, thus increasing the driving force for recharge. On the other hand, recharge from the old Danube channel will be reduced because the historic average annual flow of 2,000 m^3/s in this channel reach will be reduced to 100 m^3/s. The net change to the aquifer ground water supply due to the altered recharge regime will be minimal - possibly increasing or decreasing slightly.

Measurable impacts will occur, however, to the ground water levels adjacent to the reservoir and the old Danube River channel. Where land surface areas adjacent to the reservoir are below the normal reservoir impoundment level, seepage from the reservoir will raise the water table - possibly inundating local depressions. To manage this problem, seepage interception channels have been constructed parallel to the reservoir dikes as part of the project. These interception channels will transport the reservoir seepage to the Szigetköz side arm channels and will maintain the local ground water level near historic levels. No additional mitigation is recommended.

The planned project release to the old Danube River channel is significantly less than the historic average river flow. This reduced flow rate will lower the water level in the old Danube River channel by 5 m at the Dunakiliti weir and to no change at the old Danube River channel/power tailrace canal confluence. The ground water table in the adjacent Szigetköz area will be lowered because the Danube is the major recharge source.

To keep Szigetköz ground water levels near historic levels, an artificial ground water recharge plan has been adopted for the GNB project. The plan is to release water from the seepage interception channels and the reservoir into headwaters of the selected side arm channels and the Mosoni Danube. The extra flows in the side arm channels will provide a new ground water recharge source. Analog model studies of the Szigetköz ground water basin were conducted to help design the new side channel recharge system. These studies have indicated that the average water table level can be maintained within 50 cm of the preproject level of 80 to 90 percent of the Szigetköz, and the historic level fluctuations will be reduced. However, the analog model study included the assumption of a homogenous but unisotropic gravel aquifer is homogeneous and isotropic. For the area-wide plan, this assumption is justified and supportable. However, the Szigetköz subsurface does vary from place to place in composition and characteristics. Therefore, we suggest evaluation of specific areas where careful management of the ground water level is important, such as the heron habitat area near Ásványráró, to determine if additional ground water control measures are necessary.

Should a site-specific evaluation identify variable subsurface conditions, additional ground water control measures can b veloped, such as constructing small water supply ditches and/or drainage ditches. These evaluations should be conducted before the project is operational.

Gönyü-Nagymaros Subarea. Below Gönyü, the Danube leaves the broad, open Small Hungarian Plain and enters an area of moderate to high relief, flanked by hills and intervening lowland areas. Within the hill areas the river is confined by high banks above the maximum flood level, and there is little to no width of flood lowland. Materials underlying the hills are either consolidated bedrock, or relatively low-permeable materials.

There are three lowland reaches in this subarea; Komárom to Dunaalmás, Tát to Esztergom, and Pilismarót. These subareas are underlain by multilayered alluvial deposits to varying depths with the sand and gravel layers comprising aquifers. The water table in these areas is commonly near, or at, ground surface. Extensive drainage networks have been established for agricultural development.

Water supply in this region has been primarily oriented to surface water as a source. The ground water resource has not been developed in the vicinity of the Danube River. A major reason, it appears, is that impairment of the of shallow ground water quality is pervasive. The use of "bank-filtered" wells in the last 2 or 3 decades has allowed effective "natural" filtration of Danube water. These filter wells are located to minimize interception of ground water from the adjacent areas. Several fields of bank-filter wells are present along the Danube River in this subarea.

With the construction of the Nagymaros barrage, the mean level of the river will be raised from 1 to 6 meters in the subarea. To adjust to this new Danube water level, the water table away from the river will rise correspondingly unless some remediation measures are imposed.

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Along reaches of Nagymaros where the mean project water level would be above the land side ground level, seepage interception channels will be constructed parallel to the reservoir dike. As previously discussed, these interception channels will control seepage from the reservoir and maintain the local ground water level near the historic average level. This measure is appropriate and workable and no further mitigations are recommended.

In the hill areas, where natural high banks exceed the highest flood levels, the raised ground water will generally remain deep and have insignificant impact on the area. Protective measures are planned for some industrial plants and community facilities near the river. However, seepage may occur in areas not previously expected. It is doubtful that such occurrences would cause seriously detrimental effects, but it could result in undesirable developments, such as marshy, wt ground. It is recommended that the occurrence of ground water in those areas be reviewed to identify potential areas where unwanted seepage might occur. Ground water level measuring stations should be added to the monitoring system as necessary to allow surveillance of these local seepage areas during project operation.

The Nagymaros reservoir will impact the bank filter walls by affecting the capacities of the wells and the quality of the extracted water. With regard to the capacity of the wells, the increased river level and the reduction of seasonal fluctuation will provide a higher, and more constant driving force, or head, to induce infiltration. This will increase the potential capacity and dependability of the wells. On the other hand, sediment deposited on the reservoir bank will tend to reduce the capacity of the wells because it will develop a low- permeability layer that could restrict infiltration.

To monitor inflow to the bank filter wells, many of the wells are provided with observation wells between the river and the extraction well. The purpose has been to detect reduction in well efficiency. Monitoring these wells in conjunction with the reservoir level will also provide an indication of whether or not sediment deposition in the reservoir is affecting well capacity. Should it be proven that inflow into some wells is significantly reduce due to reservoir side sediment deposition, the sediments should be removed by dredging.

Quality of the water extracted by the bank-filtered wells will depend primarily on the quality of the river water. The filtering characteristics of the sand and gravel materials will not be affected by the reservoir. Because the water level of the reservoir will be higher than the existing water level, the wells will draw a lower percentage of ground water from adjacent areas, which are the present sources of poor quality water. Should an undesirable dissolved constituent be introduced into the Danube River, the filter characteristics will not prevent that constituent from eventually reaching the filter wells except to the extent of the adsorption capacity of the filter material.

The same concern for heavy metal accumulation exists for the Nagymaros reservoir as for the Hrusov-Dunakiliti reservoir. As previously discussed, representative sediment samples should be tested to determine the particular circumstances necessary to turn the stable adsorbed metals to the soluble state. The monitoring of bottom sediments should then track the local environment and if unfavorable conditions are observed, corrective measures already identified can be initiated.

Downstream of Nagymaros. The planned operation of the project will not significantly alter the flow characteristics or hydrology of the river downstream of Nagymaros. Some dredging has been done to improve the channel for navigation. Concern has been expressed that these efforts, or operation of the project, could disturb or affect the bank-filter wells present in the area.

The dredging work has been terminated, so that is no longer a factor. Because the project will not alter the flow of the river in this area, the project can not have a measurable impact on the performance of the wells. From a water quality standpoint, as discussed in the section on surface water, the project operation might result in an improved water quality except for a few months during the summer. The question of lower quality water occurring during the summer months should be evaluated as previously recommended. The bank filter wells located downstream from Nagymaros will yield water with the same water quality as found in Nagymaros reservoir. The occurrence and movement of ground water downstream of Nagymaros will not be affected by project operation.

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2.2 BIOLOGY

2.2.1 Impact Methodology

The impact analysis for biological resources is based on information documents listed in Appendix 1, discussions with the Institute of Ecology and Taxonomy (ELTE) and VIZITERV experts, and general biological observations made during a field reconnaissance of the project area. The reconnaissance included the Dunakiliti reservoir, Gabcikovo barrage and power station, Nagymaros barrage construction sites, biological monitoring station no. 1 at Dunakiliti, a side channel/oxbow in the Szigetköz, and a fringe forest at Pilismarót. Information regarding biological resources in the project area varies greatly. Specific biological information is limited to 12 biological monitoring stations. Nine in Gönyü-Nyergesújfalu (Tát and Almásneszmély), and one at Szentendre Island.

The impact analysis provided by VIZITERV was limited as impacts as agriculture, sylviculture, and fishing. Therefore, based upon the data provided, an impact analysis was done to determine potential impacts on biological resources, and develop mitigatious and recommendation for the monitoring program.

Significance Criteria. Several factors were used in evaluating impact significance, these factors are the: importance (e.g., ecological, legal, scientific) of the resource; total size or areal extent of the population or habitat within the ecologically equivalent area; amount of the population or habitat expected to be affected; ecological ramifications resulting from the effect; and anticipated duration of effects.

An important is considered "locally significant" if it is expected to directly as indirectly cause measurable change within the localised area in either (1) species' composition or abundance beyond that of natural variability, or (2) ecological function. To be locally significant, the size of the affected area would be relatively small compared to that of an ecologically equivalent area within the region.

An impact is considered "regionally significant" if it is expected to directly or indirectly cause measurable change within multiple localized areas or a single large area. In other words, it is considered regionally significant if the affected area is a relatively large portion of the ecologically equivalent area within the region.

An impact is considered "long-term" if the change in species composition or abundance or ecological function is expected to continue for 5 years or longer. Measurable changes expected to last less than 5 years are considered "short-term."

The threshold for significance is determined by scientific judgment and considers the relative importance of the species and/or habitat affected. Where there is uncertainty about the determination of an impact due to the limited database, judgments were conservative. In such cases, uncertainties are identified and the rationale for the conclusion is explained. In selected instances, a most likely case and a less likely, but more severe, case are both identified – particularly where impacts are generally expected to be insignificant, but could become significant given certain conditions. The probability of a significant impact in these cases is indicated to the maximum extent feasible. Identifying more than one possible level of significance may also occur where baseline information on biological resources is inadequate to support a scientific judgment.

Although the same criteria are applied to protected species (e.g., threatened, endangered, or rare), effects on only a small area of their habitat or a few individuals could result in a determination of significance. Due to factors such as limited distribution, low population numbers, or limited ability to recover from impacts, a lower level of potential impact (than for non-endangered biota) would generally result in a determination of a significant impact on rare, threatened, or endangered species.

Biological resources for which additional baseline (e.g., preproject) data are needed to enable prediction of impacts also are identified, and general guidance on the types of additional data needed is given.

2.2.2 Impact Discussion

The construction and operation of the GNB project has the potential to affect biological resources inhabiting the Danube River and adjacent floodplain areas.

Significant impacts expected to result from the construction and operation of the project are identified, their significance is assessed, project-planned mitigation measures are described, and additional mitigation measures are recommended below. In some cases, available information does not allow a determination of the likelihood or significance of an impact. In these cases, potential impacts are identified and the additional data needed to adequately assess and mitigate such impacts are described briefly. Biological impacts are identified for each of four reaches, Szigetköz-Gönyü, Gönyü-Nyergesújfalu, Nyergesújfalu-Nagymaros, and Nagymaros-Budapest.

Szigetköz-Gönyü - Vegetation. Discussion of impacts on vegetation in this section focuses on effects on natural vegetation. Effects on agricultural crops and managed (i.e., harvested) forests are discussed in Land Use (Section 2.3).

Construction of the Hrusov-Dunakiliti reservoir, the diversion canal, the Gabcikovo (Bös) Barrage System, and ancillary support facilities (e.g., access roads) included clearing of forest and riparian vegetation which is permanently lost. Although the vegetation of this area was not specifically characterized prior to clearing activities, some general conclusions can be made regarding loss of the natural vegetation.

General Impacts. Generally, the floodplain vegetation of this reach of the Danube has experienced strong anthropogenic effects from flood management, silvicultural practices, and management of wild game species. An estimated 70-80 percent of the floodplain vegetation consists of artificial (i.e., managed) stands of poplar. These poplar plantations do not support the natural understory vegetation, but instead develop an herbaceous layer following flooding. This layer consists primarily of 3 m tall stands of *Impatiens glandulifera*, (an introduced species), *Urtica dioica*, and

Aster spp.. An estimated 1,100 ha of managed poplar forest were cut and cleared for construction of the Dunakiliti reservoir.

Areas that are not easily accessible to equipment and narrow visual buffer strips have remained unmanaged. Areas that are not planted in poplars (20-30 percent) consist of natural, but altered vegetation including the following associations: willow thicket (_Salicetum purpureae_, _Salicetum triandrae_); willow-poplar gallery forest (_Salicetum albae-fragilis_); and ash-oak-elm gallery forest (_Fraxino pannonicae-ulmetum pannonicum_). It can be extrapolated from the above information that 200-300 ha of natural vegetation were cleared for the Dunakiliti reservoir and are permanently lost as habitat. Mitigation for this impact is discussed below in conjunction with the loss of vegetation due to aridification.

Aridification. Once the project is operational, diversion of approximately 95 percent of the average flow of the Danube into the navigation canal will lower the ground water table between the main channel of the Danube and the diked-off side channel system, which will concommitantly result in alteration of floodplain vegetation. As described in more detail in Section 1.3, the planned operational discharge of 100 m^3/s (continuous) into the main channel which has an average natural flow of 2,000 m^3/s is expected to lower the ground water table approximately 1-3 m. It has been estimated that a 250-300 m wide zone of vegetation will be affected by this aridification. This drier zone will extend approximately 25 km downstream along the main channel of the Danube to just upstream of where the tailrace canal rejoins the Danube (i.e., the backwater confluence). Approximately 20 percent of the vegetation in this zone is natural vegetation with most of the area consisting of planted poplar.

Based on the correlation between vegetative associations and annual mean water levels in the soil, it is expected that the natural vegetation within this zone will change over time. Areas of willow (_Salix purpurea_, _S. triandra_) and willow-poplar gallery forest (_Salix alba_, _S. fragilis_) are expected to be replaced by vegetation adapted to dryer soils, such as oak-steppe and dry grasslands.

Loss of willow thicket and willow-poplar gallery forest vegetation due to clearing for the Dunakiliti reservoir and lowering of the ground water table in the zone along 25 km of the Danube will measurably reduce the number of these natural habitats in the Szigetköz area. This loss of vegetation will be a long-term impact of the project. Vegetation cleared for the Dunakiliti reservoir is permanently lost, and alternation of willow thicket and willow-poplar forest vegetation to associations requiring less water is also expected to be permanent.

These habitats already have been reduced in the Szigetköz, and the additional reductions resulting from the project will include a considerable portion of the remaining natural vegetation. Additionally, these natural vegetation types are ecologically important because they support a greater diversity and abundance of bird species than do the planted poplar stands in the floodplain of the Danube. Because of the importance of this natural vegetation, the extent of the area to be affected, and the long-term nature of the effect, this is considered to be a long-term, regionally significant impact.

Mitigation Measures. Three types of mitigation are possible for this impact on natural vegetation. First and preferably, the impact could be reduced by increasing the flow released continuously to the main channel of the Danube. The degree of mitigation would depend on the increase in flow and associated ground water levels.

Second, this impact could be reduced somewhat by developing and implementing a revegetation plan to reestablish natural vegetation in the Szigetköz. To facilitate reestablishment of natural vegetation, riparian areas around the Dunakiliti reservoir could be planted with suitable native species. For example, the possibility of sprigging with unrooted *Salix* species should be considered. Riparian vegetation, however, is expected to establish naturally around the reservoir. This mitigation measure would expedite replacing lost habitat, but would not fully offset the acreage lost permanently to the project.

Third, a revegetation plan also could be developed to begin implementation of the planned, but currently unfunded, expansion of the remnants of native forest along the Mosoni Danube, which is one of the objectives of the Szigetköz Landscape Protection Area policy. For example, acreage immediately adjacent to the remnant oak hardwood forest at the Hédervár forest monitoring station could be obtained, cleared, and planted with appropriate species. Reestablishment of this type of natural, high-diversity vegetation which supports a more diverse fauna could offset the adverse impact of the loss of natural vegetation in the floodplain. The minimum mitigation recommended for the project includes increasing the flow releases to the main channel and reestablishment of expanded acreage of the remmant hardwood forests along the Mosoni Danube. Facilitating reestablishment of riparian vegetation at the Dunakiliti reservoir also should be included but is not considered as important as the other two mitigations.

Other Impacts. Other potential impacts on vegetation identified in the Szigetköz-Gönyü reach were evaluated and considered to be insignificant. No significant impacts are expected on the old forest vegetation (e.g., Hédervár, Feketeerdö) and associated protected plant species (e.g., *Lilium bulbiferum*, *Ophrys spp.* and *Iris sibirica*) along the Mosoni Danube because the flow of the Mosoni will be maintained (i.e., slightly increased) during project operations, and ground water levels in the adjacent areas are not expected to change (Section 2.2). Additionally, the project will not alter any land within these "strictly protected areas" of the Szigetköz.

Natural vegetation occurring in the vicinity of the Danube side channel/oxbows is not expected to experience significant adverse impacts. Reeds, willow-poplar gallery, willow thicket, and other natural vegetation comprise approximately 20 percent of the total vegetation and exist in areas not suitable for silviculture (e.g., abandoned borrow pits). This type of vegetation will be supported by maintaining the water level in the side channels. Although some localized changes in species composition are expected in response to alteration of ground water levels (e.g., decreased ground water levels toward the center of larger islands in side arms), these changes are not expected to result in significant impacts on the natural wetland and riparian vegetation.

The effectiveness of the system to maintain water in the side channels will need to be monitored. If the ground water level drops, significant impacts on natural vegetation could occur.

Areas of water-lily mats (e.g., Nymphaea alba, Nuphar lutea) are considered rare in the area (Simon and Lang, 1989), occurring in an estimated 20 locations among the side channels in shallow water depths (2 m or less). Water lily mats may be expected to be lost in localized areas where water depths increase beyond 2 m, but to develop in areas where water depths decrease to suitable depths (2 m or less). Overall, this is not expected to be a significant impact.

Szigetköz-Gönyü - Wildlife. A limited amount of specific information on birds in the Szigetköz is available and was used in assessing impacts. Due to lack of data, identification of impacts on other wildlife species and habitats is limited to a general discussion of potential impacts.

Construction Activities. Generally, exposing birds and mammals to construction noise disturbs them temporarily. It can also result in the abandonment of breeding sites or habitat, which could result in a significant adverse impact on species which have very limited abundance or specialized breeding habitats. However, no such species are known to occur, or expected to have been affected, in the vicinity of the Dunakiliti reservoir site. Because similar habitats exist in the area, and no known species of particularly sensitive bird and mammal occurs, the temporary construction noise disturbance is expected to have no significant impact. However, a definitive impact determination cannot be made because the fauna of the area was not surveyed and identified prior to construction.

Construction activities at the Dunakiliti reservoir will result in some bird and mammal mortality and displacement of additional individuals due to loss of habitat. As with construction noise impacts, this is not known to have affected any bird or mammal species of limited numbers or restricted habitat. Such impacts are not expected to be significant. Again, however, this is not a definitive determination because preconstruction, species-specific information for the reservoir site is not available.

Operating Activities. Operation of the project will result in additional displacement impacts on birds and mammals. This will be due to the loss of, or changes to, habitat along the old channel of the Danube resulting from lowering of the ground water level in the 250-300 m zone between the old channel and the diked off side arms (as described under vegetation). Because habitats and associated wildlife of this area have not been characterized and mapped, this impact cannot be quantified or assessed by species.

Danube Floodplain. It is generally known, however, that the Danube floodplain area to be affected by the project supports a wide diversity of bird species, including significant numbers of waterfowl, some of which are residents of the area during the breeding season (as observed at monitoring station no. 4) including: little grebe (*Podiceps ruficollis*), garganey (*Anas querquedula*), teal (*Anas crecca*), green sandpiper (*Tringa ochropolus*), and common sandpiper (*Tringa hypoleucos*). It is considered likely that the 95 percent reduction of flow to the old channel and resultant loss of aquatic and riparian vegetation (within the zone between the main channel and the side arm system) will affect a wide diversity of species and substantial numbers along the 25 km reach. This is expected to be a regionally significant long-term impact. Some utilization of aquatic and riparian habitat may be shifted to similar habitats in the adjacent side arm system. This will depend upon the comparable quality of the habitat and existing faunal populations. This possibility needs further study.

Increasing the operational flow to the old Danube River channel could also reduce this impact. The resultant impact on aquatic and riparian habitat and waterfowl would be smaller as the continuous minimum releases increase.

To better determine the potential impact and evaluate the need for this mitigation and alternate flow releases, quarterly seasonal surveys of waterfowl species, habitat usage, and habitat type are strongly recommended. These surveys should be conducted for a 1-year period within the area that may be affected by project operation. Once these data have been collected, the waterfowl usage and wetlands habitat of the area can be mapped. The information could then be compared to an estimation of the expected changes in habitat (based on the expected increase in depth to ground water and water requirements of dominant plant species). This would allow more definitive prediction of the expected impact and could be used for determining the mode of operation and flow release to the old Danube River channel.

Four protected bird species which utilize habitat potentially affected by project operation were identified. The little ringed plover (Charadrius dubius) is known to nest and breed between stones in the sandy areas of the floodplain along the main channel of the Danube. This species could be adversely affected by the alteration of habitat along the main channel during project operations. The likelihood of this impact cannot be assessed due to lack of information on its distribution and habitat use in the vicinity of the project.

In the Szigetköz, the protected willow tit (Parus montanus) is only known to occur and breed in the hardwood forest at Dunasziget (biological monitoring station no. 2). The oak gallery forest which it inhabits is on an elevated floodplain circumscribed by two branches of the side channels and the main channel of the Danube. Any change in habitat would adversely affect this species. While no change in the water regime is expected, additional information regarding its distribution and habitat use is needed to determine the likelihood of adverse impacts to this species.

The treecreeper (Certhia familiaris) is known to breed in the Dunasziget forest (biological monitoring station no. 2) and also has been observed at Ásványráró (biological monitoring station no. 7), but not during the breeding season. Conditions similar to those described for Parus montanus apply to this species.

The fourth protected bird species which could be affected by the project is the penduline tit (Remiz pendulinus) which nests and breeds in the willows at Dunaremete (biological monitoring station no. 5). While the ground water table maintained by the release into the side arm system is not anticipated to affect the willow habitat which this species inhabits, the likelihood of adverse impacts to this species cannot be determined at this time.

Project-related impacts on any of these four protected bird species could be long-term and regionally significant due to their limited distribution and abundance and specific breeding habitat requirements. Special attention should be directed toward preventing changes to the hydrologic regime which could adversely affect habitats of these species.

Mitigations to maintain adequate water levels and flow should include alternatives to the operation mode and flow releases. Another mitigation would be planned monitoring of changes in vegetation at these sites during project operations, and adjustments in the flow in the side channels and/or main channel should the vegetation begin to be affected adversely. A baseline survey of the four protected bird species to characterize the distribution, abundance, and seasonal habitat use of this area of the Szigetköz is recommended. Data from the surveys could be used to map seasonal habitat use so that specific areas could be monitored for adverse changes during project operations. Monitoring results could then direct any adjustments necessary in flow rates and timing in the side channels system and/or main channel to maintain these breeding habitats for these sensitive species.

Wetlands and Riparian Areas. Project operations also present the potential to affect wildlife inhabiting the wetlands and riparian areas in the floodplains of the side arm/oxbow system of the Danube. Most of the inlets of this side arm system have been diked off from the main channel and intermediate dikes have been constructed, so that the surface water in the side arm system is only recharged by seasonal flooding (i.e., "white flood" from January to March and "green flood" in May-June). Currently, the ground water gradient is such that at low river stages it slopes towards the Danube, whereas at high stages the Danube recharges the ground water in this area. Once the project is operational, around 100 m^3/s of flow are released to the main channel at Dunakiliti (compared to an average preproject flow of 2,000 m^3/s). The ground water table in the area adjacent to the old channel is expected to drop by 5 m at the Dunakiliti weir decreasing to 0 m at the confluence with the tailrace channel. This is expected to result in potential loss of water from the side arms which could result in loss of wetland or riparian habitat important to waterfowl.

Plans have been developed to maintain the preproject ground water levels in the Szigetköz area by releasing water from the Hrusov-Dunakiliti reservoir into the side arm channel system and fortifying the dikes which already separate the side arm channels from the main channel. Together with the intermediate closures in the side arms, ten small pools will be formed. Water overtopping these riprap dikes will feed successive pools. The side channel flow will recharge the ground water. The excess flow will pass over a rockfill drip structure at the downstream end of the side channel system and return to the main channel. To control variable seepage into the ground water, flow levels in the side channel system can be regulated.

To minimize the risk of an unwanted drop in the Szigetköz area ground water level and associated adverse impacts to important habitats when the flow is initially diverted from the main Danube channel, it is recommended that the flow at the Dunakiliti weir be reduced in incremental steps. At each step, the reduced flow in the main channel is held constant until the new flow into the side channel system has sufficiently stabilized the local ground water level. This procedure should continue until the Danube flow is reduced to 100 m^3/sec or the selected minimum old channel flow. This procedure should be followed when flow is diverted from the Danube channel for the first time.

Due to the uniqueness of this system and the lack of baseline data, impacts on wildlife, particularly waterbirds using the side arm system, cannot be assessed accurately. In the event that the surface water levels dropped significantly in the side arms, important breeding and feeding habitat could be lost and adverse impacts on waterbirds could result, which should be avoided by all means.

Ásványráró Area. It is evident from the limited data that one area in which the hydrolic regime requires special attention is located near Ásványráró. This area is known to support significant numbers of waterfowl, including nesting gray herons, night herons, cormorants, mute swans, mallards, coots, and a pair of black storks.

Particularly sensitive are the heronry and a black stork nest at Ásványráró. The heronry has been estimated to have 100-120 nests regularly used by gray herons (Ardea cinerea) on a single island 1-2 ha in size. The island is vegetated with Populus canadensis and Salvix alba estimated to be 40-50 years old. Additionally, a tree was observed to have approximately 20 nests. One lake in this area is of particular importance as feeding habitat for adult and young herons, due to its high density of crustaceans. The lake has been connected to a side arm/oxbow by a shallow, narrow channel which allows it to be flooded occasionally. The location of the black stork nest is known only to local foresters.

This area currently has many side channels seasonally connected to and exchanging water with the main channel. These inlets would be diked off prior to project operation in order to confine water to the side channels. The oxbow system at Ásványráró would then receive flow from one upstream channel. The flow rate should be regulated during operations so that changes in water levels and water quality will not affect the heron feeding lake or nesting trees, otherwise changes could result in a long-term regionally significant impact on the species.

Additionally, it is recommended that the area near Ásványráró which is important to herons and other waterbirds be established as a permanent preserve protected from human activities. Human use (e.g., timber management, development, recreational facilities) should be avoided to prevent additional stresses on this biologically important area.

The potential for impacts on other wildlife (e.g., protected mammals) could not be assessed because no baseline mammal surveys have been conducted. A literature search on mammals (particularly protected species) should be conducted to identify possible occurrence in the Szigetköz area that may be affected by project operations. Based on the literature search, seasonal surveys should be implemented to characterize occurrence and habitat use over a 1-year period prior to project operations.

<u>Szigetköz-Gönyü - Fish</u>. This reach is recognized as important to the fish ecology and is known to support 55 fish species. Although no fish surveys were conducted for the project, generalizations can be made regarding the abundance and distribution of some species based on fisheries production and harvest data. The carp family (Cyprinidae) is dominant both in terms of species richness and abundance. Some species have been introduced into this reach by direct stocking (e.g., grass carp, silver carp) or by escaping from other stocked areas (e.g., eel).

<u>Significant Habitats</u>. The reach from Dunakiliti as far downstream as Komárom is particularly important due to its varied hydrological conditions, which support many different fish species and life stages. The availability of heterogeneous habitat in this reach of the Danube and its laterals is advantageous to the fish populations as it provides diverse conditions to support different species, spawning and rearing habitat, and abundant food organisms. This reach is a complex system consisting of three distinct, but interrelated, water bodies: the main channel of the Danube, the side channel/oxbow system, and the Mosoni Danube.

The main channel of the Danube includes a diversity of water and substrate conditions. This reach of the Danube includes rapidly moving water masses and other conditions important to some species (e.g., barbel, pike perch, asp) which live in the main channel. Many of these species inhabit the Danube throughout most of the year, migrating upstream 50-150 km in the spring to spawn in the side channels. Currently, there is little remaining natural spawning habitat in the main channel except for five locations in protected backwater channels behind islands.

The side channel/oxbow system in the Szigetköz also provides important habitat for fish species. Currently, these laterals are closed to the Danube at their upsteam ends, open to the main channel at their downstream end, and predominantly recharged by seasonal flooding over the dikes from the Danube. Some species inhabit the side channels, dead arms, and ponds year-round (e.g., tench and crucian carp). Other species, artifically populated through stocking efforts, are common in the side arms and uncommon in the main channel (e.g., grass carp, bighead carp).

A number of species migrate into the side channel system to spawn (e.g., white fish, sterlet) and then return to the main channel. The side arm system is extremely important habitat for spawning, due to the loss of most spawning habitat in the main channel; and supporting fry, which drift through the side channels feeding on abundant plankton for several weeks before being swept downstream and eventually into the main channel. Spawning in the side arm system supports fish stock that inhabit the main channel of the Danube below Komárom. Seasonal flooding of the side arm system includes considerable sedimentation which provides organics to support food organisms. Approximately 30 spawning locations are identified on a map of the Szigetköz side arm system.

The Mosoni Danube also provides important fish habitat. Masses of adult fish migrate upstream from the Danube into the Mosoni to spawning grounds. The water quality in the Mosoni varies considerably by area and over time depending on waste water loads discharged from Györ and other locations. Occasional fish kills have been observed in the Mosoni Danube.

General Trends. The fish fauna of the Danube River has been altered considerably over time due to several activities. The most significant changes were due to river control activities including diking, dredging, and channelizing - which eliminated natural habitat (including important spawning beds). The fish fauna also has been affected by stocking with artificially hatched fish including grass and bighead carp, sterlet, pike, eel, and pike perch to support commercial fishing and angling. Also, several species have been affected by deteriorated water quality and eutrophication resulting from waste water discharges into the Mosoni and the Danube. Other species have been overfished (e.g., sterlet).

Several trends are notable as indicative of the current condition of the fish stocks and their habitat in this reach. First, the annual total catch has decreased by 11 percent from 1968 to 1986 despite stocking efforts. The amount of fish in the Mosoni Danube has declined more significantly than the overall catch of the Szigetköz area. The proportion of carp, pike, and pike perch decreased over this time.

Second, several pollution-sensitive species (e.g., barbel, sturgeon, silure) which had been observed to have decreased in fish catches (believed to have been due to deteriorated water quality and/or pollution of bottom sediments), appear in recent years to be increasing in the area. The observed increase in numbers of non-stocked species is attributed to a recent trend toward improvement in water quality in the main channel of the Danube. Increasing numbers of other species (e.g., sterlet, carp) are due to stocking efforts in the area.

A third trend noted from fish catch data is the increasing proportion of young fish caught which, considered with the steady restocking rate, indicates that the natural proliferation rate is decreasing. As an example, the pike, which has a relatively low oxygen demand and high-vitality young which begin predator feeding early, is declining. This decline is believed attributable to a decreasing proliferation rate combined with intensive fishing.

Potential Impacts. Although the fish stocks of the Szigetköz region are generally known, no specific information on species' abundance, distribution, seasonal habitat use, spawning times, or spawning areas was available. Due to the lack of specific data, impacts on fish species cannot be accurately identified. The following discussion identifies potential impacts expected to occur, but cannot defensibly quantify the impacts or predict differential impacts by species. Seasonal fish surveys are strongly recommended to provide a preproject database. The database can be used to better assess the impacts expected to occur, develop appropriate mitigation and/or monitoring programs, and monitor impacts during project operations.

The fish surveys should be designed to identify all species present, their abundance, seasonal habitat use, migration patterns, spawning locations, and spawning schedule. The surveys should be conducted over a period of 1 year prior to project operation (i.e., diversion of the water from the main channel). These surveys should include standard sampling techniques (e.g., electroshocking, gill nets, and long lines) selected to characterize different species and life stages in appropriate locations in the main channel, the side arm system, and the Mosoni Danube.

A number of effects of the construction and operation of the project may impact fish in this reach, including fish stranding, DO effects, changes in species composition due to alteration of water flow, loss of fish spawning, and entrainment/turbine-induced mortality. Due to the lack of data on fish, only potential impacts can be identified at this time. Once baseline fish surveys are completed, these impacts should be reevaluated more accurately.

Due to the reduction of surface water flows in the main channel, some fish may be stranded in pools isolated from the channel by the drop in water levels. Mortality may result. This is expected to occur immediately after diversion of most of the flow from the main channel to the diversion canal. It may also occur occasionally following temporary discharge of high flood flows which are discharged to the main channel. Because fish populations are generally resilient to limited numbers of mortalities, this is not expected to result in a significant, long-term impact on fish species, and is not expected to warrant mitigation.

Alteration of water flows resulting from the use of reservoirs and diversion canals is expected to lead to changes in the species composition of the fish stocks. Species that inhabit rapidly flowing water (e.g., sturgeon, barbel, pike perch) are expected to decrease in numbers in this reach due to decreased flow rates resulting from the creation of the reservoir and the diversion of flow from the main channel of the Danube. This effect has been observed as a result of the hydroelectric plant at the Iron Gate where sturgeon moved upstream to areas with greater water velocities. Other species adapted to slow-moving waters or lake environments (e.g., Centrarchidae) are expected to increase in numbers. Baseline data on the fish species' distribution and abundance would enable a better assessment to be made of the expected changes. Some significant, long-term changes in species composition and numbers, however, are likely to occur in the Dunakiliti reservoir and in the main channel once the flow rate is reduced by nearly 95 percent of the flow. This impact could be reduced by increasing the rate of flow discharged to the main channel.

Another potential impact of the project is a reduction in DO concentrations, as explained in Section 2.1.10, and associated effects on fish. Low DO concentrations can affect fish adversely by decreasing their growth rate (and consequently their reproductive potential) which may occur at DO concentrations of approximately 6.5 mg/l; and by causing fish mortality, which may occur at 3-4 mg/I (but varies greatly by species).

Qualitatively predicting changes in DO concentrations is difficult due to the complexity of factors influencing such concentrations. Under natural conditions, DO in a waterbody comes from dissolution at the water/air interface and as a byproduct of photosynthetic activity by algae. Dams may aerate water. Oxygen in water is reduced by respiration of aquatic organisms or biological decomposition. Further complicating the predictability, DO concentrations are related to temperature.

The potential for DO reduction and effects on fish is known to be associated with changes that can result from creation of reservoirs. Once the Dunakiliti reservoir has been filled, residence time of the water is expected to increase from about 1 day to 2 to 3 days. This, in turn, is expected to result in increased sedimentation and an associated increase in light penetration into the reservoir. Increased light is expected to stimulate additional algal production in the reservoir. Bacterial decomposition will consume oxygen and result in lower DO concentrations.

Algal numbers in the Hungarian reach of the Danube are believed to be limited primarily by light which is related in part to seasonal changes. Under existing conditions, seasonal trends in algal production have been observed. Increases in algal densities correlate with periods when the Danube is characterized by low turbidity and high light conditions. Nutrient supply in the Rajka reach of the Danube does not limit algal production.

Based on a review of the nutrient supply in the Danube and observed baseline algal production, it is apparent that algal blooms may potentially result from the Dunakiliti reservoir. Since the early 1960s, a five- to tenfold increase in algal production has been documented in the Danube and attributed to increased water residence time, sedimentation, and light resulting from impoundments constructed during this period along the upper reaches of the Danube. Based on observed trends and data, it has been estimated that the Dunakiliti reservoir will at least double algal production in the Danube.

To date, however, DO concentrations at Rajka have been measured at 6.7 - 10.2 mg/l which does not indicate current oxygen deficiency effects on fish. It cannot be determined at this time how much increased algal production, bacterial decomposition, and oxygen consumption will result from the reservoir or whether these changes will produce adverse DO effects on fish.

DO Modeling Program. It is therefore recommended that the project conduct a DO modeling program prior to operation. This is a technique that has been applied to other river systems with proposed multiple barrages (e.g., the Ohio River). Modeling would enable better determination of the potential development of DO deficiencies, provide a realistic basis for any necessary mitigation, and could be developed into an operational monitoring program to avoid adverse DO effects on fish.

A DO modeling effort is based on measured concentrations of DO and temperature data collected above and below each barrage. The data are used to calculate the expected change in DO downstream. Such a model should be run for several conditions (e.g., low flows, moderate summer flow, and average flow). It is used to predict how much the DO concentration will decrease and over what distance the decrease will extend. Because the cumulative decreases in DO resulting from a multiple-barrage system can be greater than the decrease for either system operating independently, a cumulative, system-wide model should be run.

Once the model has been run, the projected DO concentrations can be compared to DO criteria developed to minimize or avoid impacts on fish. There are three methods which can be used. The first is to compare the DO concentrations to the water quality criterion of 6 mg/l which is used in the U.S. where rivers run through multiple states. This criterion, however, is not recommended for this project because more recently developed criteria are more useful.

The second method is to compare the DO concentrations to the EPA criteria which have been developed for various types of effects on different life stages. These criteria take into account complex interactions between fish size, temperature, and other water quality features. These criteria are as follows:

- Early life stages:

No production impairment	=	6.5 mg/l+
Slight production impairment	=	5.5 mg/l
Moderate production impairment	=	5.0 mg/l
Severe production impairment	=	4.5 mg/l
Limit to avoid acute mortality	=	4.0 mg/l

- Other life stages:

No production impairment	=	6.0 mg/l+
Slight production impairment	=	5.0 mg/l
Moderate production impairment	=	4.0 mg/l
Severe production impairment	=	3.5 mg/l
Limit to avoid acute mortality	=	3.0 mg/l

A third method which could be used is bioenergetics modeling, which develops quantitative estimates of production impairment over an annual growing season under different scenarios. These models consider the interaction of juvenile fish growth with oxygen concentration, temperature, fish size, and other water quality factors such as dissolved ammonia concentration. Bioenergetics models have attained widespread use in the U.S. for assessing potential impacts on fish.

Based on the results of the DO modeling program, a determination can be made regarding the potential for dissolved oxygen deficiency. If the modeling reveals a potential for adverse effects on fish, mitigation can be developed to operate the project while maintaining adequate DO concentrations.

Mitigation Measures - Oxygen. If deemed necessary, mitigation measures that could be considered include:

- Spilling flows
- Mechanical aeration techniques such as pumping air through nozzles into the turbine draft tubes or some type of diffuser in the tailrace

- Operating the Gabcikovo power station in continuous mode, or alternating between peak and continuous operation (to reduce algal production)
- Drawing down the reservoir during certain conditions (algal blooms)

DO deficiency associated with the Hrusov-Dunakiliti reservoir could affect not only fish in the reservoir but also fish in the Mosoni Danube, the side arm system, and the main channel of the Danube, all of which will receive flow from the reservoir. If DO levels in the reservoir are adequate to maintain fish production, no significant impacts would be expected on fish in these downstream systems. If a DO deficiency developed in the reservoir, however, it could adversely affect fish in the Mosoni, the side channels, and/or the main channel.

A definitive determination of the potential for DO deficiency could not be made based on available data. For example, the current DO levels in the side channels are not documented. During operation of the project, the DO concentration of the water in the side channel system may increase due to increased flow at the reservoir end. Alternatively, increased light conditions due to sedimentation in the reservoir could result in increased algal production and decreased DO concentrations in the side arm system. In addition, nutrient exchange, currently occurring from seasonal flooding over the dikes along the reach downstream of Dunakiliti to Ásványráró, will be altered (i.e., managed annual flooding will be discharged at one point, from the side wall of the ship lock at Dunakiliti). This in turn may affect algal production and decomposition rates and DO concentrations in the operational closed side arm system. The net effect of the changes in this system could not be predicted at this time.

Changes in water quality due to operation of the project also may affect fish in the Mosoni, side arm system, and the main channel. If no DO deficiency develops at the reservoir, water quality in the Mosoni may be expected to improve relative to fish needs, due to the increased rate of flow which will allow for increased dilution of waste waters. Temperature effects cannot be projected based on available information. As discussed previously, DO, temperature, and nutrients may change in the side arm system which may lead to changes in fish productivity, species composition, and distribution.

For example, pike perch are sensitive to DO concentrations, and additionally, pike perch populations are dependent on the fry (present in April and May) obtaining sufficient numbers of planktonic crustacean prey which in turn is related to inundation of the side arms. If fry of this species do not obtain this specialized prey, large numbers of mortalities occur. If this affected multiple-year classes of pike perch due to changes in the side arm habitat, it could result in a significant long-term impact on this species. These types of potential changes could not be addressed in the scope of this study.

Mitigation Measures - Spawning. Operation of the project as planned is expected to adversely affect the natural spawning of some fish species in the side arm system. The species that will be affected are those that live in the main channel as adults, but migrate into the side arms to spawn. As described previously, some species migrate 50-150 km upstream in the main channel and then into the side arms (which currently have their outlet ends open to the main channel). Once they have spawned, the adults return to the main channel while the fry drift in the side arm channels and feed for a period of time before joining the adults in the main channel.

During operation of the project, all of the remaining side arm outlets to the main channel will be diked. Additionally, a rockfilled drop structure will be installed near Ásványráró in order maintain the water level in the side channel system. Although this is advantageous from the standpoint of maintaining water in the side arms needed to support resident fish, riparian/wetland vegetation, and waterbird habitat, it will result in the permanent blockage of migratory fish access to spawning habitat in the side arm/oxbow system, which currently provides much of the remaining natural spawning habitat to support fish stocks in the Hungarian reach of the Danube. Natural stocks of some species are expected to be reduced over time with continued low recruitment. This loss of access to spawning habitat is expected to result in regionally significant, long-term impacts on some fish species (e.g., pike perch, sturgeon).

Other species which inhabit the side arm system year-round or those which are artificially stocked and raised in dead side arms or abandoned borrow pits will not be adversely affected in this manner. From a managed fisheries standpoint, this may not be considered adverse, because stocking efforts may be used to maintain fisheries production. From an ecological viewpoint, however, this is expected to be a significant adverse impact on the already reduced natural fish stocks of the Danube.

The most effective mitigation would be to maintain sufficient flow in the main channel, but this apparently is not compatible with operation of the Gabcikovo power station as planned. It is recommended, nonetheless, that an evaluation of alternative means of operating the Gabcikovo barrage/power station system (including seasonal changes) be conducted to assess the feasibility of maintaining the natural fish stocks which spawn in this area.

At a minimum, consideration should be given to a means of maintaining migratory fish access to the side arms during spawning times. Baseline surveys recommended previously should be conducted to identify the locations and timing of spawning in the side channel. Once this information is available it should be assessed to determine how spawning can be maintained.

One possibility is the installation of a gate (rather than the rockfilled drop structure) at the location near Ásványráró to hold water in the side arms, which could be opened to allow fish passage upstream into the side arms system during the spawning migrations. This could be disadvantageous to other aquatic-dependent biota (e.g., waterfowl, wetland vegetation), however, unless adequate water levels can be maintained during the period the gate was opened. This mitigation would allow some fish passage to spawning areas in the side arms.

<u>Mitigation Measures - Mortality</u>. Entrainment and turbine-induced mortality also will result from the project. Organisms that may be entrained include phytoplankton, zooplankton, fish eggs and larvae, and juveniles or smaller (< 5 cm) of certain fish species. Passing through the hydroelectric

turbines at Gabcikovo presents three potential means of injury or mortality to fish. First, fish or other organisms can be physically struck by the rotating turbine blades which can result in fish being cut apart or other severe trauma. Secondly, fish can be injured by rapid changes in water pressure (associated with the hydraulic system). Such pressure changes may result in rupture of their air bladders. The third type of injury may result from shear associated with differential water velocities occurring near solid walls or turbine blades. This tearing action can result in immediate death or delayed mortality. Damage from entrainment into turbines is generally more severe on larger fish.

Studies of turbine-induced mortalities have shown varied results. For example, large numbers of mortalities (American shad, striped bass) were recorded in the Bay of Fundy, while low numbers of mortalities of salmon were recorded in the Columbia and Merrimack Rivers.

Entrainment and mortality studies are complex and expensive. In lieu of performing mortality studies, some projects have quantified entrainment rates and developed appropriate compensation for assumed losses. Quantification of entrainment, however, also is difficult using current techniques. Netting is logistically problematic in turbine wells and discharges and acoustic sampling does not provide reliable species identification.

Alternatively, some projects install fish protection devices rather than performing difficult and expensive entrainment and mortality studies. This would be the preliminary recommendation for this project, but this recommendation should be reviewed in conjunction with turbine design once the one-year baseline studies have been completed establishing the species distribution, abundance, and migration patterns. Data could reveal that fish use of this upper reach does not warrant installation of a fish protection system.

Fish protection and guidance devices include lights, noise, electric fields, physical barriers, screens, and bar racks. Often a louver system or angled bar rack system is selected, consisting of a rack of vertical steel bars or louvers spaced 5-10 cm apart placed at the intake and angled to the direction of water flow and fish movement.

However, the appropriateness of such a system must be reviewed, taking into account the physical configuration of the barrage/powerhouse system and the river, and the fish species present. For example, considerations must include: whether the protection system is expected to be effective for the fish species; the physical potential for orienting such a system appropriately to the flow of water and fish relative to the location of the powerhouse; the size of fish to be protected and compatibility of appropriate bar spacing with the operating head of the facility; and potential incompatibility with ice floes and large debris.

An innovative fish protection device has recently been proposed for one project which consists of a 490 m long porous rock dike upstream of the powerhouse intake. Prototype evaluation studies were performed for such a structure in Massachusetts which concluded that it was nearly 100 percent effective for screening juvenile and adult fish, but resulted in the loss of zooplankton, fish eggs, and larvae presumably eaten by filter-feeders living in the dike. The structure also had a reduced volume of flow (although head was unaffected) due to clogging which had to be backflushed.

Barrage systems also present the potential for blocking fish passage of migratory species. The project has incorporated a fish lock into the Dunakiliti barrage system to accomodate fish passage. It is an automatic system operating on a 2-4 hour cycle. Fish are attracted to the entrance by means of flowing water (simulating the natural flow in the channel) and a light duct. After approximately 2 hours, the lower gate is closed, the upper gate is opened, and the sluice is filled from the headwaters during which time the fish migrate upstream and exit the fish lock. The fish lock design is based on a system currently in use in Austria which is demonstrating good results, and is reportedly preferred over a fish ladder. It is assumed that this system will mitigate impacts on migrating fish.

Gönyü-Nyergesújfalu - Vegetation. The vegetation along this reach was only generally characterized in the project's summary documents, and consequently the impact analysis is limited to general conclusions. Natural riparian vegetation along this reach of the Danube floodplain is generally poor and limited to a zone of willow-poplar fringe forest with willow shrub undergrowth. Oak-elm-ash fringe forest occurs along higher streambanks in areas around Gönyü, Ács, Komárom, and Nyergesújfalu. Large settlements and industrial areas have developed along the Danube, with a resultant reduction of fringe forest, and agricultural and silvicultural use have contributed to the degradation of the remaining stands of natural vegetation.

Areas of natural riparian and vegetation wetlands will be lost due to armoring streambanks with riprap to minimize bank erosion due to water level fluctuations. The acreage of natural vegetation to be lost (i.e., cleared and filled or excavated) due to dike reinforcement or strengthening, channels, or placement of riprap for slope stabilization could not be estimated because the fringe forest vegetation along this reach has not been inventoried. The river bank slope fluctuation will occur along dike exposed to daily water level fluctuations and will generally be protected from erosion through placement of riprap. It is expected that a significant portion of the existing fringe forest will be permanently lost to flood protection.

Due to the rise in water depth in the Danube (estimated at 2 m at Komárom and 3.5 m at Nyergesújfalu relative to mean water level) and daily fluctuations in water level, the ground water level will change in some areas adjacent to the Danube River. This will result in changes in vegetation. In low-lying areas, ground water levels will be maintained to approximate current conditions through the use of dikes, seepage interceptor channels, and pumping stations. Thus, the potential for effects on adjacent vegetation will be reduced to some extent. Areas of higher streambanks are expected to experience greater increases in ground water levels, and the composition of the vegetation in such streambank areas may tend to change toward more hydrophilic plant species and communities.

Effects on fringe forest and other riparian vegetation are expected to be long term or permanent. This reach appears to have proportionally less natural vegetation remaining along the Danube, due to more settlements and industrial development. A substantial portion (approximiately 300 ha) of the natural fringe forest along this reach is expected to be lost or altered. This is considered to be a significant impact.

The most effective mitigation for these impacts on vegetation would be to operate the Gabcikovo (Bös) power station in the continuous mode. This would eliminate the periodic increase in the water depth, the daily water level fluctuations and associated slope stabilization measures (i.e., riprap), and the resultant impacts on natural vegetation.

Alternatively, a revegetation program could be developed to replace the natural vegetation lost to project development. A revegetation program plan could be developed by a multidisciplinary team including project engineers and biological experts - such as the ELTE staff who are performing the biological monitoring and are familiar with the natural vegetation of the Danube floodplain. Such a program should consider slope stability, erosion control, appropriate vegetation, and visual considerations.

First, to maintain the structural integrity of the dike system, areas where it is undesirable to reestablish trees or understory vegetation, such as tops of dikes or steep banks, should be identified. For revegetation, consideration should be given to using native species of grasses or non-native species that provide both suitable erosion control (e.g., rapid establishment of adequate cover) and habitat value to wildlife. Using native grasses adapted to the local area and site-specific conditions is advantageous because native species will establish permanent cover that does not require periodic maintenance treatments (such as reseeding), and provide better wildlife habitat.

Reestablishment of native shrubs or forest to replace a portion of that lost to project development should be considered. Where possible, topsoil should be spread over fill material to provide a substrate conducive to supporting vegetation, and then the areas should be planted or seeded with native plant species. Several different revegetation treatments could be used for different conditions. For example, some riparian areas (with high soil moisture content), could be planted with shrubby vegetation (e.g., Salix purpurea). Other areas could be planted or seeded with tree species (e.g., Quercus robur, Q. pubescens, Acer campestre, Sambucus nigra), and possibly understory species (e.g., Cornus mas, Sanguinea ligustrum vulgare) as appropriate.

The biologists at ELTE have collected and developed information that would be very useful in designing a cost-effective revegetation program. Revegetation recommendations could be made based on established revegetation techniques, the experts' knowledge of the existing natural vegetation in currently undeveloped areas, species water requirements (based on Zolyomi's water requirement categories), and Simon's nature conservation ranking system. The development and implementation of a revegetation plan could mitigate a portion of the loss of natural vegetation that will result from the project.

Gönyü-Nyergesújfalu - Wildlife. The wildlife inhabiting this reach, including protected birds or mammals, was not characterized prior to project development. Consequently, impacts cannot be accurately assessed. Generally, construction impacts would include temporary noise disturbance, mortalities, injuries to individuals, and displacement resulting from loss of habitat due to dike and seepage interceptor channel construction and riprap placement (as described previously). The fringe forest along this reach does not support the diversity or abundance of bird species found in the Szigetköz.

Impacts could be mitigated by replacing habitat lost to flood protection and riverbank stabilization through the development and implementation of a revegetation program (as previously described).

Gönyü-Nyergesújfalu - Fish. The only potential impact on fish identified for this reach would be effects of DO deficiency on fish in the main channel should this condition develop in the Hrusov-Dunakiliti reservoir (as described previously). Mitigation would be the same as that described for the previous reach (i.e., system-wide DO modeling and mitigation as required). Impacts on migratory fish inhabiting this reach, but spawning in the Szigetköz side arm system, were discussed previously.

Nyergesújfalu-Nagymaros - Vegetation. Generally, impacts on natural fringe forest along this reach of the Danube would be similar to those described for the previous reach. This area, however, appears to have more natural vegetation left undisturbed along the Danube (i.e., less industrial development and fewer settlements).

Much of the reach from Nyergesújfalu to Esztergom is bordered by low stream banks. Consequently, much of the remaining fringe forest is expected to be lost to dikes constructed for flood protection. From Esztergom to Nagymaros, much of the reach is bordered by high stream banks, which will require less clearing and diking. These areas, however, may experience an increase in the ground water table associated with the rise in mean water level from elevation 102 to approximately 108 m/asl once the Nagymaros barrage system is operational.

As a result of construction and operation of the project, some stream bank vegetation will be inundated, some will be lost to slope protection (e.g., armoring with riprap), some will be lost to fill in the vicinity of project structures, and some will change toward more hydrophilic associations. The acreage of natural vegetation to be affected by the project could not be estimated.

Overall, loss of and changes to the natural vegetation along the Nyergesújfalu to Nagymaros reach are expected to affect a substantial portion of the remaining fringe forest and other riparian vegetation. Such changes are expected to be permanent. This is considered to be a long-term significant impact.

The project has identified a potential technique proposed to reduce loss of the fringe forest in some areas between Nagymaros and Dömös where fill will be required to raise the streambank. In areas along the river where 1-3 m depth of fill is needed, the project plans to spread the fill material throughout existing fringe forest rather than first cutting and clearing such areas. Filling and grading would be conducted in phases (i.e., fill would be placed in the same area at two different times), in an attempt to avoid killing the trees.

This method was used by the project on the island of Bergman Sziget near Nagymaros, where the local residents were concerned over the potential loss of a 40-50 year old stand of poplar (Populus canadensis) trees. On this island, a total depth of 1-1/2 m of sandy/gravel fill material was applied in two phases, in an attempt to reduce the impact of resultant changes in ground water levels on the poplars.

The effectiveness of this technique over time is currently being studied, and to date shows variable results. The trees have died in some areas, but not in others. It was suggested that this technique could be improved by placing an apron of rocks 4-5 m high around the trees as a sort of filter.

This mitigation is not believed to be an effective and cost-efficient mitigation in the long term. A phased approach to filling and grading will be costly because it requires mobilization of construction crews and activities at two different times. Use of the proposed rock aprons placed around individual trees would be very labor intensive, time consuming, and costly. Furthermore, the proposed phased filling method is unproven and not considered likely to be very successful for maintaining the fringe forest over time.

A more effective mitigation measure would be the development and implementation of a revegetation program along the Danube as described earlier. This program could apply several different treatments designed to facilitate reestablishment of natural vegetation and would be a more effective means of maintaining riparian vegetation in the project area.

Nyergesújfalu-Nagymaros - Wildlife. Project-related impacts on wildlife along the Nyergesújfalu-Nagymaros reach cannot be accurately assessed because no baseline surveys were conducted to characterize species' occurrence and habitat use. Similarly to the previous discussion of the upstream reach, construction activities related to flood protection and bank stabilization are expected to result in temporary noise disturbance, mortality and injury of individuals, and wildlife displacement due to loss of habitat. Impacts resulting from habitat losses could be mitigated to some extent by a revegetation program as described previously.

The Nature Conservation District of Börzsöny (bordering on the left bank of the Danube Bend from Zebegeny to Nagymaros) is known to support protected birds, reptiles, and amphibians. A number of endangered birds of prey may be found including the imperial eagle (Aquila heliaca), the lesser spotted eagle (Aquila pomarina), the saker falcon (Falco cherrug), the short-toed eagle (Circaetus gallicus), the red kite (Milvus milvus), and the black kite (Milvus migrans), and rare species may also be present including the eagle owl (Bubo bubo) and black stork (Ciconia nigra). Several protected mammals also inhabit the closed forests of this conservation area: (Martes martes), (Martes foina), (Mustela erminea) and (Mustela nivalis).

No specific information could be obtained on the occurrence of these species in the vicinity of ongoing project-related construction activities near Nagymaros. Discussion with biologists at ELTE and others suggest that these species tend to occur toward the interior of the area, away from affected riparian areas. Whether any avian nesting trees would be affected along this reach of the Danube could not be determined. The project has reduced impacts on raptors and migrating waterfowl from transmission lines (i.e., electrocution, collision injury) by using underground cable mains.

Nyergesújfalu-Nagymaros - Fish. A potential impact on fish identified for this reach would be DO deficiency effects should this condition develop in the Hrusov-Dunakiliti reservoir (as described previously). Mitigation would be the same as that described for the previous reach (i.e., system-wide DO modeling and mitigation as required). Fish entrainment and turbine-induced mortalities similar to those described for the Gabcikovo power station are expected to occur at the Nagymaros power station. Baseline survey recommendations and mitigation developed were described under the Szigetköz-Gönyü reach. Potential disruption of fish migration due to the barrage has been mitigated by the use of a fish lock as described for the Gabcikovo barrage/power station. (Impacts on migratory fish inhabitating this reach, but spawning in the Szigetköz side arm system were discussed under the Szigetköz-Gönyü reach.)

Nagymaros-Budapest - Vegetation. Natural vegetation along the reach from Nagymaros to Budapest, downstream of the project facilities associated with the Nagymaros barrage system, is not expected to be affected by the project. Because the system will be operated in the continuous, run-of-the-river mode, no changes in water levels and associated bank or flood protection measures are planned. Consequently, no vegetation will be cleared.

Nagymaros-Budapest - Wildlife. No baseline surveys were conducted to characterize wildlife use of this reach. Limited data on birds observed at Szentendre Island (biological monitoring station) were available. Because the Nagymaros barrage is a run-of-the-river system, it will not significantly alter the downstream flow of the Danube or the recharge of Szentendre Island. No significant impacts on wildlife are expected.

Nagymaros-Budapest - Fish. The only impact on fish identified for this reach is potential for DO deficiency effects downstream of the Nagymaros barrage and power station. Reduction in DO concentration below this power station would be cumulative from the two barrage systems. Mitigation for such impacts could be developed (as described for the Szigetköz-Dunakiliti reach) if warranted by the system-wide DO modeling effort. (Impacts on migratory fish species inhabitating this reach as adults, but spawning in the Szigetköz side arm/oxbow system were discussed in the section on the Szigetköz-Gönyü reach.)

2.3 LAND USE

2.3.1 Description of Significance Criteria

Identification of land use impacts related to the project is based upon significance criteria, which determines the importance of a land use change, either beneficial or adverse. Assessment of impacts on land use considers the effects of the project on existing and proposed agricultural, industrial, sylvicultural, residential, and special land uses. Recreation impacts and fishery impacts are discussed in Sections 2.6 and 2.2, respectively. In addition to land use changes brought about by the project, impacts created by induced population growth and future development should also be considered.

Significant impacts to land use include conflicts with adopted environmental plans and goals of affected communities, substantial increases in population concentration, disruption or diversion of an established community, loss of agricultural land, or reduced productivity. Criteria used to determine significance of impacts include loss or gain in agricultural production caused by the project, including construction activities, access to markets, and traffic. Impacts to agricultural land uses should be assessed by identifying the areal extent in hectares that would be affected, crops affected, and value of resource lost or gained. The greater the value of the resource loss or gain, the more significant the impact. Any long-term loss of high-value agricultural land is a significant impact.

Significance of impacts on industrial enterprises would include considerations of whether the project would interfere with or displace industrial operations, or interfere with access to industrial facilities. The extent of the disruption would reflect the level of significance of the impact.

Impacts to residential land use are significant if new land use is incompatible with proposed development and existing residential land use. Improvements for residential land uses, such as increased access, or improved water supply or sewage disposal, would constitute a beneficial impact, but it could also result in adverse impacts if it induces population growth. The significance of impacts on residences is gauged according to the number of residential properties affected, and the number of project-related conflicts and incompatibilities with affected settlement patterns.

Special land use conflicts resulting from the project, (e.g., encroachments on nature conservation areas), and the significance of the conflicts is a function of the extent of the area affected, and the regulatory protection afforded the special use. Impacts on special land use are significant if the special land use area is decreased or objectives of the special land use area cannot be met as a result of the project. Beneficial impacts would be realized if special land use areas were increased or objectives exceeded.

Growth-inducing impacts associated with the project reflect the ability of a community to absorb effects such as increased traffic or potential conflicts with local policies designed to achieve physical, social, and economic goals.

An impact is considered significant if it causes a change in existing land use patterns, and/or growth or development trends. The change must be an identifiable trend. Land use trends may be affected either directly or indirectly by construction or project operations. For example, constructing new infrastructure to support project activities, such as sewage treatment facilities and roadways, can also enable new industrial, commercial, and residential land uses to develop that could conflict with existing land uses. An impact may be significant if it affects other existing or proposed land uses or conflicts with land use plans and policies. For example, a reduction in agricultural land use may affect agriculture-related industrial or residential patterns.

2.3.2 Discussion of Impacts

The principal land use in the Szigetköz area (composed of 40,100 ha) of the project area, between the Mosoni Danube and main arm of the Danube from Rajka to Gönyü, is agricultural and forestry (84 percent of land use). Below Gönyü to Visegrád and Nagymaros, agricultural, recreational, residential, and industrial land uses are intermixed near settlements such as Komárom and Süttö.

Without mitigation measures, potential impacts associated with the project in the Szigetköz area would have included reduced productivity of crops and forests due to changes in ground water levels. However, this potential impact will be mitigated by the implementation of the artificial recharge system.

The recharge system is designed to maintain existing ground water levels and flooding regimes in the side channels during operation of the project. Plans call for the system to be augmented by a monitoring program to determine changes needed during operations to maintain ground water levels. Without the artificial recharge system, timber productivity would be reduced by one-third, and one-fourth of the current value would be lost.

With the artificial recharge system in place, approximately 300 of 7,803 ha of forest land will be adversely affected by changes in the ground water levels along a 250-300 m strip adjacent to the Danube River. This area represents approximately 3 percent of total forest area. Mitigation to reduce this impact focuses on substituting more xeric tree species for more water intensive poplars. Shift to the more xeric species would constitute a loss in timber value of approximately one-third of present production, along this stretch of the Danube. This future loss in timber value was compensated. No significant impact on forest production is anticipated.

The transportation costs of timber harvested in the Szigetköz area would increase due to the diking of the side arms of the Danube. Harvested timber is currently transported by barge along those side arms. The dikes which are part of the artificial recharge system will make barge traffic impossible and alternate means of transportation are necessary. Compensation has been made through funding for new road construction, to provide alternate transportation means. While this will likely increase transportation costs, the increase cannot be quantified.

Approximately 1,100 ha of forest stands in the Dunakiliti reservoir area have been cleared. While the area was previously forest intermixed with meadow/pasture, no net loss in production has occurred since the Rajka farm cooperative was compensated for the loss with other land.

Implementation of the planned artificial recharge system integrating agricultural and forestry concerns will also produce several beneficial impacts. Agricultural and forestry losses due to floods will be reduced (not yet quantified). With more controlled ground water levels, hectares of arable land can be increased by reducing areas subject to waterlogging, especially in the northern part of the Szigetköz, Szöny-Komárom, and Feketeerdö at Almaspuszta, and in the vicinity of Szentlélek and Kenyérmezo Creeks. Gross revenues anticipated from increasing arable land are estimated at about 9.1×10^6 Ft/ha/yr. Controlled water sources for irrigation and crop selection/rotation will reduce the uncertainties and risk of agriculture production dependent on water availability, since the amount of water available for irrigation would be known. This benefit has been estimated at an additional gross income of 104.0×10^6 m^3/year.

Agricultural activities downstream of Gönyü include approximately 25,249 ha or 69 percent of the 41,440 ha Komárom County area. Agricultural production on 677 ha will be lost due to the project (approximately 14.76×10^3 Ft/ha or 9.99×10^6 Ft). This loss in agricultural production is less 2 percent of total production for the county. Changes in production value on 659 ha are also projected at 1.132×10^6 Ft/ha. Compensation for these losses has been made and no significant impact on agricultural production is anticipated.

Project plans call for certain improvements to be made near settlements (i.e., sewage and waterworks system) and new roadways to be built from Györ to Nagymaros to replace theose affected by reservoir and protective dike construction. This new infrastructure could promote growth in areas where present growth is restricted due to limited sewage, water supply, or road capacity. Anticipated growth is discussed in Section 2.6. Losses of 100 residences and 20 public buildings have been compensated through the court system. Given these compensations, no significant impact is anticipated on land use.

2.4 ARCHAEOLOGY AND HISTORIC MONUMENTS

2.4.1 Description of Significance Criteria

Methods for identifying impacts to archaeological and historical resources are based on criteria used in determining the significance and importance of the resources and impacts on the resources.

In general, an archaeological or historical artifact, object, or site should be evaluated on the basis of its integrity and quality, research potential, ethnic and historical value, and potential for public appreciation. For purposes of this evaluation, the determination of significant project-related impacts is based on the following criteria:

- Significant impacts are those that result in the loss or overall reduction in the integrity or research potential of important archaeological or historical resources
- Beneficial impacts are those which would improve conditions relative to preproject conditions. With regard to archaeological and historical monuments, this would apply to project-related effects which could improve future accessibility to sites (for scientific research and public observation), or which would improve or enhance the quality of the archaeological or historical monument

The archaeological and monument values in the project area have been described in the informatory document prepared for the GNB project. Bechtel has not questioned or disputed the technical expertise and judgments regarding the value of the archaeological and monument assets evaluated in this document.

If previously unknown archaeological and historical monument sites should be uncovered during project construction, construction must be halted and a qualified archaeologist consulted to determine the significance of the site and the need to excavate. This general rule is designed to minimize adverse impacts. Construction workers will not be allowed to collect or damage any archaeological resource.

2.4.2 Discussion of Impacts

Szigetköz-Gönyü. Both construction and operation impacts could potentially occur within this segment of the project area. Construction impacts resulting from proposed bed cuts for the recharge system and the water outlet canals could potentially affect currently unknown archaeological relics in the areas of Darnözseli, Püski, and Dunaremete. The significance of any potential impact would be based on the presence of archaeological resources, the importance of these resources, and the overall damage to these resources resulting from construction activities. The bed dredging of the old Danube River channel could also potentially impact currently unknown archaeological resources in the Kisbajcs, Nagybajcs, and Vének areas.

Construction of the originally proposed flood protection system in Györ could have impacted a IX-Xth-century settlement containing the first semifinished raw iron rod find in Hungary (site no. 24.1.11). The water engineering director of Northern Transdanubia, in agreement with the museum, modified the design of the proposed system to protect two-thirds of the archaeological site. This will reduce the overall impact to this site.

During the bed regulation and the resulting drop in surface water level of the old Danube, ethnographically significant relics may come to the surface in the Lipót and Ásványráró areas. This will be a beneficial impact, if archaeological relics are present within areas of the riverbed.

Gönyü-Nyergesújfalu. Future construction activities along this stretch of the Danube could potentially impact archaeological sites. Construction impacts generally result from earthmoving activities (such as blasting, cutting, grading, and earthfilling) and from heavy construction equipment, such as bulldozers, which can easily crush archaeological artifacts.

Construction activities near the mouth of the Bakony could impact Roman Age relics which have not been excavated (site no. 25.2.3). In the vicinity of Szöny, construction of the proposed sewage treatment facility and disposal canal could potentially affect three archaeological sites. These include site no. 29.1.1, where clay pits and waste pits belonging to a potters' settlement were found; site no. 29.1.2, Roman fortress foundations; and site no. 29.1.3, a Roman settlement (Canabae, Castrum, municipium). The significance of this potential impact would be determined by the overall damage to currently unexcavated archaeological resources resulting from construction activities. In the Almásneszmély area a number of archaeological relics have been discovered. However, a relatively small percentage of the area has been surveyed. It is anticipated that during construction a number of additional relics could be encountered and potentially damaged by earth recovery and the creation of a new bed in the Altalér. Archaeological sites (sites no. 31.1.1-6) on the Danube bank of Lábatlan could also potentially be damaged during construction of the embankment.

On the bank of the Altalér there is a Turkish watermill which would have been destroyed during construction of the barrage project (site no. 30.2.3). By modifying the flood protection dike, this irreplaceable XVIIth-century monument will be preserved. This can be considered a benefit of the project.

Project operations could also impact archaeological resources along this stretch of the Danube. A cemetery on the Lovad meadow could be affected due to its location on lowlands along the Danube. A section of the Roman road in Komárom running along the bank of the Danube, and the foundations of a Roman watchtower (site no. 26.1.1.) could be inundated.

Project operations would produce a beneficial impact on the Csillag fortress in Komárom. The seepage system has been designated so that there would be water in the presently dry moat. This would enhance the aesthetic quality of the fortress.

Nyergesújfalu-Nagymaros. This stretch of the Danube has the greatest concentration of archaeological and monument resources. A number of sites have been successfully excavated due to project funding (a project benefit). Mitigation measures have been developed in conjunction with the Monument Plan Council of the National Committee for Technical Development to protect some of the most significant resources. In spite of this effort, impacts to archaeological and monument assets could potentially occur in this area.

Construction impacts, resulting from earthmoving activities and the use of heavy construction equipment, could impact a number of archaeological sites. Additionally, construction of protection levels and embankments would bury a number of Roman watchtower foundations, eliminating future access for scientific research or public observation. Table 2-1 lists potential archaeological sites which could be damaged.

The original project design would have resulted in significant adverse impacts to the very important monasteries of Szentkirály (site no. 35.1.5) and Sziget (site no. 35.1.7), and the wall of Vizivåros (site no. 35.1.11). Following coordination with project engineers, these three sites will be protected and the possibility of future display ensured. Construction of the originally proposed project would also have damaged site no. 36.1.2, the remains of a Roman stone fortress of 30-38 m in size. As a mitigation measure, this site will be rescued and future display made possible by the redesign of the project.

Agreement was reached with archaeologists as to which archaeological sites were to be preserved by modification of project design. The significance of impacts to those archaeological resources not preserved cannot be made by Bechtel.

A construction plan was also developed with the archaeologists to mitigate impacts to specific archaeological sites. To further mitigate potential impacts, the construction plan should be expanded to include sites listed on Table 2-1. The plan should clearly identify sites which are considered to be of outstanding significance and therefore warrant further excavation. Excavation should be completed prior to construction.

Table 2-1

ARCHAEOLOGICAL RESOURCES AFFECTED BY CONSTRUCTION ACTIVITIES

Site No.	Area	Description
35.1.16	Esztergom	Roman watchtower foundations (half soured by Danube) would be buried by slope protection eliminating the possibility of future display or research.
35.1.18	Esztergom	Roman watchtower foundations would be buried in the embankment eliminating the possibility of future display or research.
35.1.21	Esztergom	Roman watchtower foundations would be buried in the embankment eliminating the possibility of future display or research.
36.1.1	Pilismarót	Roman watchtower foundations. Would be buried in the embankment or inundated.
36.1.3	Pilismarót	Roman watchtower foundations. Would be buried in the embankment or inundated.
36.1.4	Pilismarót	Roman watchtower foundations. Would be buried in the embankment or inundated.
36.1.5	Pilismarót	Settlements of the Neolithic, Iron, Celtic, and Roman Ages, prehistoric and medieval graves. About 30 percent of the site has been excavated. Site would be dredged during construction activities.
36.1.6	Pilismarót	Roman watchtower foundations. Would be buried in the embankment or inundated.
36.1.7	Pilismarót	Roman watchtower foundations. Would be buried in the embankment or inundated.
36.1.10	Pilismarót	Settlements of the Neolithic, Bronze, Iron, Celtic, and Roman Ages. No excavation has been done. Site would be buried during construction activities.
36.1.11	Pilismarót	Traces of a Bronze Age settlement. Not uncovered yet. Site would be buried.
36.1.13	Pilismarót	Remains of settlements of the Bronze and Late Bronze Age. Not excavated. Site would be dredged during construction activities.

Table 2-1 (Cont'd)

Site No.	Area	Description
37.1.1	Dömös	Roman watchtower foundations would be buried during construction of the dike.
37.1.2	Dömös	Roman watchtower foundations and settlement of the Bronze Age, would be under fill.
37.1.3	Dömös	Roman watchtower foundations would be buried.
37.1.5	Dömös	Construction of a new roadway would traverse a settlement and cemetery of Arpadian Age. Northern portion of this site would be dredged or inundated. The greatest part of the site has not been excavated.
37.1.6	Dömös	Traces of prehistoric and medieval settlements not yet excavated. Site would be traversed by the new roadway, and the northern portion would be dredged or inundated.
40.1.1	Zebegény	Prehistoric pottery has been found at this site. Future road construction would make future excavation difficult.
40.1.2	Zebegény	Sporadic Scythian arrow heads found at this site. Future road construction would make future excavation difficult.
40.1.3	Zebegény	A site approximately 500 x 50 m in size immediately on the Danube bank where settlement traces of the Copper, Bronze, Celtic, Quad, and late Avar Ages are present. Bank regulation and construction of the roadway would make future excavation difficult.
41.1.3	Szob	On the Danube bank there is a site of outstanding significance with the remains of a settlement of the Copper, early Iron, Celtic, and late Avar Ages which would be difficult to excavate due to embankment fill. Small amount of excavation has been done.
41.1.4	Szob	Relics of the medieval village. Very small amount of excavation has been done. Would be difficult to excavate due to embankment fill.

Table 2-1 (Cont'd)

Site No.	Area	Description
41.1.6	Szob	Another site of outstanding significance approximately 550 x 200 m in size with finds of Neolithic, Copper, Bronze, early Iron Ages, Quad, and Arpadian settlements presently under railroad tracks, additional riprap would be placed on riverside slope of railroad track.
42.1.1	Ipolydamásd	Prehistoric settlement of 100 x 50 m could be damaged during construction of the roadway.
42.1.3	Ipolydamásd	A site with a few pieces of prehistoric pottery would be, or has been, partially or totally destroyed by construction of the road.
43.1.1	Letkés	A site of outstanding significance (800 x 100 m) with a settlement of the Neolithic, Copper, Celtic, Quad, late Avar, and Arpadian Ages and a cemetery of the early migration period. About 5 percent of the site has been excavated. Construction of the dike did damage to the site.
43.1.2	Letkés	One of the most important sites along the Ipoly. About 50-60 percent excavation has been completed on a 150 x 100 m site with graves of the late Bronze Age. Dike construction did damage to this site.
43.1.3	Letkés	The village of Davidrév of the XIV-XVth centuries. Was impacted by dike construction.
43.1.4	Letkés	On the site of 700 x 100 m there were settlements of the Copper, late Bronze, Celtic, and early Arpadian Ages. Was damaged by dike construction.

A qualified archaeologist should be present during construction activities that could potentially affect archaeological sites. Construction activities should be scheduled well in advance, both with the museum and with archaeologists, to ensure that there is sufficient time to make appropriate arrangements. This would help ensure that special construction methods are followed, and it would reduce the likelihood of false accusations about impacts resulting from construction.

Project operations could also result in significant adverse impacts to archaeological and monument sites in this area. Helemba sziget will be inundated (site no. 35.1.29). On this site, there are remnants of settlements of the Neolithic, Bronze, and Celtic Ages (pits in the earth, houses, furnaces, etc.), remnants of an Arpadian Age Church and the graves of its cemetery, as well as the walls of the archiepiscopal holiday palace. Only 10 percent of the settlement and medieval cemetery have been excavated. To mitigate this impact, the entire site should be excavated and significant artifacts and relics removed to the museum. A small fortress in Visegrád built in the IVth century (site no. 38.1.1) is of outstanding significance for its archaeological and monument value. It has been excavated and further project plans have been prepared for its protection. Watchtower foundations of the Roman Age (41.1.1) would be inundated; however, they are currently being excavated which will mitigate this impact. A settlement of the Copper and Celtic Ages would also be inundated during project operations (site no. 41.1.2).

One monument (no. 37.2.5) would be inundated. The monument is the boat station at Dömös, built in 1910. This cast concrete station building is characteristic of the first decades of the century and is the only remaining example of station-building in the Hungarian section of the Danube. Project plans have been prepared for its protection.

Changes in the ground water level could also potentially affect the accessibility of archaeological artifacts in the Esztergom Royal Town area (site no. 35.1.10). This area has settlements from the Copper, Bronze, Celtic, and Roman Ages, and has been a flourishing settlement from the time of the Hungarian conquest. This is a historical-archaeological monument of outstanding significance. The relics of early Hungarian town history can be found here, in some places at a depth of 4-5 m beneath the surface (102 m above sea level). The ground water level in the area will be controlled by the Kis-Duna pumping station facilities at the mean ground water level of 103.5 m/asl. Occasionally, the ground water could possibly rise to 104.8 m/asl during flood conditions.

Controlling the ground water level at 103.5 m/asl will reduce the accessibility of deep-lying resources in this area, but it will also improve the accessibility of those resources buried above the mean ground water level. Currently, access to these artifacts is limited due to extensive surface development (buildings, roads, etc.).

Accessibility to these areas in the future could be ensured by construction of a local dewatering system. The system could be operated during those times in the future when archaeologists require access to these resources. Because of the limited surface access to these sites and the uncertainty of future excavation, it is not recommended that funding for a dewatering system be included as part of the project. Future funding of excavation activities should include dewatering system.

During project operations, this area as well as the new town centre area should be monitored to ensure that the ground water level does not rise above the mean ground water level (except for short durations during flood conditions). If monitoring indicates that the ground water level is increasing, then increased pumping along the seepage canal or Kis-Duna should be implemented by the project.

Because the GNB project may involve river dredging, additional archaeological relics (artifacts, arms, ship remains, ornamental pieces, etc.) may be recovered. All archaeological relics found should be collected and delivered to an appropriate museum.

Nagymaros-Budapest. No additional impacts are anticipated.

2.5 VISUAL RESOURCES

Visual resources are the physical characteristics of a landscape that determine its scenic quality and relevant value to the viewing public. These characteristics are both natural and manmade features that make up a specific landscape scene. Natural features include water, landform, vegetation, and soils. Manmade features include physical structures, roads, and so on. Since scenic quality is a measure of human sensory experience, the visual resources most important are those within the "seen area" of areas accessible to people (road and railways, waterways, trails, recreation sites, residential areas, etc.).

2.5.1 Description of Significance Criteria

Visual impacts are determined by simultaneous consideration of four aesthetic factors. The four factors are defined as follows:

- Scenic Quality: Scenic quality is directly related to the distinguishable features in the landscape, such as vegetation, water, landform, and soil; human modification (e.g., buildings, fences, roads, etc.); and their contribution to the line, form, color, and texture of the landscape composition. A key determinant of high scenic quality is the visual dominance of some element (form, line, color, texture) of at least one landscape feature (land or water surface, vegetation, physical structure) that makes that particular landscape stand out among surrounding landscape.

- Landscape Condition: The landscape condition addresses the degree to which the landscape has been altered from its natural state and the inherent capacity of the landscape to absorb visual changes resulting from the project.

- Predicted Visibility: The predicted visibility addresses the degree of visibility that project facilities would have in the landscape. This is based on the position of facilities relative to significant topographical or physiographic features, as viewed from those areas where the proposed facilities could be seen by an observer standing at ground level.

- Potential Population Exposure: Potential population exposure takes into account the number of people and the locations from which people could potentially view proposed facilities. Three aspects of public visual exposure are incorporated into this factor: 1) the distance between the landscape being observed and the viewing point, with specific reference to the amount of scenic detail that is apparent from these points; 2) the relative value the public places on maintaining the existing landscape characteristics; and 3) the visual dominance of the facility from key viewing locations such as roadways, recreation areas, and residential areas.

The factors above are analyzed and synthesized in an overall evaluation of landscape visual sensitivity to a proposed project. The determination of "significance" is based on:

- o The extent to which the potential facilities would alter, or contrast with, the existing dominant landscape features (landform, vegetation, water, and structures), and visual elements (color, form, line, and texture)
- o How sensitive these changes could be to the viewing public

An impact is normally considered significant if the project component contrasts with an existing landscape of high scenic quality, the existing landscape is unable to absorb the resulting visual changes, and the project feature is perceived by the public as obtrusive. Visual impacts are considered insignificant if they do not change the overall visual condition of an area; they temporarily change the visual condition of an area for 2 years or less; (e.g., revegetation would take place); and they change the visual condition of an area of low or medium scenic quality with low population exposure. Visual impacts are considered beneficial if they improve the visual condition of the landscape. For example, returning previously disturbed landscapes to a more natural condition.

2.5.2 Discussion of Impacts

Where possible the landscape features for the project area were evaluated according to the four factors that affect visual sensitivity: scenic quality, landscape condition, predicted visibility, and potential population exposure. It should be noted that most of the project area was not seen by the Bechtel team, and that visual characterizations are based primarily on available data sources.

Szigetköz-Gönyü. The Szigetköz region is visually characterized by its lowland floodplain terrain, with dense forest vegetation along the Danube and its side arms in the floodbed area, and agricultural fields and small settlements between the Danube and its floodbed and the Mosoni Danube. The natural beauty of the smooth backwater and floodplain forest coupled with the numerous waterways (Danube River, the side arms and backwaters, and the Mosoni Danube), and the regions generally undisturbed nature contribute to the area's high scenic quality. The most dominant feature in this landscape is the Danube and it's side arms. Overall, the landscape condition of the area has not been drastically altered from its natural state of appearance, with the exception of the introduction of poplars in the floodbed and agricultural fields.

Operation of the project would result in a significant drop in the water level in the old Danube River channel, from the reservoir to approximately Dunaremete. The drop in the river would significantly alter the appearance of the existing river bed channel from one which alternates from being covered with water during high flow exposing dry riverbanks during low flows; to one of a dry "empty" riverbed with a much smaller water surface. Perhaps the most significant visual change would not come from the dry "empty" riverbed, but instead from the modifications to the riverbank vegetation. The river would no longer provide the necessary ground water to support the riverbank forests and vegetation. Consequently, the forests and natural riverbank vegetation along the existing floodbed would die or be harvested (refer to Section 2.2 for a complete description). However, eventually new riverbank vegetation will re-establish along the new riverbank over a period of several years.

The Danube banks are currently in a somewhat natural state with only slight modifications in a few areas. The lower portions of the Danube bank (below Nagybajcs) would be modified with protective embankments which would change the visual appearance of the Danube. Other project induced visual changes would result from the Hrusov-Dunakiliti reservoir and structures. The structure of the weir from the old Danube will be very visible and intrusive. After a few years, the reservoir itself would be a water surface which would eventually look natural for the area.

These changes would only be visible in the immediate Danube riverbank. Beyond the immediate riverbank, forested areas along the side arms and the topographic terrain (lower elevation of the riverbed) would reduce the degree of visibility considerably. Consequently, most of these visual impacts would be absorbed by the landscape condition within 0.5 m from the Danube.

The potential population exposure to these changes is relatively low. The old Danube is currently visible from the existing riverbank and a few Szigetköz embankments, and from the settlements of Nagybajcs and Vének. The old Danube is not visible from roads, railways, or lookouts. This area is used for recreation to some degree, and visual changes would consequently be visible to people using it for this purpose. Overall, the population exposed would be limited, except for the settlements of Nagybajcs and Vének.

The drop in the flow of the old Danube and the presence of the Dunakiliti weir would substantially alter the natural condition of the riverbank, degrading the scenic quality of the area. However, due to low population exposure and the ability of adjacent landscapes to limit views of the changes, these impacts are considered to be insignificant. However, it should be noted that revegetation of the old Danube would preserve its natural appearance.

The construction of protective embankments would also alter the natural appearance of the old Danube riverbanks. This could significantly impact the scenic quality in the area of Nagybajcs to Vének. To mitigate this impact the embankment slopes will be covered with grass, or lawn. Natural vegetation should be planted at the foot of the land side of the embankment (refer to Section 2.2 for recommended vegetation). This would reduce this impact to an insignificant level.

Gönyü-Nyergesújfalu. The Danube River section between Gönyü and Nyergesújfalu is primarily of lowland terrain becoming more mountainous towards Nyergesújfalu. The Danube River is the dominant visual feature. The Danube riverbank between Gönyü and Komárom is high. Agricultural and forestry activities cover a significant area, recreational activities occur at Koppanymonostor, and Ács woods is an environmental protection area. The natural riverbank along this stretch has been slightly modified in certain areas and scenic quality is considered to be high. Between Komárom and Nyergesújfalu the Danube riverbank is flat. This section of the Danube is dominated by builtup areas with industrial plants, factories, slurry pumps, and settlements. Most of the riverbank along this stretch has been modified, only a small portion is left in natural condition. There are fewer strips of gallery forest and willows along this reach, with more planted trees and scattered vegetation. The scenic quality along the Danube riverbank is considered to be medium in areas not dominated by industrial facilities. Where industrial plants and factories are located along the riverbank, the scenic quality is low. Public views of the Danube from Gönyü to Komárom are limited to the settlements Gönyü, Koppanymonostor, and Komárom and small segments of local roadways. The number of people exposed to these views is unknown. From Komárom to Nyergesújfalu, visibility of the Danube is much greater, with views available from major segments of the railway and roadway, four lookout points, and a number of small settlements. It is assumed that there are more members of the viewing public along this reach.

As a result of construction and operation of the project, the riverbank character and Danube scenery would not change significantly along the reach from Gönyü to Komárom. Visual impacts from disturbance related to reinforcement of some embankments would be short term and would be reduced to insignificance after the embankments are revegetated. In addition, the proposed riverbank recreation area, with a bike and pedestrian path along the top of the embankments, will provide new viewing opportunities of the Danube to the public using the park. This will be a benefit.

The visual changes to the riverbank would be more visible along the lowland stretch from Komárom to Nyergesújfalu. However, most of the riverbank has already been modified and the scenic quality is medium to low along this reach. The industrial areas along the Danube would absorb and block a major portion of these visual changes. No visual impacts would be expected in the industrial portions of the landscape. Those areas which offer open views of the Danube to the public (from road and railways) would experience significant visual impacts. Views of the Danube will be blocked by the elevated

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embankments. These visual impacts would be reduced to insignificance when the slopes of the embankments are covered by grass or lawn, natural vegetation reintroduced at the foot, and the new riverbank recreation park is created.

Nyergesújfalu-Nagymaros. This reach of the Danube is characterised by a relatively narrow strip of riverbank. This landscape is dominated not only by the Danube, but also by the foothills of the Pilis, Börzsöny, and Gerecse mountains which provide a scenic variation to the terrain. This reach of the project area provides high scenic quality.

Roughly half of the riverbank in this portion of the project area has been slightly modified or not modified at all. From Esztergom upstream to Nagymaros there are sections of gallery forests, willows, and thick riverside vegetation. Visibility of the Danube and the potential population exposed to project impacts are high along this reach. Views of the Danube can be seen from numerous hillsides and mountain ridges, 12 lookouts, and segments of the road and railways, as well as form the popular settlements. Approximately 300,000 people visit this region annually and enjoy these views, not to mention residents who live in the area.

Any adverse visual change in this area would represent a significant impact, especially along those portions of the riverbank which have only been slightly modified and were gallery forests and riverbank vegetation are thick. Because of the sensitivity of these visual impacts, it is important that all embankments be covered with lawn, and revegetation started immediately following construction. Once revegetation has been established the visual impacts would not be obtrusive in the surrounding landscape. In addition, the proposed riverbank recreation park will increase the visibility of the Danube to the viewing public using the park.

Nagymaros-Visegrád. The natural beauty of the Danube at Visegrád is outstanding. This is one of the most - if not the most - scenic areas along the Danube. The intensively eroded volcanic hills of the Visegrád mountains are scattered around the Danube bend in an uneven pattern. The rocky peaks and foothills of the Pilis mountains are situated somewhat at a distance from the river while the foothills and ridges of the Gerecse mountains reach almost all the way to the riverbank.

The landscape is further shaped by a number of different land uses including national parks, environmental protection areas, holiday resorts, small settlements, vacation homes, and industrial and mining activities. Visibility along this reach is good. Views are provided from the hillsides, rail- and roadways, and six lookouts. The potential population exposed to project visual changes include a number of tourists, weekend recreationists, and residents.

Expected changes in landscape character, riverbank formation, and scenic views caused by construction and operation of the Nagymaros River barrage system will alter the area's existing appearance. The barrage structure would represent a new large structure in the predominantly natural viewshed. On the Nagymaros bank there are existing industrial facilities and introducing an additional structure would therefore not be as severe. This would not be true for the nonindustrial Visegrád-Dömös. The view of the river from both banks would no longer be open and unobstructed. The immediate landscape would be dominated by the barrage structure.

The aesthetic aspects were a major consideration in the design of the front view of the Nagymaros barrage structures to be built in the bed of the Danube River and along the riverbank. The barrage would have a new road across the top. The roadway approach to the barrage would be curved so as not to create the visual image of a long straight line across the horizon. The new roadway would be built on elevated/filled land, which would also help the road and the barrage blend into the surrounding hilly terrain.

The riverbank structures would be partly hidden underground (panel-beam storage and utility transmission lines) or designed to fit into the landscape by up-to-date architectural means (service buildings, residential buildings, heating plant, boat lift). The control tower has also been constructed as an observation tower, open to the public.

Along the Visegrád-Dömös bank, where the Danube River has currently been diverted due to construction of the Nagymaros barrage facility, the area would be elevated and filled and a chain of bays would be created. Three of the bays would be upstream of the Nagymaros barrage and one downstream. The surface waters would provide over 30 ha of water surface with a natural shoreline of roughly 5,000 m. This new recreation area would be landscaped with ornamental trees. It would substantially reduce the overall impact associated with the new barrage, especially if it is well landscaped with large attractive trees and green lawns. Creating a visually attractive area adjacent to the barrage would help break up the view of the barrage structure and also help direct the viewer's eye away from the structure.

The new barrage and its auxiliary structures would significantly change the visual appearance of this scenic landscape. The impact would, however, be substantially reduced by the architectural design of the structures and creation of the new recreation area. The short-term visual impacts would be considered significant. In the long term, after landscaping has been completed and the viewer's expectations of what the scenery should look like have changed, the barrage facility would not represent a significant visual impact. In fact, to some it will become a point of interest.

The project would also introduce new linear structures, such as bank protection structures and roads. New road construction includes service roads built on bank protection structures, old roads diverted to new locations, and elevating old roads. It is not anticipated that the impact from construction of these roads would be as significant as construction of the bank protection structures.

Due to the permanent high water level upstream of the barrage, and the necessary bank protection structures, shingle beaches and sandy riverbanks would disappear and forest and riverbank vegetation would be cleared. Visually this would significantly reduce the riverbank's scenic quality. To mitigate this impact all areas disturbed will be immediately revegetated.

2.6 RECREATION AND TOURISM

Recreational resources are defined as geographical areas which provide enjoyment and relaxation to the public (local, regional, national, or international). Recreational resources include developed and formally designated recreation areas (such as parks, campgrounds, boating facilities, national monuments, etc.) as well as undeveloped areas where public opportunities for solitude or unconfined recreation exist, such as the Szigetköz area.

Fishing resources within the project area provide recreational opportunities for sports fishing, but also represent an important commercial resource. For this reason, potential effects on the area's fishing resource is discussed in Section 2.7 - Socioeconomics.

Tourism plays an important role in the local economics along the Danube River. Tourism refers to the stock of lodging facilities, measured in terms of number of rooms, lodging room revenues, and expenditures made by visitors for lodging and overnight expenses.

2.6.1 Description of Significance Criteria

Impacts on recreational resources are considered significant if they threaten the physical viability of a resource or its recreational quality, or if they prohibit access to a resource. Impacts are considered significant if they meet the following criteria:

- o Permanently alterating a recreational resource, e.g., using recreation lands or waters; destroying a recreational area's unique vegetation, habitat, or outstanding landscape characteristics; or eliminating the possibility for specific recreational activities

- o Reducing the quality of the recreational experience, such as reduced visual quality due to landscape modification, reduced water quality, reduced sport fishering, etc.

- o Restricting access to recreation areas and to riverside areas used for recreation

Significant recreational impacts are determined according to the nature of the impact, the magnitude of change, and the duration of change. Temporary impacts lasting less than 2 years or two visitor seasons, are generally considered insignificant.

Beneficial impacts on recreational resources include the following:

- Creating new recreation areas, facilities or opportunities, such as parks, campgrounds, water impoundments, boat camps, ports, hiking trails, etc.
- Improving the quality of the recreational resource, such as better water quality, improved landscaping, and upgraded recreational facilities

Any reduction in tourist expenditures due to the project could result in a reduction of income and employment. Impacts on tourism are directly related to project effects on visual resources, recreation, community infrastructure, cultural resources, and transportation. Significant adverse impacts on one or more of these resources, all of which contribute to the quality of a region traditionally known for tourism, could create significant decreases in tourist-related revenues. Conversely, improvement or enhancement of these resources could beneficially affect tourism.

2.6.2 Discussion of Impacts

Szigetköz-Gönyü. The natural beauty of the smooth backwater and floodplain forest coupled with the numerous waterways (Danube River, the side arms and backwaters, and the Mosoni Danube) provide an outstanding recreation experience in the Szigetköz. Because the area is quiet and uncrowded, riverside recreation is popular. During construction of the project, the drainage and artificial recharge system and dikes will be constructed in this area. Construction activities should be of a short duration lasting less than 2 years and should not impact the recreation resources of the Szigetköz.

Project operation impacts on recreational resources in this segment of the project area would be related to the creation of the Hrusov-Dunakiliti reservoir, increased and controlled flows to the Mosoni Danube and the side

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arms, decreased flows in the old Danube channel, and fluctuations in the surface water level in the Danube. The impacts associated with project operation, which will be both adverse and beneficial, are summarized below.

Though the reservoir at Dunakiliti would have a large surface area, pleasure boating in the reservoir will be restricted due to reasons of border protection (though this may change in future). The steep slope of the reservoir bank and areas generally windy conditions will not be attractive for bathing. No project-related recreational facilities are planned for this area. Previous recreational activities along the Danube in the vicinity of the reservoir were not characterized. The significance of the impacts on recreational resource in the area of the reservoir cannot be determined. However, without boating and bathing opportunities, it is not anticipated that the reservoir will produce beneficial impacts.

It is anticipated that the planned release of controlled flows into the side arms and the Mosoni Danube on a year-round basis will improve water quality and enhance the recreational opportunities in the Szigetköz inland from the old Danube channel. In addition, water quality should improve in the Mosoni due to installation of the proposed sewage treatment facility at Dunakiliti. Hence, bathing and boating opportunities are expected to improve. Sport fishing in this area could also improve if pròposed fish stocking is successful.

Tourism in the Szigetköz can be expected to increase due to two factors - improved recreational opportunities, and installation of a new sewage treatment facility which will increase the number of vacation homes. Due to the fragile biological conditions in this area, specific protective measures are necessary to preserve its natural state. a recreational plan for the area should be developed by local authorities. Specific recreation areas and facilities could be developed outside the biologically sensitive areas to help reduce the impact of increased tourism. Recreation areas should be set aside for public use and could provide such facilities as parking lots, picnic benches, restrooms, and trash containers. Recreation sites should be identified after consultation with biologists to reduce potential conflicts with sensitive biological resources. Construction of new vacation homes should be limited by local authorities to areas around existing settlements, outside of agricultural and sensitive biological areas. Local control of tourism by directing and diverting recreational activities to certain locations, and by restricting vacation home development should ensure that increased recreational opportunities and tourism do not adversely impact this sensitive area. If properly controlled, increased recreation-tourism will be beneficial to both the general public and to local economies, while remaining compatible with the natural values of the Szigetköz area.

Operation of the project will adversely affect pleasure boating opportunities in the Danube channel from the Dunakiliti weir to the confluence with the tailrace. The reservoir will impair river boat traffic (small pleasure boats) from upper to lower stretches of the Danube. Recreational boating may be further restricted from Dunaremete downstream to Gönyü due to high surface water fluctuations which could be as great as 5 m daily (over a 5-hour period). The high fluctuation will create safety hazards for small pleasure boats. Consequently, due to safety considerations, continuous river traffic for small- and medium-size pleasure boats may need to be restricted. Alternately, modification of the power station peaking operations could be considered.

It is anticipated that the fishing resource along the Danube channel (below Hrusov-Dunakiliti reservoir) will be significantly reduced, adversely impacting fishing opportunities in this stretch of the Danube. Bathing opportunities along this stretch will also decrease, especially below Dunaremete, due to high water fluctuations. The reduction in recreational fishing and bathing opportunities could be mitigated with increased recreational fishing and bathing opportunities in the side arms due to continuous fresh water inflow from the reservoir.

Fluctuations in Danube surface water during the peak operating mode will also cause fluctuations up to Győr on the Mosoni Danube. High fluctuations along this stretch could decrease the natural flushing of the Mosoni in this reach,

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where raw sewage is currently discharged, potentially decreasing water quality. The poor water quality problem will be mitigated by installing a wastewater treatment facility and with the increased flow in the Mosoni Danube.

Both Vének, located at the confluence of the Mosoni Danube, and Nagybajcs, on the bank of the Danube, are popular river side recreational resorts with beaches. These beaches will be replaced with slope-stabilizing riprap and water sport will be eliminated due to high fluctuation during the peak operating mode.

To mitigate the adverse impacts created by fluctuations during the peak operating mode, the project could be operated so that the rate of change in the water level would be less than 1 cm/min. This would substantially reduce the safety concerns for bathing and pleasure boating, and would reduce the level erosion along the reach - possibly eliminating the need to preserve the beaches with riprap.

Gönyû - Nyergesújfalu. This reach of the Danube has fewer recreational opportunities and lower visitor use. Komárom, Koppánymonostor and Almásneszmély offer the best tourist attractions along this portion of the river. Opportunities provided include riverside recreation, thermal baths and cultural tourism. A few of the smaller settlements have bathing opportunities at the riverside. No construction impacts are anticipated along this reach.

Bathing opportunities will be eliminated because of restricted access due to riprap and protective dikes, and high surface water fluctuations during peak operating modes. However, riverside bathing is currently limited along this reach due to pollution. Consequently, the project impact is considered to be insignificant.

Small pleasure boating along this reach will also be a safety concern. However, due to border protection, pleasure boating opportunities along this reach of the Danube are limited and controlled by permits. The number of annual pleasure boaters along this reach is not known and, consequently, the impact of reduced pleasure boating in this area cannot be determined.

As previously stated, tourism along this reach of the Danube is relatively low, and recreational opportunities are few. As part of the project, a new linear riverside recreation park will be developed from Nagymaros up to Györ. By using the dikes and protective embankments, a paved biking/hiking trail will be created along the river. This will introduce new recreational opportunities (biking, hiking, sightseeing, etc.) to the region. The trail will also interlink the numerous settlements along the river and help disperse tourism away from heavily concentrated recreation centers in the Danube bend area. This could benefit tourism along this reach of the Danube.

Nyergesújfalu-Nagymaros. The Danube bend (which extends to Visegrád) is one of the most significant recreational resorts of Hungary. It accommodates about 10 percent of the total national tourism demand and ranks fourth (after Budapest, Lake Balaton and Matra-Bükk) among the recreational regions. The tourist attractions include the Danube, with its water sports and riverside recreational facilities; the forested Pilis and Börzsöny mountains; the natural beauty of the narrow gorge of the Danube at Visegrád; the thermal water resources; and the historic settlements rich in cultural values.

Landing and camping sites for water tourism are available in the region and during recent years, pleasure craft tourism and pleasure craft landing ports have started to develop (e.g., Esztergom-Primas Island and Nagymaros motorboat club). Less than one-fourth of the 40-km-long shoreline is suitable for riverside recreation and water sports. Public bathing areas (with a total capacity of 10,000) may be found at all of the settlements and their receiving capacity is well below the regional demand.

Construction and operation of the project will significantly change the recreational resources at the riverside. Protective dikes and embankments will be built along the riverbank and on the islands, and certain areas will be filled, eliminating the existing boat landing sites, campsites, picnic areas, and 10 km of bathing area.

The existing bank protection will be reinforced and land cuts and fills made in Esztergom along the low banks. The flood levee to be constructed at Primas

Island will eliminate ports and camping sites at the main Danube branch site. The existing pleasure craft landing in the Kis-Duna branch will be moved to the main Danube branch since access by ship or pleasure craft to the Kis-Duna branch will be restricted. Project plans include building ports for boats and sports boats at the Primas Island flood levee; a landing place for boats at Csenke Creek; and a planned 10-ha bay downstream of the existing ship port to accommodate tourist pleasure craft. These plans provide mitigation measures for existing ports and boat landings that will be eliminated by project construction and operation (estimated at five in total).

As with the Gönyü to Nyergesújfalu reach, pleasure boating along most of this reach (up to Zebegény) is limited by permit. The number of pleasure boats using the river in this stretch is not known.

An open water surface of 180 ha, used as a borrow area during construction, will be used as a water sports center following project construction. To further enhance the recreational opportunities, a sandy bathing beach could be created and the area around the water surface could be landscaped.

By protecting the islands and controlling the water levels in the Kis-Duna, pleasure boating and other recreational opportunities in this area will not be impacted.

The Pilismarót area is a recreation area. Waterfront bathing, camping, and picnicking opportunities exist and approximately 500 vacation homes have been constructed. This area was in danger of being inundated by the original project design. It is now proposed that a protection dike be constructed to protect the vacation homes (19 will be lost); a small lake of 40 ha created; and a bay established. To enhance the recreational value of this area, the lake should be flushed frequently so it can be used for bathing and water sports, and a sandy beach or lawn area provided. A bike/walking trail on the top of the dike around the bay could provide additional recreation. The area immediately around the bay should be landscaped and camping sites and picnic areas could also be provided.

In summary, it is anticipated that construction and operation of the project will eliminate ± 10 km of riverside recreation area. This will reduce the present and future opportunities for bathing, boating, and camping. Some of this impact will be offset by the 180 ha water area adjacent to the Kis-Duna and the new lake and recreation area at Pilismarót. Additionally, due to water pollution and border protection, bathing and boating is rather limited along this reach. Consequently, impacts to the existing recreational opportunities are not considered to be significant.

The proposed riverside recreation park will also provide new recreational opportunities for biking, hiking, sightseeing, and picnicking. This will be a beneficial impact.

Tourism in this area could be expected to increase primarily due to the new sewage treatment facility and the new roadway over the dam. Construction of vacation homes in this area is somewhat restricted because of inadequate sewage treatment. With improved sewage treatment and the new roadway, this area could experience new growth. Growth could be beneficial to local economies, but adverse if not properly planned. It could place heavy demands on other infrastructures (roads, water supply, etc.) and public services (schools, hospitals, police, grocery stores, etc.). If local authorities control the amount and speed of growth, and appropriate infrastructure and public services are enhanced, these impacts will not occur.

Nagymaros-Visegrád. The discussion of the types of recreational impacts for the previous reach of the Danube Bend apply to this reach of the study area and therefore are not repeated in this subsection.

Impacts to the natural beauty of the narrow gorge of the Danube are described in the visual resources section of this report. The following describes the mitigation measures proposed to reduce the recreation impacts along this reach.

The Visegrád-Dömös bay, where the Danube River has currently been diverted for construction of the Nagymaros barrage facilities, will be filled up and a chain of bays at the riverside will be created. Three of them upstream of the

Nagymaros barrage and one downstream. This new recreation area would provide 30 ha of water surface which could potentially, provide bathing opportunities (if the water quality of the interconnecting Danube improves), small boating, and possibly fishing opportunities (if stocked fish can survive in this manmade environment).

Most importantly, the area would be nicely landscaped and visually pleasing. In addition, observation towers along both sides of the river have been constructed. This would be a new tourist attraction offering scientific information and sightseeing opportunities.

Construction of the new roadway over the river barrage would enable a larger number of tourists to visit the Nagymaros-Visegrád areas. In addition, the new sewage collection network could promote the growth of vacation homes. This increase in recreation and tourism could adversely impact the local settlements if not properly planned and controlled. Vacation homes are already intruding upon the nature preservation area in the hills surrounding Nagymaros. This should be strictly controlled by the local authorities.

To promote the desired appearance of a Nagymaros-Visegrád recreational town, an architectural review committee could be created to oversee the permitting of new structures to ensure that they are visually compatible with the existing and desired town structures. Any construction of small structures currently not subject to the permit process should be regulated in the future.

2.7 SOCIOECONOMICS

Construction and operation of the project could affect the study area's social and economic conditions. For purposes of this evaluation, the following social and economic conditions were qualitatively evaluated by reach: employment, income, growth, and development.

Regional, national, and international social and economic conditions could also be affected by the project. These have been discussed under the following headings:

- Generation of Electric Power
- International Navigation
- Flood Protection

2.7.1 Significance Criteria

Social and economic impacts are considered adverse if they bring about the following changes:

- Annual decrease in employment or income
- Increased demand for community services and infrastructure which exceed operating capacities
- Rapid increase in population
- Increased traffic on currently congested roadways, or on roadways operating at or near capacity

Social and economic impacts are considered beneficial if they bring about the following changes:

- Improvement in community services and infrastructure (water, wastewater treatment, electricity, schools, medical services, grocery stores, etc.) allowing communities to meet the existing and future demands
- Improvement to existing navigational capacity
- Annual increase in employment and income
- Improvements in flood protection reducing structural, agricultural, and silvicultural damage

- National decrease in the international dependency on energy supplies and sources

2.7.2 Impact Discussion - Employment, Income, Growth, and Development

The following socioeconomic evaluation does not quantify impacts on social and economic conditions. Consequently, the significance of adverse or beneficial impacts is not indicated.

Szigetköz-Gönyü. In the Szigetköz area, between the main Danube and the Mosoni Danube arm, down to the villages of Vének and Gönyü, agriculture and silviculture represent approximately 84 percent of the land use. In this area, the majority of the population works in agriculture and silviculture. It is anticipated that the project will result in an increase in agricultural and forestry productivity due to three factors: agricultural and forestry losses due to floods will be reduced; controlled ground water levels will reduce the amount of hectares subject to waterlogging; and a controlled water source for irrigation will reduce risks to agricultural production dependent on water availability.

This will benefit the employment and income levels of the local population.

The diverse and extensive side arm system, and the permanent inundation in many locations, provide favorable spawning grounds for mature fish populations and suitable habitats for offspring. There are 55 different species of fish living in this area. The most commercially important include the following: carp, pike, pike perch, stone perch, catfish, barbel, sterlet, amur, and eel.

Hauling data for the last 19 years indicate a decrease of 11 percent between 1968-1986. The hauled stock is also getting younger, which is a possible indication that natural reproduction is becoming imparied in the Szigetköz area. The annual average of 5 years of fishing production of 200 tons, valued at 11 million florints.

The project will eliminate the natural water flow from the main branch through the Szigetköz area back to the main channel. The area will become a closed system. Natural reproduction for some species will be completely eliminated, while stocked species, able to adapt to the new environment, will do well.

Consequently, the fishing hauls of some species are anticipated to decrease. The fishing hauls for other species will increase with increased stocking efforts. In 1986, restocking included 8,000 specimens each of pike and pike perch, 35,171 kg of carp, and 200 kg of other species. Future stocking efforts should be focused on specific species able to survive and reproduce under the new environmental conditions.

In this portion of the project area, industrial development is only located in Györ and Mosonmagyarovar. It is estimated that approximately 45,000 persons are employed in Györ in industrial jobs. A benefit to industrial development in Györ, and even Mosonmagyarovar, will be the improved navigation along the Mosoni Danube and Danube River. However, industrial development is primarily dependent on the national economy and national policies, and will therefore not be expected to surge immediately following project construction. Consequently, industrial employment is not expected to increase in the short term due to project construction, but improved navigation, a relatively inexpensive means of transport, will be advantageous to industrial growth in the long term.

The artificial water recharge system of the Szigetköz will not only have a beneficial effect on agriculture and forestry, it will also improve the existing recreational opportunities in the area. Both the quantity and quality of the water in the Mosoni Duna and the side arms will increase. There will be year-round flows in the area providing boating, fishing, and bathing opportunities. As recreation improves, visitors to this area would increase as will the demand for vacation homes. Additionally, the project will provide a new sewage treatment facility which will be advantageous to new growth in the area. These two factors are likely to contribute to an increased rate of growth in both permanent residencts and seasonal tourists (with and without vacation homes).

As discussed in previous sections (Section 2.3 - Land Use and Section 2.6 - Recreation and Tourism), community growth can be both beneficial and adverse to local settlements and their existing community services and infrastructure. If well planned and implemented appropriately, growth can increase the affected settlements' employment opportunities and income levels. If not well planned, rapid growth can exceed the capacity of existing infrastructure and services.

In addition, growth in the Szigetköz area could adversely affect the existing land use patterns of agriculture and silviculture if vacation homes or new infrastructure begins to infringe upon, or replace, these land use areas. This area is also biologically sensitive and planners must be extremely careful to regulate recreation use in critical habitat areas (see Section 2.2 - Biology).

Overall, growth in this area will benefit the local population if it is planned for and strictly regulated. If the area begins to experience strain on existing infrastructure, planners could enforce temporary growth controls (limited building permits) until infrastructure has been improved to meet the new demands. Anticipated future infrastructure improvements can also be partially financed through additional fees incorporated into building permits.

Gönyü-Nyergesújfalu. Between Komárom and Nyergesújfalu there are numerous industrial plants located along the Danube. These industries dominate the region, as they provide employment and are an integral part of the industrial structure of the country. Most of these industries use road and rail transport while some also use water transport. As is the case with Györ and Mosonmagyarovar, industrial growth is dependent on the national economy and national policies. However, enhancing navigation along the Danube River will allow existing industry to increase its annual cargo shipments and will make future industrial growth advantageous.

It is anticipated that fishing productivity along this reach will be affected by the project. The waters downstream of Gönyü do not provide the necessary natural conditions for fish proliferation. Virtually no natural spawning grounds exist within this reach of the Danube due to bottom disturbance from commercial dredging. However, this reach of the river does have a variety of fish species and a relatively abundant fish stock. This is due to the fact that during spawning season, large populations of fish migrate into the Szigetköz side arms and successfully spawn. In addition, this portion of the river is stocked with carp, northern pike, pike perch, silure, and aspius.

Fishing data collected for this reach indicate that the fishing yield has been declining for commercial species, such as carp, northern pike, and aspius. Up to the early 1970s the share of carp in the total catch was around 5 percent but had dropped to around 3 percent by the early 1980s. The catches of northern pike have remained relatively constant over the past 11 years. The steady population downstream of Komárom is attributable to continuous restocking. Pike perch are sensitive to oxygen levels in the river, and the young require sufficient amounts of planktonic crustaceans. Of the young introduced, less than 10 percent are likely to survive, regardless of continuous restocking efforts.

The silure population declined in the late 1960s, but have begun to recover in recent years. Being responsive to water pollution, the growing population may imply improving water quality in the Danube. For example sturgeon, which require very clean water, were rare in the late 1960s but have been increasing in the 1980s. The Aspius is less responsive to water quality changes, because its proliferation rate depends primarily on the food chain (the presence of Albuinus sp.). Large numbers were caught in the early 70s, but less in the mid-80s.

Barbel (Barbus barbus) is typical in the main stream of the Danube. Barbel feed on organisms living in the vicinity of the bottom and, therefore, are sensitive to increases or decreases in bottom pollution.

White amur and grazing carp utilize the Danube lateral arms and oxbows. The ecological conditions prevailing along this reach of the Danube have been favorable to these grazing fish and the stocked young develop to commercial size within brief periods of time.

The Szigetköz side arms will be diked, eliminating access from the Danube. Fish populations which currently migrate to the area to spawn will no longer be able to do so. A decrease in these populations is anticipated. Stocked fish which do not rely on the Szigetköz side arms for reproduction are not expected to decrease or increase due to project implementation. The success of fishing hauls will become more dependent on restocking efforts.

The project is not expected to significantly increase other employment and income opportunities along this stretch. Tourists could increase due to the development of the new riverside linear park. However, because other popular tourist areas (such as Esztergom) are also nearby, tourism is not expected to increase significantly unless local planners establish additional recreational facilities - such as camp and picnic sites adjacent to the proposed park.

Nyergesújfalu-Nagymaros. Land use between Nyergesújfalu and Nagymaros is varied and includes agricultural, recreational, residential, and some industrial uses. Industrial plants of medium size are found only in Esztergom, and smaller plants can be found in Szob and Nagymaros. It is not anticipated that the project will produce significant increases in employment and income from increased agricultural and industrial productivity along this reach. Project effects on fishing productivity are similar to those discussed previously under Gönyü-Nyergesújfalu.

Regional growth is anticipated for this portion of the project area due to project implementation. The project will significantly improve sewage treatment and collection, flood control, and roadways. In conjunction with construction of the river barrage project, new roadways will be built between Nagymaros and Szob on the left bank and between Visegrád and Dömös on the right bank. The new bridge across the barrage structure will become an important interconnecting roadway between left and right banks. These road improvements will increase accessibility to settlements in the Danube bend area.

Development in the Danube bend area is currently limited by the lack of adequate sewage treatment and floodplain restrictions. The project will provide new sewage capacity and eliminate the need to restrict construction in the floodplains. Increased sewage capacity, coupled with improved roadway access, will foster regional growth. This growth could be beneficial to local economies, but adverse impacts could occur if not properly planned. If local authorities control the amount and rate of growth, adverse impacts to local infrastructure and public services will not occur. In addition, vacation homes are already infringing upon the nature preservation area in the hills surrounding Nagymaros. This should be strictly controlled by local authorities.

Nagymaros-Budapest. Socioeconomic conditions for the settlements potentially affected by the project are described in the previous discussion for the Nyergesújfalu-Nagymaros reach.

2.7.3 Impact Discussion - Regional, National, and International Conditions

Generation of Electric Power. The need for electrical energy is increasing in both Hungary and Czechoslovakia due to rapid economic development. Historically, electrical power demands were met primarily by using oil or relatively poor quality brown coals in power plants. In recent decades, there has been increased public pressure to shift the emphasis away from brown coals, which have a high sulphur and ash content, to cleaner sources of energy. Under international agreements, Hungary must comply with a commitment to reduce SO_2 and NO_x emissions by 30 percent. These environmental measures represent significant additional costs for power plant production. The project's total annual power output of 3,775 GWh would be equivalent to the combustion of 3.8 million tons of brown coal or 1 million tons of oil.

The possibilities of exploiting fossil fuels are limited and, realistically, imported electrical energy can be increased only to a limited extent. Rising fuel prices in the world market put the Hungarian power industry at a disadvantage and jeopardize the country's foreign currency holdings. Consequently, developing inexhaustible Hungarian sources of energy is one of the primary economic interests of the nation.

The GNB project provides an inexhaustible, clean source of energy, does not require imported goods, and relies on a new and as yet unused resource. Although the power to be generated by the river barrage stem will provide only a small portion of the nation's total power production, it could play a significant role due to the peak-energy generation possibilities of the daily hydraulic storage scheme.

International Navigation. Maintaining and developing the Danube River as an international waterway are the tasks of the riparian countries, as formulated by the proposals of the Danube Commission. One of the main objectives of the GNB project is improved navigation. The Bratislava/Pozsony-Nagymaros river reach is the narrowest part of the Danube, in terms of navigational requirements, and is a significant obstacle to the development of international shipping transportation. This reach is impeded by 20-25 shallow crossings to such an extent that the average annual navigation time is restricted to 250 days. Navigation obstacles have been gradually eliminated in both the upper and lower Danube reaches. Consequently, the reach between Bratislava and Budapest has now become a bottleneck to international navigation.

Understandably, the implementation of the river barrage project is of international importance. Anticipated improvements resulting from construction of the river barrage system are as follows:

- Navigation time would be increased to 330 days annually
- Nighttime navigation would become permanent
- The efficient use of freighter fleet cargo capacity would be increased by at least 20 percent
- The probability navigation accidents would decrease

These benefits would be shared by the Danube countries, as well as other countries involved in navigation along the waterway. It is anticipated that project construction will double the tonnage of cargo shipped on the Danube in 10 years.

Although the project would double cargo transport it would not be expected to double the Hungarian share of cargo shipments (which is less than 10 percent). Hungarian industrial growth (and resulting cargo) is dependent on national growth and national policies. The rate of industrial growth is not related to navigational shipping opportunities. However, improvement of this relatively inexpensive means of transportation, coupled with national industrial growth, could eventually lead to an increased percentage of Hungarian cargo ships and fleets on the Danube. This could be very valuable as international markets open up to Hungary.

Water Management. Another primary objective of the project is water management. Water management includes flood protection, river training, riverbank regulation, and water supply.

Flood levees have been constructed along the Danube and its tributaries requiring substantial investment and high maintenance expenditures. Although the dikes were constructed to offer a relatively high level of safety, they cannot provide full protection against the floods that endanger large areas along both sides of the river. Alluvial deposits of greatly varying geological character form the layers underlying the flood levees. During floods or long-lasting high water levels, finer particles may be leached out of the levees, a situation that might cause dike ruptures. In 1954, there were three dike failures on the Hungarian side, while in 1965, the dikes of the Czechoslovak side failed at two locations. With the construction of the river barrages, the total discharge capacity of the old Danube channel in the Szigetköz and the new diversion canal will provide protection against the 10,000-year flood in the region upstream of Palkovicovo/Szap. Along the downstream reaches, levees would provide protection against the 1,000-year flood. Over the life of the project, this should result in significant protection to Danube River landowners and residents, who could experience agricultural and silvicultural loss, structural damage to buildings, and even loss of life during large floods.

The cost of maintaining and repairing flood protection dikes over the life of the project should also be reduced, ultimately resulting in savings to

Hungary. Unfortunately, neither local nor national savings have been quantified. Hence, the true value of this benefit will require further research. The supplementary water recharge system of the Szigetköz area will also have a beneficial effect on agriculture and forestry. Irrigation water will become readily available for agricultural production at any time, while the drainage of excess water will be quicker than is currently possible. As a result, the northern part of the Szigetköz, where waterlogging damage occurs frequently, should no longer experience this effect (Szöny-Komárom area, Feketeerdö at Almaspuszta, and in the vicinity of Szentlélek and Kenyérmezo Creeks). Consequently, there is potential for these lands to be reclassified as agricultural (e.g., from grass to arable land, or even meadow or ploughland instead of forest). On the section downstream from Gönyü, the possibility of extracting surface water for irrigation will improve as a consequence of controlled water management.

Recommendations. The true cost and benefits of the project have not been quantified and therefore cannot be determined. If possible, a project cost/benefit analysis should be conducted. The quantification of public benefits could help increase public support for the project.

The cost/benefit analysis should quantify all costs associated with the project over its estimated life. These costs include:

- Construction costs
  - Purchased or leased material and equipment
  - Labor cost broken down by Hungarian labor and other labor
- Operational costs
  - Repairing and maintaining the system
  - Labor costs
  - Energy costs (if any) to operate
  - General operational costs
- Mitigation costs
  - Costs of mitigation measures (biology, fisheries stocking, archaeology, etc.)

- Compensation for loss of lands, income, buildings, etc.
- Monitoring program costs (labor, computer, etc.)

Benefits associated with the project (over the life of the project) should also be quantified. Benefits include:

- Employment and income
  - Number of construction and operations employees and estimated income
  - Number of hectares of new farm land resulting from the project and resulting income
  - Increased productivity on farm and forestry lands resulting from water supply
  - Estimate of annual increase in tonnage (and revenue) associated with improved navigation
  - Estimated income tax revenue generated for the government
  - Estimated local spending by construction workers
- Flood protection
  - Cost of maintaining and repairing existing flood protection system
  - Loss of crops and livestock revenues resulting from floods without the project
  - Loss of human life without the project
  - Cost to repair structural damage caused by floods (infrastructure, buildings, homes, etc.)
- Generation of electricity
  - Number of residences and businesses which will use the electricity
- Sewage treatment
  - Capacity in terms of number of people to be served

2.8 SUMMARY OF POTENTIAL IMPACTS AND MITIGATION MEASURES

Table 2-2 summarizes the potential project related impacts and mitigation measures proposed by the project and additional measures recommended by Bechtel.

Table 2-2

SUMMARY OF IMPACTS AND MITIGATION MEASURES

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Surface water	Hrúsov-Dunakiliti reservoir	Impound water at a normal level above the adjacent right bank ground surface. Seepage from the reservoir dike will raise landside ground water level and inundate local depressions.	Seepage/drainage interception channel will be constructed parallel to the reservoir dike. The seepage will be intercepted and routed to the side arm channels. The water level in the interception channel will be kept below the adjacent ground surface level at existing ground water level.	None.	None.
Reservoir sediment deposition		Sediment deposition will be largest at upstream end of reservoir where flow velocities are daily reduced to 0.1 m/s. This deposition may block passage of navigation.	Assuming an even distribution of sediment deposits, the dead storage portion of the reservoir will be filled in about 60 years. Dredging or sediment flushing by lowering the gates at Dunakiliti may be required after 60 years.	Remove excessive sediment deposition in navigation channel areas by dredging.	
Surface water	Old Danube channel Szigetköz	Inflows, up to 4,000 m^3/s, will be diverted from 30 km of the old Danube channel.	Continuously release 100 m^3/s to the old Danube channel, 50 m^3/s to the left and right bank side arm channels, and 20 m^3/s to the Mosoni Danube. Increase these minimum releases as necessary to meet area environmental requirements.	None.	
		Peak flood discharges in the old Danube channel will be reduced by 4,000 m^3/s.	Increase land development opportunity in newly protected area on land side of the flood levels.		Benefit.

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Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Surface water quality	Hrusov-Dunakiliti reservoir	Surface water quality could improve due to clarification with sediment deposition and longer detention time for biological breakdown of organics providing sufficient DO is present. During summer months, water quality may be significantly reduced due to temperatures, nutrient loads and longer detention times. Increases in algal blooms may occur.	Lower gates at Dunakiliti weir and flush water downstream, temporarily reducing reservoir detention time.	No quantitative evaluation has been made to determine if water quality degradation will occur. Water under project conditions should be modeled using available computer programs to quantitatively determine changes to water quality indices. Such evaluations should establish what combination of parameters river flood, organic load, DO, etc. would yield reduced water quality. When critical conditions are identified, proposed mitigations can be modeled to determine the most cost-effective mitigation measures.	
Sediments, heavy metals	Hrusov-Dunakiliti reservoir	Heavy metals may combine with fine sediments. These sediments will be deposited in the reservoir. When the DO content above the deposited sediments is depleted, the heavy metals in solution could be passed into the ground water and thereby reduce its quality for drinking water standards.		The amount of ground water contamination due to inflow of heavy metal from the deposited sediments have not been quantified. If the resulting ground water quality proves to be undesirable, alternative mitigation measures should be evaluated, i.e., dredging, reduce heavy metal inflow by treatment at industrial plants, and sediment flushing.	

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Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Surface water quality	Old Danube channel, Szigetköz area	Surface water quality will be controlled by the quality of water released from the Hrusov-Dunakiliti reservoir. Releases from the Dunakiliti weir will be aerated when the flow tumbles over the energy dissipation blocks. Flows in the side arm channels will be continuous compared to stagnate waters for the existing conditions.			
Surface water	Nagymaros reservoir	Surface runoff will be blocked from draining into the Danube by new and improved river levees along the right bank. Also, the normal reservoir water levee will be above right bank ground surfaces in some areas. Both cases will impact landside surface drainage by causing some areas to be temporarily inundated.	Seepage/drainage interception channels will be constructed parallel to the levees. Pumping stations will be located at the downstream end of each interception channel to lift the intercepted flows into the Danube. The pumping stations will maintain channel water levels below the adjacent ground surface levels.	None.	
Surface water	Nagymaros reservoir	Peak power generation at the Gabcikovo power plant, according to original project agreement (KET) will raise upstream reservoir water surface by 2.5 m^3/min and 3 m/24 hours.	VIZITERV has prepared alternative operation plan which would decrease the upstream water surface rise to 0.75 m^3/min and 2 m/24 hours.	Consider alternate mixes.	

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Surface water quality		Flow in the Mosoni Danube between Györ and the Danube main channel will be reversed daily due to peak power operations. Raw sewage discharged into the Mosoni Danube at Györ will be restricted from flow into the Danube due to the reversed flow.	Construction of sewage collection and treatment facilities will be completed by 1993 before Nagymaros barrage is operational.	None.	Benefit.
Sediment deposits	Nagymaros	Sediment deposition over riverbed gravels will decrease flow into the riverbank filtration wells.	Construct channel side bank walls upstream of water wells. Constricted channels will accelerate river flow and pass suspended sediments downstream of water wells.	Lower gates at Nagymaros weir and flush sediments. Remove sediments with special dredger.	
Surface water quality	Nagymaros reservoir	The upstream reservoir provides 85% of the inflow into Nagymaros reservoir. Poor quality water might be passed from the upstream reservoir during the summer months. This poor quality water could pass into the riverbed gravels and flow into the riverbank water wells.		The degree of water quality degradation in the upper reservoir should be quantified using the QUAL2E and QUAL2E-UNCAS computer program. Should the upper reservoir water become degradated, the water quality changes occurring in the lower reservoir should also be quantified. Finally, the changes to the well water quality should be quantified.	

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Surface water quality	Nagymaros Reservoir			Possible mitigation measures can then be tested to determine the most cost-effective means to maintain the desired water quality, e.g., periodic flushing of flows through both reservoirs, treating pollutant loads at source and/or treating well water.	
Sediments, heavy metals	Nagymaros reservoir	Same as described for the Hrusov-Dunakiliti reservoir. However, additional heavy metal loads have been measured from the left bank tributaries. These tributaries contribute 10% of the inflow into Nagymaros reservoir.		Same as discussed for the Hrusov-Dunakiliti reservoir.	
Ground water	Szigetköz	Water table lowered up to 5 m, potentially impairing vegetation, forestry, wildlife.	Maintain water table by releasing surface flows into side channels, infiltration canals.	Recommend detailed analysis of critical areas to ensure acceptable water levels can be maintained.	
		Shift of recharge from old channel to Dunakiliti, rise of water table, and waterlogging in area adjacent to reservoir.	Seepage interception channel installed parallel to reservoir dike to contol rise of ground water level.	None.	

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Ground water	Szigetköz	Sediment deposition in reservoir potential source of quality impairment of recharge water.		Monitor sediment deposition and water quality. Removal of sedimentation if necessary.	
	Gönyü-Nagymaros	Rise of water table in high areas. Potential seepage into floors of buildings.	Installation of cutoff walls and sump pump to maintain dry conditions.		
Biology vegetation	Szigetköz-Gönyü	Loss of natural forest and riparian vegetation in Dunakiliti reservoir due to clearing.		Reestablish riparian vegetation with revegetation program around Dunakiliti reservoir.	Cannot be determined.
		Lowering of ground water table along 25 km of Danube resulting in vegetation changes in 250-300 m wide zone.		1) Increase flows seasonally to main channel of Danube. 2) Reestablish expanded acreages of remnant native hardwood forests along Mosoni Danube.	Cannot be determined.
Wildlife	Szigetköz-Gönyü	Changes to habitat along 250-300 m wide zone along 25 km of Danube. Baseline data needed to determine extent of impact.		Conduct seasonal surveys to establish waterfowl species habitat usage in order to determine expected changes in habitat resulting from ground water changes and to determine appropriate seasonal flow increases to old Danube River channel.	Cannot be determined.

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Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Wildlife	Szigetköz-Gönyü	Potential loss of breeding and feeding habitat at Ásványráró and other areas in side arms of Danube, particularly habitat of gray herons, night herons, and black storks as well as cormorants, mute swans, and other waterfowl.	Recharge plan for side arm system.		Cannot be determined.
				For initial Danube diversions reduce flow in incremental steps to assure stable ground water level in side arm system.	
				Establish a permanent preserve for protection of herons and water birds from all human activities at the area near Ásványráró.	
		Potential loss of habitat of four protected birds: little ringed plover, willow tit, treecreeper, penduline tit. Baseline data needed to determine impacts.	Some utilization of similar aquatic and riparian habitat in adjacent side arm system.	Conduct baseline seasonal surveys to determine distribution, abundance and seasonal habitat use in area of Szigetköz potentially affected by lower ground water table including side arms. Monitor areas where habitat use occurs and adjust flow rates inside channels or main channel to maintain breeding habitat.	Cannot be determined.

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Wildlife	Szigetköz-Gönyü			Less effective mitigation is to monitor vegetation changes during project operations and adjust flows to side channels or main channel.	Cannot be determined.
		Potential loss of other (non-avian) wildlife. Baseline data needed to determine impact.		Determine occurrence of wildlife species in area of Sxigetköz that would be affected by project through literature review. Based upon literature review conduct seasonal surveys to determine occurrence and habitat use. Adjust flows to reduce effects to important habitat identified.	
Fish	Sxigetköz-Gönyü	In the main channel, fish stranding mortalities after initial project startup and after flood releases.		None.	
		Changes in species composition and abundance due to slow-moving water.		Increase flow rate to main channel seasonally, to simulate preproject patterns.	Cannot be determined.

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Fish	Szigetköz-Gönyü	Potential DO deficiency effects on fish in reservoir, side arm system, Mosoni, and main channel. Effects cannot be determined without baseline fish surveys and DO/temperature measurements.		Conduct system-wide DO modeling program to assess potential for effects. Based on results of DO modeling, develop appropriate mitigation (e.g. spill flows, mechanical aeration, alternating operational modes) as warranted.	Cannot be determined.
		Loss of access to spawning habitat in side arm system due to diking of outlets and weir at Ásványráró and resultant reduction of populations of some species. Impact cannot be determined without baseline data on fish species' distribution, abundance, and spawning times and locations.		Evaluate ability to operate Gabcikovo power station on basis that maintains adequate flow to main channel, or install a fish passage gate rather than a weir at Ásványráró which can be opened to allow fish movement during spawning periods.	Cannot be determined. Cannot be determined.
		Entrainment and turbine-induced mortalities at Gabcikovo power station. Impact cannot be determined without baseline fish survey.		Based on preproject survey, develop appropriate fish protection and guidance system, if warranted.	Cannot be determined.
		Blocked fish passage during spawning migrations.	Fish lock.	None.	Cannot be determined.

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Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Vegetation	Gönyü-Nyergesújfalu	Riparian vegetation and fringe forest lost due to flood protection structures and water level changes. Amount of loss cannot be determined without baseline survey of vegetation along river.		Establish revegetation program based upon established techniques to replace revegetation lost due to the project.	Cannot be determined.
Wildlife	Gönyü-Nyergesújfalu	Loss of wildlife and habitat due to construction of dikes and seepage inceptor channels and placement of riprap. No baseline data available to determine extent of impact.		Replace habitat lost through revegetation program.	Cannot be determined.
Fish	Nyergesújfalu-Nagymaros	Potential DO deficiency effects cannot be determined without baseline fish surveys.		Conduct system-wide DO modeling program to assess potential for effects. Based on results of DO modeling, develop appropriate mitigation as warranted.	Cannot be determined.
Vegetation	Nyergesújfalu-Nagymaros	Loss of natural vegetation, fringe forest and other riparian vegetation due to project structures and rise in water level of reservoir.		Establish revegetation program based upon established techniques to replace vegetation lost due to the project.	Cannot be determined.
Wildlife	Nyergesújfalu-Nagymaros	Loss of wildlife and habitat due to construction activities related to flood protection and bank stabilixation		Replace habitat lost through revegetation program.	Cannot be determined.

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Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Fish	Nyergesújfalu-Nagymaros	Potential DO deficiency effects cannot be determined without baseline fish servings.		Conduct system-wide DO modeling program to assess potential for effects. Based on results of DO modeling, develop appropriate mitigation as warranted.	Cannot be determined.
		Entrainment and turbine-induced mortalities at Nagymaros power station. Impacts cannot be determined without baseline fish survey.		Based on preoperational survey, develop appropriate fish protection and guidance system if warranted.	Cannot be determined.
		Blocked fish passage during spawning migrations.	Fish lock.	None.	Cannot be determined.
Vegetation	Nagymaros-Budapest	No impacts expected.			
Wildlife	Nagymaros-Budapest	No impacts expected.			
Fish	Nagymaros-Budapest	Potential DO deficiency effects cannot be determined without baseline fish surveys.		Conduct system-wide DO modeling program to assess potential for effects. Based on results of DO modeling, develop appropriate mitigation as warranted.	Cannot be determined.

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Land use agriculture	Szigetköz	Loss in arable land and production. Loss of production of 0.03 t/ha wheat, 0.27 t/ha maize without artificial recharge system.	Artificial recharge system.	None.	Benefit. Increase in arable land of 1,000/ha. Opportunity for increased crop production with more certain water supply. Reduction in risk of crop failure dependent on increased water requirements.
Forestry		Loss of forest in Dunakiliti reservoir and 250-300 m wide area along old Danube River channel.	Compensation has been made.		
		Transportation of forest products, elimination of barrage transportation. Increase in transportation costs. Compensation has been made for new road construction to mitigate transportation costs due to elimination of barrage transportation.	Maintain existing production except for approximately 300 ha - with reduced productivity - plant alternate species more suitable for drier conditions.		
	Downstream of Gönyü to Nagymaros	Loss in arable land and production of 667 ha, 9.94×10^6 ft. Change in production of 659 ha.	Compensation has been made.		
Archaeology	Györ	Construction of flood protection would impact a IX-Xth-century settlement.	Modification of design to protect two-thirds of site.		One-third of archaeological settlement lost.

1152x/12

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Archaeology	Gönyü – Nyergesújfalu	Construction impacts to archaeological sites.	Agreement with archaeologists on which sites to preserve by modifying project design (described below).		Potential damage to 11 known sites. Significance of this residual impact cannot be determined by Bechtel.
		Impacts to watermill building of the XVIIth century.	Modification of flood protection.	None.	Benefit.
	Komárom	Water in the presently dry moat of Csillag fortress. Beneficial impact.	None.	None.	Benefit. Enhancement of aesthetic quality of the fortress.
	Nyergesújfalu–Nagymaros	Construction impacts on known archaeological sites.	Agreement with archaeologists of which sites to preserve by modification of project design (described below) and what construction techniques to be used to ensure that sites to be buried are left intact.		29 sites potentially affected by construction activities. Significance of this residual impact cannot be determined by Bechtel.
		Impact to 3 monasteries and the wall of Vizivaros and a Roman stone fortress.	Modification of flood protection.	None.	Benefit. Preservation and public display made possible.
		Inundation of Helemba sziget.	Partial excavation.	Full excavation, removal to museum.	Benefit. Preservation and public display made possible.

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Archaeology	Nyergesújfalu-Nagymaros	Inundation of settlement of Copper and Celtic Ages, and a boat station at Dömös.	Protection of the boat station at Dömös.		Significance of these impacts cannot be determined by Bechtel.
		Changes in ground water level would reduce accessibility to deep-lying archaeological artifacts in the Esztergom Royal Town area.	Seepage system in Kis-Duna with pumping station to maintain mean ground water at 103.5 m/asl.	Implement a localized dewatering program in the future when excavation is desired. Monitor ground water levels to ensure that ground water is maintained at mean. If ground water level increases above mean, increase pumping along the seepage canal or Kis-Duna.	None.
	Nagymaros-Budapest	Inundation of a small fortress in Visegrád.	Excavation and protection of fortress.		None.
Visual resources	Szigetköz	Decrease in water flow in the old Danube channel resulting in the appearance of a dry "empty" riverbed and loss of vegetation.	None.	Implement a revegetation plan.	None.
		Introduction of new protective embankments along natural riverbank, reducing the area's scenic quality.	Cover embankment slopes with grass or lawn, revegetate at foot of embankment.		None.

1152x/14

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Visual resources	Gönyü-Komárom	Clearance of forests and riverside vegetation reducing the area's scenic quality.	Cover embankment slopes with grass or lawn, revegetate at foot of embankment.		None.
		Scenic quality improved with new park offering new viewing opportunities.			Beneficial.
	Komárom Nyergesújfalu	Elevated protection embankments vegetation clearance, in areas (not industrial in nature) where views of Danube are provided, would impact visual quality.	Cover embankment slopes with grass or lawn, revegetate at foot of embankment.		None.
	Nyergesújfalu Nagymaros	Clearance of forest and riverbank vegetation and construction of new protective embankments would impact visual quality.	Cover embankment slopes with grass or lawn, revegetate at foot of embankment.		None.
	Nagymaros-Visegrád	Construction of barrage facilities would introduce new structures in a natural and scenic landscape.	Extensive architectural design modifications. Development of an attractive recreation area adjacent to barrage site.	None.	Short-term significant visual impacts until landscaping is established, and visual expectations are modified.
		Introduction of bank protection structures and clearance of forests and vegetation, resulting in a disappearance of natural beaches and impacting the natural scenic quality of the riverbank.	Cover embankment slopes with grass or lawn, revegetate at foot of embankment.		None.

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Recreation/ tourism	Sxigetköz	Increased water flow and quality in Mosoni Danube and Danube side arms, improvement and enhancement of boating and swimming opportunities.	None.	None.	Beneficial impact.
		Increased recreation opportunities and installation of sewage treatment facility could promote tourism, potentially impacting existing land use and sensitive biological areas.	None.	Local authorities should develop recreation and land use plans to enhance benefits of new tourism opportunities while limiting adverse impacts to existing land use and sensitive biological areas.	None.
		Decrease in water flow of the old Danube channel would impact boating and fishing opportunities.	None.		Recreationists would most likely seek recreation opportunities in side arms of Mosoni Danube.
		High fluctuation of water levels from Dunaremete to Gönyü, creating unsafe small boating and bathing conditions.	Modification of project operations to maximum fluctuations of 2.5 m tailrace (Danube confluence).	Additional modification to project operations during summer months to maximum fluctuation of 1 cm/min. If modifications to project operations are not made, bathing and small boating should be strictly prohibited.	None.

1152x/16

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Recreation/ tourism	Nyergesújfalu Nagymaros	Elimination of existing boat landing sites, campsites, picnic areas, and bathing places.	Creation of a new riverside park along embankments with a bike and/or pedestrian trail.	Local planners should designate camping and picnicking areas adjacent to the new embankment area. Landscape new area, and provide sandy beach around new lake if possible.	Loss of some recreational opportunities, such as bathing and camping, but creation of a new recreational resource which would be beneficial to the region.
	Nagymaros Budapest	Elimination of existing boat landing and bathing areas.	Creation of new recreation areas to provide 30 ha of water surface in a chain of bays along Danube. Two observation towers. New riverside park along protective embankment.	None.	New riverside park would be a beneficial impact.
		Construction of the new roadway and sewage treatment facilities could result in increased tourism and growth in the Danube bend. This could impact community infrastructure and existing land use.	None.	Local authorities should develop land use plans to control growth and tourism impacts.	None.
Socio-economics	Szigetköz area	Potential for increased agricultural and forestry productivity, resulting in increased employment and income opportunities.	None.		Beneficial impact.

1152x/17

Table 2-2 (Cont'd)

Issue Area	Project Area	Impact Summary	Proposed GNB Project Mitigations	Additional & Recommended Mitigations	Residual Impact
Socio-economics	Nation	Utilization of a clean inexhaustible source of energy for the generation of electric power, reducing reliance on international sources of energy.	None.		Beneficial impact.
	Entire area	Improvement of international navigation, enhancing future opportunities for international trade and industrial development.			Beneficial impact.
		Improvement of flood protection, reducing property and structural damage over the life of the project.			Beneficial impact.

1152x/18

3
Monitoring Program Evaluation

Section 3

MONITORING PROGRAM EVALUATION

3.1 MONITORING PROGRAM EVALUATION

The Gabcikovo (Bös)-Nagymaros Barrage (GNB) environmental monitoring program was reviewed for overall adequacy of the program to define potential project-related impacts as discussed in Section 2; assess effectiveness of planned mitigations and additional proposed mitigations; identify changes and trends in the environment resulting from project operations; and assess effectiveness of mitigations and operational rules designed to reduce adverse impacts or enhance beneficial effects.

Recommendations for the monitoring program focus on the adequacy of the preoperational database to define preproject conditions and quantify impacts, and additional data needed to define environmental conditions during operation. Monitoring stations established for structural engineering purposes were not considered. In our experience, preoperational environmental measurements are normally taken at more frequent intervals than operational measurements (until baseline conditions are established). Generally, preoperational data collection over a 1-year period is judged adequate. The frequency of measurements usually are reduced to a level appropriate to evaluate changes or trends in a particular resource area during operation.

The GNB project has collected a substantial amount of data over a number of years, which has established an extensive base for all aspects of engineering, hydrology, and hydraulic data required for the project. These data include streamflow, surface water quality, channel cross sections, ground water levels, sedimentation and ice conditions, as well as soils, land use, meteorology, archaeology, agriculture, and forestry. Additional data collection is recommended for biological resources.

Since August 1989, VIZITERV has started operating an integrated computer database for all information collected. This computerized database presents data in a wide variety of formats, including statistical, graphical summaries and in two-dimensional plans and maps. These formats are sufficient for data presentation necessary to evaluate changes in environmental resources. Once all environmental data are entered into the system, rapid review and analysis of data will be possible. Comparison of two or more interrelated aspects are also possible with the system, which can facilitate interdisciplinary resource evaluations. Overall monitoring will be an efficient, effective tool for analyzing project-related impacts and mitigation effectiveness.

Substantial cost savings will be realized by tailoring the monitoring system and sampling program to the operational requirements for tracking environmental changes over time. Once the baseline conditions are established, the number of locations and sampling frequencies can be reduced. The reduced program must be established by a detailed review of the key areas which signal changes in existing conditions. This entails selecting specific sampling stations which provide overall representative data throughout the project area. Additional sampling locations must be designated in specific areas which are more sensitive to changed environmental conditions.

The following discussion presents a general evaluation of the existing monitoring systems along with recommendations for future monitoring in specific resource areas. Table 3-1 summarizes monitoring program recommendations.

3.1.1 Surface Water Monitoring

A network of measuring stations for river flows, sediment transport, and water quality has been implemented. Data obtained from these stations have established the baseline condition for the project area surface water regime. Data will continue to be collected to expand this database up to completion of the GNB project. At the time of project commissioning, the network will be modified to monitor only the key surface water variables.

Table 3-1

SUMMARY OF MONITORING SYSTEM RECOMMENDATIONS

Type of Resource	Project Area	Monitoring Comments and Recommendations
Surface water streamflow	Total project	- Existing conditions database is satisfactory.
		- Develop streamflow correlations with sediment load and possibly pollutant loads.
		- Test various project operating rules to determine optimum rule for given input conditions (average daily streamflow, sediment load, and pollutant load).
		- Reduce number of streamflow measuring stations to all river and tributary project input points, after operation rules have been verified as effective.
Surface water levels	Total project	- Develop water level correlations for reservoir level vs landside ground water levels, Szigetköz sidearm surface water level versus adjacent ground water level, and reservoir level changes versus Gabcikovo powerhouse discharge.
		- Verify preliminary correlations.
		- Reduce existing and proposed stream gauging stations to headworks and tailraces of project structures, two locations along old Danube channel, and control structures for seepage/drainage interception channels near the Ásványráró heronry.
Surface water sediment transport	Hrusov-Dunakiliti reservoir	- Conduct cross section surveys at 1 km intervals along reservoir to establish areas of major deposition for first 2-4 years. After deposition areas are identified, reduce number of annual surveys to four cross sections. One cross section should be maintained at upstream end to check clearance in navigation channel.
		- Conduct annual analysis of bottom sediments to determine heavy metal content.
	Nagymaros reservoir	- Conduct annual cross section surveys during the first 2-4 years at 3 km intervals and at reaches where filter bank water wells are located (to monitor sediment deposition expected along the sidebanks of the 50 km downstream section of the reservoir). After areas of deposition are identified, the annual surveys should be reduced to five cross sections.
		- Conduct annual analysis of bottom sediments to determine heavy metal content.

Table 3-1 (Cont'd)

Type of Resource	Project Area	Monitoring Comments and Recommendations
Surface water quality	Total project	- Conduct water quality sampling and analyses during the first year of project operation for the two reservoirs, Mosoni Danube, old Danube channel, and the Szigetköz sidearm channel to check that the water quality model is properly calibrated, and the project operation is maintaining the required water quality level.
		- Increase frequency of sampling and analyses during summer months when algal blooms are occurring. After the first year, sampling frequency can be reduced to monthly, and the number of measuring stations may be reduced to selected key locations.
Ground water levels	Szigetköz	- Reduce measurement program both by number of locations and frequency of measuring now that extensive baseline data has been obtained. Select wells for a specific purpose or multipurposes. 1. Long-term trends to be recorded by semiannual measurements of all holes. 2. At least three representative profiles to measure response to surface flow fluctuations should be measured monthly. Continuous monitoring of two wells in each profile should be considered. Additional monitoring should be selected for specific needs in critical hydrologic areas such as sensitive biological sites and the biological monitoring stations.
	Downstream of Gönyü	- Reduce measurement program both by number of locations and frequency now that sufficient baseline data has been obtained to determine hydrologic characteristics. Wells to be selected for specific purpose: 1. Long-term trends recorded by semiannual readings in all holes. 2. Monitor special areas such as: potential areas of seepage for higher reservoir levels; critical biological or archeological sites; monitoring wells between the river and the bank filter wells (to detect variations in well efficiency and capacity).
Ground water quality	Szigetköz	- Begin vertical sampling of a few deeper holes (2 years of accumulated data is sufficient for the baseline conditions). Test water quality in critical areas and on a widely spaced grid covering both river and background areas on 3-month frequency, also for heavy metals if necessary.
	Downstream of Gönyü	- Develop and implement sampling program based on river and background including critical or sensitive locations. Sample monthly for 2 years to develop baseline data. Reduce frequency to every 3 months after baseline established.

Table 3-1 (Cont'd)

Type of Resource	Project Area	Monitoring Comments and Recommendations
Meteorology	Total project	- Reduce number of stations used to collect precipitation, air temperature, and evaporation data to at least the two reservoir sites.
Archaeology	Esztergom	- Monitor ground water levels in the Royal Town area of Esztergom quarterly, to ensure effectiveness of the Kis-Duna pumping system.
Land use	Total project	- Sufficient baseline data has been obtained for agriculture and forestry. Monitoring recommended for forestry to assure that ground water levels in Szigetköz are maintained at planned levels. No monitoring for acid rain effects is recommended.
Biology	Total project	
Vegetation		- Include ground water level data collection at each biological monitoring station.
Wildlife		- Conduct annual waterfowl surveys on main Danube channel and side arms along length of Szigetköz during breeding season and outside of breeding season. Compare survey results to preproject survey results (recommended in mitigation section).
		- Collect stream gauging and water quality data at sensitive waterfowl areas such as Ásványráró for correlations with changes in waterfowl use.
		- Conduct seasonal surveys on four protected bird species in the Szigetköz to compare to preproject conditions (seasonal surveys recommended as mitigation) and detect changes in habitat use and abundance.
		- Continue seasonal surveys during monitoring if protected mammal species are identified during recommended preproject surveys.
Fish		- Conduct annual fish surveys to monitor cumulative impacts on fish in main channel and side arms of Szigetköz and Mosoni. Include migration and spawning conditions in surveys.
		- Monitor DO levels.

The purpose of the operational monitoring network will be to provide sufficient information to verify that environmental requirements are being met. At the same time, it will also allow project operators to maximize the available water resource in terms of hydroelectric generation, navigation, and municipal, agricultural, industrial, and environmental water supplies.

In general, the surface water resource can be successfully managed by knowing all current project inflows (streamflow, sediment load, and water pollution loads). Knowing the current input values and verified interrelationships between these variables and other environmental factors, appropriate water releases through the power plants, shiplocks, and weirs can be selected.

The following evaluation of the GNB project surface water monitoring network is based on the above general data collection and processing approach. It is understood that VIZITERV is in the process of evaluating surface water variable interrelationships and developing system models. However, our review schedule did not allow us to examine the intended data processing work; therefore, some of the following recommendations may have already been implemented.

Streamflow. The current number of streamflow measuring stations is 14, all operated in Hungary. Another 15 stations, located both in Hungary and Czechoslovakia, are planned for project operation. This streamflow database will allow development of streamflow correlations with sediment load and possibly pollutant load. These correlations are important input to system models which will simulate project operation scenarios with resulting changes to the sediment transport and water quality indices. The key stations for stream flow monitoring will be:

- Bratislava
- Dunakiliti, Gabcikovo, and Nagymaros
- At all tributaries - located upstream away from backwater
- At all project water-regulating gates and pump stations

Both the eventual set of project operating rules or, alternatively, a computer model for selecting optimum operating rules, will require current and historic streamflow data from these stations.

Stream Water Level (Gauge). Monitoring water levels will be an important function because many project impacts are related to water levels (e.g., water level relationships between reservoir levels and ground water levels; surface water level in Szigetköz side arm channels; relationships with local ground water; and reservoir level changes during operation of the Gabcikovo powerhouse). To establish these relationships, over 150 stream gauges are being measured. Another 150 gauges are planned for the operating project to confirm the relationships for the new surface water regime. The number of stream gauges can be significantly reduced after the correlations and models are verified or revised. The minimum required number of stream gauges will not be estimated; however, some key locations will be:

- Headworks and tailraces of each project structure
- Two locations along the old Danube channel
- Control structures for the Szigetköz side arm channels
- Control structures for the seepage/drainage interception channels
- Near the Ásványráró heronry

Meteorological Stations. About 28 meteorological stations which record precipitation, air temperature, wind, and evaporation have been used to establish the environmental baseline conditions and to evaluate basin water balance. The amount of data available is extensive and sufficient for understanding baseline conditions.

For the operational GNB project, of the 28 stations, two is the minimum number of meteorological stations required - one at each of the two reservoir sites. These stations should record precipitation, air temperature, and evaporation.

About 85 percent of the project inflow is from the upper Danube basin above Bratislava. Therefore, local precipitation over the 160 km reach of the project area will not contribute such large amounts of runoff to warrant development of a precipitation runoff simulation model.

Bed Deformations and Sediment Transport. There are two impacts identified for sediment deposition in the reservoirs which will require monitoring:

- Sediment buildup in the navigation channel at the upstream end of the Hrusov-Dunakiliti reservoir
- Sediment deposits blanketing riverbed gravels in the Nagymaros reservoir which could reduce Danube River flow into the riverbank filter wells

At the Hrusov-Dunakiliti reservoir, benchmarks are being set every 500 m along the dike crest from which sediment deposition surveys can be conducted. Over the first few years of reservoir operation, surveys from a number of the 56 cross section locations should be conducted to establish the areas of concern. Later the number of survey sections should be reduced to four, with one survey always conducted at the upstream end of the reservoir.

A number of cross section surveys should also be conducted along the long, narrow Nagymaros reservoir - particularly along reaches with adjacent bank filter wells. After a few years, the surveyed cross sections could be reduced to about six, located at sites of noticeable sediment buildup.

The future monitoring program includes suspended sediment surveys along four cross sections of each reservoir. These surveys would be of interest to establishing sediment settling rates and flow velocity relationships. But after these relationships are verified these surveys should be discontinued.

Sediment measurements should be made at each river and tributary inflow location where streamflow measurements are also conducted, and downstream of the Nagymaros barrage. Such sediment surveys should be made once monthly and before and after flood events.

Water Quality. Seventeen surface water sampling stations, located along the Danube and Danube tributaries, have recorded water quality indices for a number of years. This database is sufficient to establish current baseline conditions. Currently 28 water components are evaluated for each water sample.

As previously discussed, historic combinations of principal water quality indices, together with corresponding streamflows, should be combined with a computer model of the GNB reservoir system to evaluate probable water quality levels under project conditions. Such evaluations are required to determine whether special mitigation measures are required to keep the project surface water quality equal to or better than historic levels. It would be desirable for such evaluations to also identify what trends in streamflow, water temperature, and dissolved oxygen (DO) levels at Bratislava would likely yield critical water quality conditions in the project reservoirs. By recognizing hydrologic trends which might lead to critical conditions, project operators would have lead times to initiate operation mitigation measures, such as releasing more flow over the barrage weirs to aerate the water, or changing the power plant operations to constant baseload mode to reduce reservoir detention times. Such measures could be temporary, for a week or a weekend, and might avoid critical conditions which would affect municipal water supplies and aquatic life.

During the first year of project operation, close monitoring of water quality in the reservoirs will be important. This data will be needed to check and revise the results from the water quality computer model. Approximately three cross sections across each reservoir should be sampled. Sampling locations and frequency will depend on parameters being monitored. Samples should be taken from about 1-m depths and analyzed for the 28 water components. At one sampling location in each reservoir, measurements for temperature, conductivity, and DO should be made at two additional levels to establish depth variations. Also, during the sample day, the DO measurements should be taken twice (morning and night) to record the diurnal DO changes.

About 21 new water quality measuring stations are planned for the operating monitoring system. After the first year of measurements have been evaluated and the preliminary correlations and water quality model have been verified, the number of monitoring locations can be reduced. At a minimum, measurements should be continued at Bratislava, all tributaries, and in the two reservoirs. Measurement frequency can be reduced to monthly.

3.1.2 Ground Water Monitoring

The following recommendations for the monitoring program will address that portion of the project area between Dunakiliti and Gönyü, and the area from Gönyü to Nagymaros. Because there is no impact associated with the project downstream of Nagymaros, ground water monitoring is not needed for this reach. In general, the monitoring for water level data is more comprehensive than for water quality monitoring. The data and monitoring program in the Szigetköz is more comprehensive than it is for the area downstream of Gönyü.

Dunakiliti to Gönyü. The network of over 200 monitoring wells and several years of water level measurements have produced a sufficient database to establish ground water level responses to changes in Danube surface water levels, and develop the Szigetköz ground water recharge plan.

During project operation, the monitoring well system should be modified to check that the water table adjacent to the Hrusov-Dunakiliti reservoir is being maintained near historic levels and that the Szigetköz ground water recharge plan is working. The seepage rate and water table responses have been predicted for the area adjacent to the reservoir. Nevertheless, actual response data for the filled reservoir is needed, both for verification of predictions and for safety of the structure. An array of wells is selected for that purpose. Once the initial verification of seepage rates is established and deviations from predicted conditions are explained and rectified as needed, the number of monitoring wells can be reduced to those used for monitoring seepage under the reservoir dike. The number of dike seepage monitoring wells will not be reduced because they are required for structural stability and safety.

It appears that the Szigetköz ground water can be properly observed by monitoring three general areas and other areas of specific concern. The general areas can be monitored with lines of wells already in place between the old Danube and the Mosoni Danube. These lines will provide information on the actual ground water profiles which can be checked against the planned ground water profiles. One or two lines are recommended for each general area, with six or more wells per line. The actual number of lines and wells per line should be based on a more detailed evaluation of the area subsurface characteristics.

The three general areas to be monitored are:

- o Bezenye-Dunakiliti area - which has shown slow responses of the water table to river fluctuations
- o Ásványráró area - which has shown rapid responses to the river fluctuations
- o Lower end of the Szigetköz - the area of ground water basin discharge

During project startup and the initial year of project operation, the monitoring wells in the Szigetköz and the surface water levels in the side arm channels should be measured weekly to allow adjustment of discharge into side arm channels to maintain the required ground water levels. Once the side arm discharge and ground water level relationship is properly calibrated, the monitoring can be reduced to continuous staff readings in key side arm locations and measurements three or four times per year at the monitoring wells.

There are some specifically sensitive areas in the Szigetköz which will require additional ground water monitoring because the local environments are less tolerant to water level fluctuations. These local environments include:

- o Biological monitoring stations
- o Bird habitat areas (such as Ásványráró)
- o Fish spawning areas

The number of monitoring wells and frequency of measurements must be established after more detailed evaluations of the local environments and potential project impacts.

Ground water quality monitoring is much less extensive than the water level measurements, both in number of wells sampled, and in length of time that monitoring has been conducted. The number of wells sampled is less than one third of the total monitoring wells and, according to the data provided, no regular sampling of wells open to deeper intervals in the basin has been conducted. Regular sampling of wells open to the shallowest zone, less than 30 m deep, commenced in 1988.

Once drilling and well construction effects are accounted for, 2 years of regular sampling on a monthly basis should be sufficient to establish the water quality character (including sampling variabilities) for a baseline reference. Once that baseline is established, frequency of monitoring is usually reduced to 3-month intervals. Recognizing that ground water migration is unusually rapid in this basin of extremely high permeability, it would seem that quarterly frequency is sufficient. In addition, the number of wells being sampled should be reviewed for possible reduction. Several wells may be found to be in an area of similar hydrologic characteristics and similar quality; thus, the number to be sampled may be reduced.

Important characteristic areas in which quality sampling should be performed are the recharge areas, particularly in the vicinity of Dunakiliti reservoir. In addition to shallow monitoring, at least one deep zone well should be monitored down gradient of Dunakiliti. Other well sites should be selected in reference to specific concerns, such as fish spawning areas in the basin discharge region in the vicinity of Vének, and the biological conditions of the heronry at Ásványráró.

The ground water quality parameters to be measured should continue to be those included in the current testing procedures. Additional testing parameters can be added to the present program should it become desirable to apply more stringent quality standards in specific areas. The current testing parameters are sufficient to cover the purpose for which the water quality is being monitored.

<u>Gönyü to Nagymaros</u>. The subsurface conditions in this subregion are more complex than in the Szigetköz. The ground water occurs in a series of small subbasins which in turn are comprised of multiple aquifers. Sufficient data have been collected from the nearly 200 observation wells in the area (at least one well is reportedly installed in each aquifer) to establish the hydraulic interrelationships between the ground water regime and the Danube. Most important is the fact that only the upper aquifer is in direct contact with the Danube. Further, ground water flow direction surveys have been conducted to establish the historic ranges of the water table gradient.

During project operation, ground water monitoring will be required to check that the seepage/drainage interception channels and pump stations are maintaining the ground water at desired depths, and special protective measures at industrial plants, urban structures, and historical sites are properly functioning. A specifically sensitive area which will require additional ground water monitoring because of the influence of water level fluctuations is the Royal Town area of Esztergom.

Initially, ground water level measurements should continue to be taken to confirm or revise the ground water gradient relationships with the water levels in the Nagymaros reservoir and in the seepage interception channels. These measurements should be made weekly until the relationships are firmly established. Operational control will subsequently be maintained according to automatic water level measurements in the interception channels and at the drainage pumping stations. Measurements in key observation wells can be reduced to four times per year. Measurements at specific structural sites should be made at intervals appropriate to the expected local ground water fluctuations.

Water quality data in the Gönyü-Nagymaros reach of the project area are apparently quite limited. It is recommended that the regular water quality monitoring program started in 1988 be continued. Monthly samples should be collected at least from a few wells in selected critical areas in each subbasin to establish baseline water quality. Water quality of both the deep and shallow aquifers should also be established. The ground water parameters being monitored should be the same as discussed previously for the Dunakiliti-Gönyü reach of the project.

Monitoring wells should be constructed and observed at locations between bank-filter wells to establish baseline data. With continued monitoring after reservoir filling, any decline in well performance can be related to sediment deposition in the reservoir and identified.

3.1.3 Biology

The project has planned and implemented preproject monitoring at 12 established biological monitoring stations. This monitoring system will provide valuable information on vegetation, birds, and invertebrates for use in detecting project-related operational impacts. This monitoring program was reviewed relative to the potential impacts that may result from the project.

Based on available information, some recommendations can be made at this time. Other recommendations for the monitoring program would need to be developed after reviewing the additional biological baseline data recommended for collection (see Section 2.2).

Vegetation. The monitoring program designed and implemented at the 12 biological stations provides a sound basis for evaluating impacts on natural vegetation in areas that may be affected by the project. The stations have been located in different habitat types in areas which could be expected to be affected by changes in hydrological conditions. The control or reference areas are also well located. Emphasis on vegetative monitoring in the Szigetköz is well founded. Additionally, the vegetative sampling scheme is well designed and the baseline information collected to date will provide a preproject comparison basis for evaluating operational impacts.

One additional recommendation for the monitoring program (if it is not already being conducted) is collection of data on ground water levels at each monitoring station or an existing nearby well. This information could prove useful should any changes in the vegetation be detected. Changes in species composition, abundance, and water requirements (Zolyomi's water requirement categories), and measured changes in ground water levels could be correlated.

Wildlife. The project plans to conduct monitoring of birds and six insect species selected as indicator species sensitive to changes in the water regime. Data collection is ongoing at the 12 biological monitoring stations, and baseline information is available.

The planned monitoring of avian species at the biological stations should be continued. The stations established are in a variety of habitat types which support a diversity of bird species. Operational monitoring data on birds can be compared to preproject data and correlated with any changes documented in the vegetative sampling. Quantitative data and information currently being collected on residents during the breeding season provide a good basis for assessing any changes during operations.

Because riparian/wetland vegetation provided by the main channel and the side arm system is important to waterbirds, a preliminary recommendation is to expand avian monitoring to include annual waterfowl surveys of the region both during and outside the breeding season. This monitoring should include the main channel and the side arm system along the length of the Szigetköz. These surveys should record species present, estimated numbers of waterfowl, and breeding activity. Survey results could be compared to the baseline waterfowl survey data recommended in Section 2 to determine whether any significant changes in distribution, estimated abundances, or breeding patterns occur during operation of the project. This recommendation should be reviewed and the survey design developed based on the data collected from the preproject surveys.

Also, stream gauging and water quality sampling should be conducted at several locations in the side arm system determined to be important habitat for waterfowl (e.g., Ásványráró). Water levels and quality should be monitored in these locations for correlation with any significant changes in waterfowl use detected by the monitoring program.

Additionally, monitoring surveys should be conducted for the four protected bird species described in the impact section. Once baseline surveys have identified their preproject seasonal habitat use of the area, monitoring surveys should be conducted to identify whether any significant changes in species' distribution, abundance, or seasonal habitat occur. These surveys should be designed based on the information collected in the baseline surveys.

If any protected mammal species are identified in the recommended 1-year baseline survey, a monitoring program should be developed for these species.

Fish. Currently, the monitoring of fish stock appears to be limited to collection of fish catch data. As noted in the report on the monitoring network, the fish surveys need to be expanded to include data on spawning grounds, spawning times, and restocking.

Several monitoring recommendations are made in this section, but it should be noted that these recommendations are preliminary and based on very limited information. The monitoring program should be reviewed and better developed after baseline fish surveys are conducted over a 1-year period prior to project operations.

Subsequent to the baseline seasonal fish surveys, annual fish surveys should be developed and conducted once the project is operational. These surveys would be designed to monitor for overall cumulative impacts on fish in the main channel (above and below the barrages), the side arm system, and the Mosoni. Such impacts could result from one or a combination of effects discussed in the impact section. Should this monitoring detect any measurable changes in fish stocks, more specific data collection programs could be designed to assess the reasons for the effect and mitigation that should be employed. The monitoring also should focus on migration and spawning to detect any changes in these activities which may result in reduced reproduction and recruitment over time.

A permanent monitoring system for DO and temperature above and below each of the barrages should be implemented. This is commonly done by use of an electronic system that automatically records continuous DO and temperature measurements. In conjunction with the preproject DO modeling results, this monitoring can be used to detect significant DO deficiencies developing during operations, and to guide the project in making operational alterations to mitigate DO deficiencies and effects on fish as needed. As described in the impact section, these measures may include:

- Spilling flows over the weir
- Mechanical aeration techniques such as pumping air through nozzles into the turbine draft tubes or some type of diffuser in the tailrace
- Operating the Gabcikovo power station in continuous mode, or alternating between peak and continuous operation (to reduce algal production)
- Drawing down the reservoir during certain conditions (algal blooms)
- Release of small discharges from the reservoir bottom (which tend to have low DO concentrations) mixed with surface waters

Federal licensing of hydroelectric plants in the U.S. often requires continuous monitoring of DO and temperature and special measures when DO levels fall below established criteria. As an example, the Martinsville Hydro Electric station must shut down whenever the DO measured falls below 6 mg/l, until the DO returns to 6 mg/l or it is demonstrated that the power plant operation does not further reduce the DO as recorded in the headworks. The Norris Hydroelectric Project operated by TVA has an air injection system which is activated when the DO drops below 5 mg/l.

Additionally, DO and temperature measurements should be collected at several locations in the side arm system and the Mosoni which would be determined after review of the baseline fish survey data.

Finally, operational surveys should be conducted to monitor the effectiveness the fish lock. Fish passage via this system should be monitored until it is established that the system provides an adequate means of migration.

3.1.4 Land Use

No forestry impacts are anticipated. Therefore, future forestry observations related to the project are not necessary, unless ground water monitoring indicates a trend (over 5 years) towards a decrease in ground water levels below those originally predicted in the Szigetköz. If ground water levels are lower than predicted, additional forestry monitoring could include the following parameters:

- o Tree growth
  - Species
  - Age
  - Average height
  - Average diameter at chest height
  - Timber volume
  - Comparison to earlier observations
- o Logging data
  - Date of logging
  - Logging site
  - Area cleared
  - Species logged
  - Lumber volume
  - Total tree volume
  - Lumber value
  - Comparison to earlier observations

Monitoring should be limited to only those areas experiencing a trend in decreasing ground water levels (below the predicted levels).

No monitoring for acid rain effects on forestry is recommended. While acid rain has been shown to be a problem that affects forestry productivity in the U.S., it is not associated with the project and could not be considered alone from the many factors potentially affecting forest productivity.

No agricultural impacts are anticipated. Therefore, no additional agricultural monitoring of crops or animal husbandry is necessary or recommended.

3.1.5 Archaeology/Historic Monuments

Increases in ground water levels above the existing mean level could affect the accessibility of deep-lying archaeological artifacts in the Esztergom Royal Town area (site no. 35.1.10). It is proposed that the ground water level in the area will be controlled by the Kis-Duna pumping station facilities at the mean ground water level of 103.5 m above sea level. Currently there is no proposed monitoring program for archaeological impacts. It is recommended that the existing wells in the Royal Town area continue to be monitored, as discussed in Section 3.1.2 - Ground Water Monitoring. These wells should be monitored quarterly to ensure that the Kis-Duna pumping system is effective in maintaining ground water levels at the current mean levels of 103.5 m above sea level.

3.1.6 Visual Resources

Monitoring of visual resource impacts is not necessary and is not recommended.

3.1.7 Recreation, Fishing Resources, and Tourism

A monitoring program is proposed for fishery resources and is discussed in Section 3.1.3. No additional monitoring is proposed or necessary for recreation resources or tourism.

3.1.8 Socioeconomics

No monitoring is proposed or necessary for socioeconomic considerations, with the exception of fisheries is discussed in Section 3.1.3.

3.2 SUMMARY OF RECOMMENDATIONS

Table 3-1 presents monitoring system recommendations.

3.3 EXISTING MONITORING PROGRAMS

The monitoring program implemented for the GNB project tracks a comprehensive array of hydrological and environmental parameters. Similar water management projects in the U.S. were reviewed to identify the scope and reliability of operational monitoring programs. Our review did not find any existing monitoring program which can compare to the GNB program with respect to the range of environmental parameters being measured. Perhaps the most comparable U.S. program is the one established for the Columbia River by U.S. and Canadian agencies. However, the Columbia, Ohio, and Tennessee River programs do provide important additional features which are applicable to the operational needs of the GNB Project.

3.3.1 Columbia River Operational Hydromet Management System

The Columbia River is a major river located in the northwestern portion of North America. The river drainage area is over 259,000 square miles. More than 100 hundred water management projects are currently operated on the river. These are multipurpose projects - power generation, navigation, water supply, and flood control - and are managed by government and private agencies. In a coordinated effort, these agencies have designed and implemented a basin-wide data collection, processing, and display system called the Columbia River Operational Hydromet Management System (CROHMS). The purpose of CROHMS is to provide project operations with an accurate, continuously updated database which allows more efficient management of water resources. The system was commissioned in 1978 and originally collected data from over 450 stations, covering stream flows, precipitation, air temperatures, snow depths, and hydroelectric generation. The database has since been expanded to include water quality parameters and fish counts.

Data are transmitted to the CROHMS computer center located in Portland, Oregon. The center is managed by the U.S. Army Corps of Engineers (USCOE). At the computer center, the data are validated and used in various computer simulation models which help develop monthly, weekly, and daily project operation rules.

CROHMS has proven to be an effective tool which aids project operators in maximizing the benefits of this large river resource. Plans are currently being developed to expand the database to include more environmental parameters and to develop new software which will screen incoming data and automatically issue alert notices whenever environmentally critical threshold conditions are being approached.

Literature which describe the Columbia River projects and the development of CROHMS are included in Appendix 4.

3.3.2 Ohio River

The Ohio River is 980 miles long and supports a variety of uses including navigation, power generation, industrial processes, municipal water supply, fish and wildlife habitats, and recreation. This river receives treated wastes from over 220 industrial and 126 municipal sources. There are 28 water control projects on the river. Three groups have major roles in managing the Ohio River. They are USCOE, federally licensed hydroelectric operators, and the Ohio River Valley Water Sanitation Commission (ORSANCO).

USCOE has been authorized by the U.S. government to construct and operate a series of locks and dams along the Ohio River for navigation service and flood control. The plan and profile of the USCOE Ohio River system is included in Appendix 4. The USCOE division office at Cincinnati, Ohio is responsible for general management of the Ohio River projects. Day-to-day management is assigned to four district offices which are each responsible for four to eight projects.

Each district office maintains a monitoring system which continuously measures river and reservoir water levels, precipitation, air temperature, and project releases through low level outlets, spillway gates, and navigation locks. These data are input to subbasin operation models to establish weekly and daily operation schedules. Water quality parameters - DO, water temperature, pH, and conductivity - are measured. Should undesirable water quality indices be observed, some project operation responses, such as releases over spillways, are activated to improve the water quality.

A number of hydroelectric powerhouses have been added to the USCOE dams. These powerhouses are owned and operated by public and private utilities under licenses issued by the Federal Energy Regulatory Commission (FERC). An example of such a project is the new Martinsville Hydro Electric Project which adjoins the Hannibal Lock and Dam. This power plant houses two 17 MW bulb turbine generator units and it must pass the incoming river flows as regulated by USCOE. The FERC License requires the continuous monitoring of DO and water temperature. Whenever the DO level falls below 6 mg/l, the power plant must be shut down and the river flows passed through the spillway gates in Hannibal Dam. Power plant operations cannot be restarted until the DO level returns to 6 mg/l or it is proven that the power plant operation does not further reduce the DO level as recorded in the headworks.

Each FERC licensed project is also required to transmit daily DO and water temperature readings to ORSANCO which maintains a basin-wide water quality database. ORSANCO is an interstate agency which has the primary function of promulgating standards of sewage and industrial waste water treatment and monitoring water quality along the Ohio River. The commission also maintains a quality assurance program. Aspects of this program include specifications of sample collection and handling techniques, service of electronic equipment, submission of check and duplicate samples collection and handling techniques, laboratory inspections, and immediate review of all data collected. A special aspect of the quality control program for a large river such as the Ohio is the need to assure that all monitoring locations are representative of conditions across the river. A program of cross sectional sampling, with analyses for all water quality parameters measured in the monitoring program, was initiated in 1984. Eight monitoring locations are scheduled to be covered each year. The types of water quality monitoring included in the ORSANCO program are discussed below.

Electronic Monitoring. Electronic monitors connected to the ORSANCO office in Cincinnati, Ohio, are operated at 15 Ohio River and 7 tributary locations. The monitors provide hourly measurements of DO, temperature, pH, and specific conductance.

Manual Sampling. Monthly samples are collected at 24 Ohio River and 14 tributary locations. Samples are analyzed for 25 physical and chemical constituents on a monthly basis; an additional 7 parameters are measured quarterly.

Constituents sampled include cyanide, phenolics, mercury, copper, zinc, lead, cadmium, iron, maganese, BOD, suspended solids, sulfate, hardness, nutrients total phosphorous, total Kjeldahl nitrogen, ammonia nitrogen, and nitrate/nitrate nitrogen.

Organics Detection System. Daily samples for organic compounds are collected by 13 participating utilities. Data from 11 of the utilities are used to provide a continuing record of ambient levels of 17 purgeable, halogenated organics. The other two utilities operate as spill detection sites.

Water Users Network. Results of river sampling by 12 water utilities, industries, and power plants on the Ohio River and its tributaries are currently utilized to augment the commission's other data sources. Data are collected for alkalinity, chloride, phenolics, and fecal coliform bacteria. The fecal coliform data are particularly valuable since the commission's stream criteria require a minimum of five samples per month for assessment. The water users provide the only continuous source of data at this required frequency.

Biological Sampling. The current biological monitoring program includes two major aspects: biennial lock chamber studies of fish populations, and sampling of macroinvertebrates through the use of artificial substrates. Both of these are cooperative efforts, with the commission coordinating participation by several state and federal agencies.

Special Studies. Special studies are often undertaken to evaluate emerging problems or to provide additional information on problems identified in the ongoing monitoring programs. Current studies include instream toxic effects screening and special sampling for fecal coliform bacteria.

3.3.3 Tennessee Valley Authority (TVA)

The TVA is a U.S. federal agency and is responsible for building and operating water control projects on the Tennessee River for navigation, hydroelectric generation, and other beneficial uses. The TVA plan and system profile are included in Appendix 4.

The TVA operates a data collection program for the operation of its water projects. The major parameters monitored are:

- Precipitation for each subbasin
- Streamflows
- Reservoir data including headwater and tailwater elevations; turbine, low-level, and spillway discharges
- Water quality - primarily DO and water temperature

The collected data are transmitted to the computer center located in Knoxville, Tennessee. The reservoir operation department is responsible for evaluating the incoming data and establishing project operation schedules. The precipitation data are input into precipitation runoff models. The resulting streamflows are verified by key streamflow measuring stations. The new streamflow data are then used in eight separate subbasin operation models to prepare weekly and daily project operation schedules which maximize the use of available water to meet electrical, water supply, and environmental demands.

Water quality downstream of reservoirs is also monitored. When undesirable DO and/or water temperature levels are detected, special reservoir releases from multilevel outlets are made to improve the downstream water quality.

A special feature exists at the Norris Hydroelectric Project, one project operated by TVA. The Norris power plant houses two 50 MW Francis type turbines with a design head of 165 feet. Whenever the reservoir DO drops below 5 mg/1, an air injection system is activated. The air injection system is comprised of air vents which connect to the hub of the turbine runners. When the air vents are open, the negative pressure under the turbine pulls air into the draft tube. This system can raise the DO above 6 mg/1.

3.3.4 Coachella Valley Water District

The Coachella Valley Water District is responsible for supplying municipal and agriculture water to a large service area located in southern California. Most of the water is delivered via 75 miles of open canal. To help operate this water delivery system, the district has developed an automated data collection and processing system which tracks water levels throughout the canal system. By knowing the water demand at each turnout structure, the operator determines the required water levels needed throughout the canal system to transport the accumulated water demand. Once the water levels are known, control gates are automatically adjusted to control the water at the specified levels. This type of water level control system would be applicable to the water level controls required for the GNB project seepage interception channels and the waterways in the Szigetköz area.

A more detailed description of the Coachella automatic control system is contained in Appendix 4.

Appendix 1
References

Appendix 1

REFERENCES

VIZITERV, Consulting Company for Water Engineering, July 1989. Informatory Documents[a] for the Gabcikovo/Bös-Nagymaros River Barrage System.

1. Summary Description, compiled by Dr. Endre Zsilak, Chief Project Engineer.

2. Standard Specifications, Regulations and Orders on Environmental Protection.

3. Engineering Geology. Compiled by: Dr. Jeno Mantuano, Chief Project Engineer.

4. Hydrological Conditions of the Danube and its Tributary Streams.

4.1 Surface Water Regime. Prepared by Ferenc Papp, Chief Project Engineer.

4.2 Subsurface Water Regime. Prepared by Dr. Jeno Mantuano.

4.3 Sediment Regime of the Danube Stretch Affected by the Gabcikovo-Nagymaros Hydroelectric Development Project.

4.4 Comprehensive Report "Exploration of the Ice Regime over the Danube Reach Influenced by the Bös-Nagymaros River Dam Project."

4.5 Quality of Surface Waters, Prepared by: Mrs. Eva Bartalis-Tevan, Biologist, Technical Advisor; Dr. Szabolcs Tyahun, Biologist; Dr. Pal Varga, Chemical Engineer; and Mr. Nandor Varday, Chemical Engineer.

4.6 Subsurface Water Quality, Prepared by: Ferenc Herzog, Chief Project Engineer.

5. Biological Conditions.

5.1 The Flora, Vegetation, Fish Fauna, and Biological Monitoring of the Gabcikovo/Bös-Nagymaros River Barrage System, Experts: Dr. T. Simon, Doctor of Biological Sciences and Dr. G. Lang, Candidate in Biological Sciences.

(a) Please refer to pages A1-4 through A1-35 for contents of these Informatory Documents.

5.2 Plant Nutrient Supply in the Danube River and its Hydrobiological Features, Experts: Dr. T. Kiss Keve, Candidate for Biological Sciences, MTA-OBKI, Hungarian Danube Research Station; Mrs. E. Tevan-Bartalis, Biologist, Technical Consultant, EDU-KÖVIZIG; Dr. Sz. Tyahun, Biologist, KOV-KÖVIZIG; Dr. P. Varga, Chemical Engineer, Head of Department, KOV-KÖVIZIG; Dr. N Varday, Chemical Engineer, Head Section EDU-KÖVIZIG.

6. Agricultural and Silvicultural Land Use, Compiled by Consulting Company for Water Engineering.

7. Archaeological and Monuments Assets and Annex, Compiled by: VIZITERV with participation of experts.

8. Aesthetic Quality and Character of Landscape, Produced by: VIZITERV based upon experts.

9. Recreation - Tourism, Compiled by: VIZITERV based upon the expert's report.

10. Social and Economic Aspects, Prepared by Ferenc Kollar, Chief Engineer of the River Barrage Project.

11. Evaluation of Conditions and Effects. Compiled by: Dr. D. Orloci, Civil Engineer, Senior Research Fellow.

12. The Monitoring Network 1.

12.1 The Monitoring Network Operative in 1988, Compiled by: Dr. Jeno Mantuano, Chief Project Engineer.

12.2 Comprehensive Report on Observations up to 1985. Szigetköz

12.2.1 Comprehensive Report

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12.3 Comprehensive Report on Observations up to 1985. Section Downstream of Gönyü.

12.3.1 Legend to Table 1 - Table 22

12.2.2 Legend to Figures 1-16 and Maps 1-3

Power Engineering Influences of Introducing An Environment Protecting Operation Pattern on the Operation of the Bös-Nagymaros River Barrage System. Research Report. Budapest Technical University, Department of Water Management, 1989.

The Monitoring System of the Bös (Gabcikovo)-Nagymaros River Barrage System. Conception of Evaluation.

A Kisaalföld: Duna-szaKasz és a Kajesolodo mellékvizek halai és halaszato. 1987. Kalman Jancso anl Janos Toth authors. Translated from A Kisaalföld Duna-szaKasz Ökologiaja.

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GABČÍKOVO-WWF, THE PROS AND CONS.

Prof. Igor Mucha
Bratislava, April 1994

(Appendix omitted)

GROUND WATER CONSULTING
Ltd.

Office: Karloveská 2, 841 04 Bratislava TEL: 42 - 7 - 728392,792449
Postal address: P.O.Box 6, 840 00 Bratislava 4 FAX: 42 - 7 - 728392,792355

GABČÍKOVO - WWF

the pros and cons

Elaborated by Prof. Igor Mucha

Bratislava, April 1994

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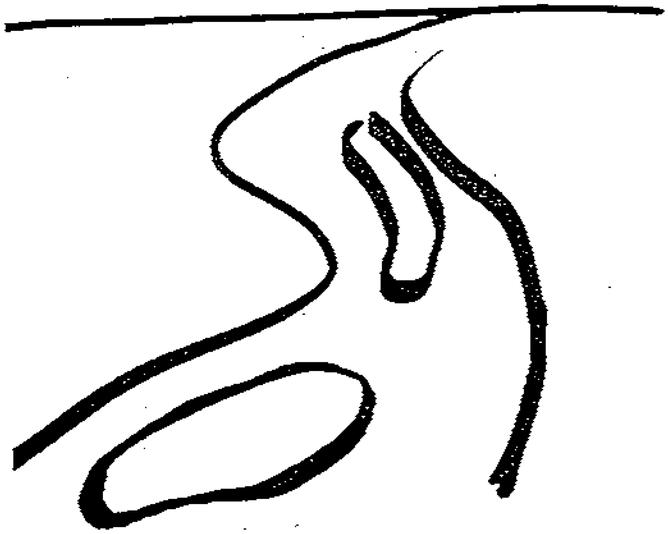
WWF (World Wide Fund for Nature)
published a pamphlet with the following obverse page:



A NEW SOLUTION FOR THE DANUBE

WWF Statement

on the EC Mission Reports of the
„Working Group of Monitoring
and Management Experts"
and on the Overall Situation
of the Gabcikovo Hydrodam Project

Authors
Dr. Emil Dister, WWF Institute for Floodplains Ecology, D-Rastatt
Prof. A. L. Roux, Laboratoire d'Ecologie des Eaux Douces, University F-Lyon
Prof. Tomas Paces & Andre Jager, Czech Geological Survey, CZ-Prague
PD Dr. Hans Helmut Bernhart, Inst. f. Wasserbau & Kulturtechnik, Univ. D-Karlsruhe
Dipl. Geogr. Alexander Zinke, WWF Austria, A-Vienna (coordination and editing)

Vienna/Rastatt, December 1[illegible], 1993 (final version 31 January 1994)

WWF

PREFACE

In the following text we would like to provide the reader with a review of the basic characteristics of the Gabcikovo surrounding area, to explain the work of the European Union (EC or EU) experts and to oppose the WWF Statement on the cause Gabcikovo.

1. INTRODUCTION

The importance of the Danube, the necessity of its regulation and development was already recognized in ancient times. The Romans excavated a canal to bypass the dangerous rapids in the Iron Gate section on the Lower Danube. Emperor Tiberius ordered the building of regulated banks and a towpath to facilitate the upstream passage of barges. Queen Mary, wife of Bela IV. who ruled from 1235 to 1270, had a new straight bed excavated for the Danube between Bratislava and Gönyü to protect her Mosoni estates from the floods on the river. Since 1886 until 1896 there was realized regulation of the Danube because of navigation from the rkm 1880 (Devin) to 1747 (Radvan nad Dunajom, downstream from Almasfüzitö). Regulation was done to fulfill navigation conditions by the mean water level. This was the first large regulation on the Danube. There was used 3.6 mil. m^3 of stone for fortification of banks and dredged 8 mil. m^3 of gravel. At the beginning of this century, the regulations continued to fulfill navigation conditions during low water levels. This was done by:

- closing of the river branches, cutting off and bundling of river branches into one main straightened and heavily fortified channel,
- regulation dikes (groynes) across the Danube to concentrate the water flow in the navigation canal,
- dredging of moving sand banks and fords in the Danube.

These measures had not fulfilled the aim to improve the navigation.

The lowlands on the both Danube sides were regularly flooded in the far past. Floods devastated last time large parts of Hungarian Szigetköz area in 1954 and Zitny ostrov area in 1965. The first dam on the river Danube, the Kachlet Dam, inaugurated in 1927, was followed by about 29 similar projects upwards from Bratislava. Construction of any river dam entails changes in the environment. Any interference is associated with changes, both adverse and beneficial. In particular, the various and sometimes delicate equilibrium or conditions, that have been developed over many decades, aimed at water resource exploitation and surface down flow control, have been significantly modified by the human activities and by the Danube upstream hydropower schemes. Recently the area has been changed by the new hydropower scheme Gabcikovo.

Characteristic of the Area

Danubian Lowland between Bratislava and Komarno (Fig. 1.1) is geologically formed by the Central Depression of the Danube Basin. The Central Depression is filled with Quaternary, Rumanian, Dacian, Pontian and Pannonian sediments [14]. The Quaternary and Rumanian sediments represented by gravel and sands are of interest. The deeper horizons are

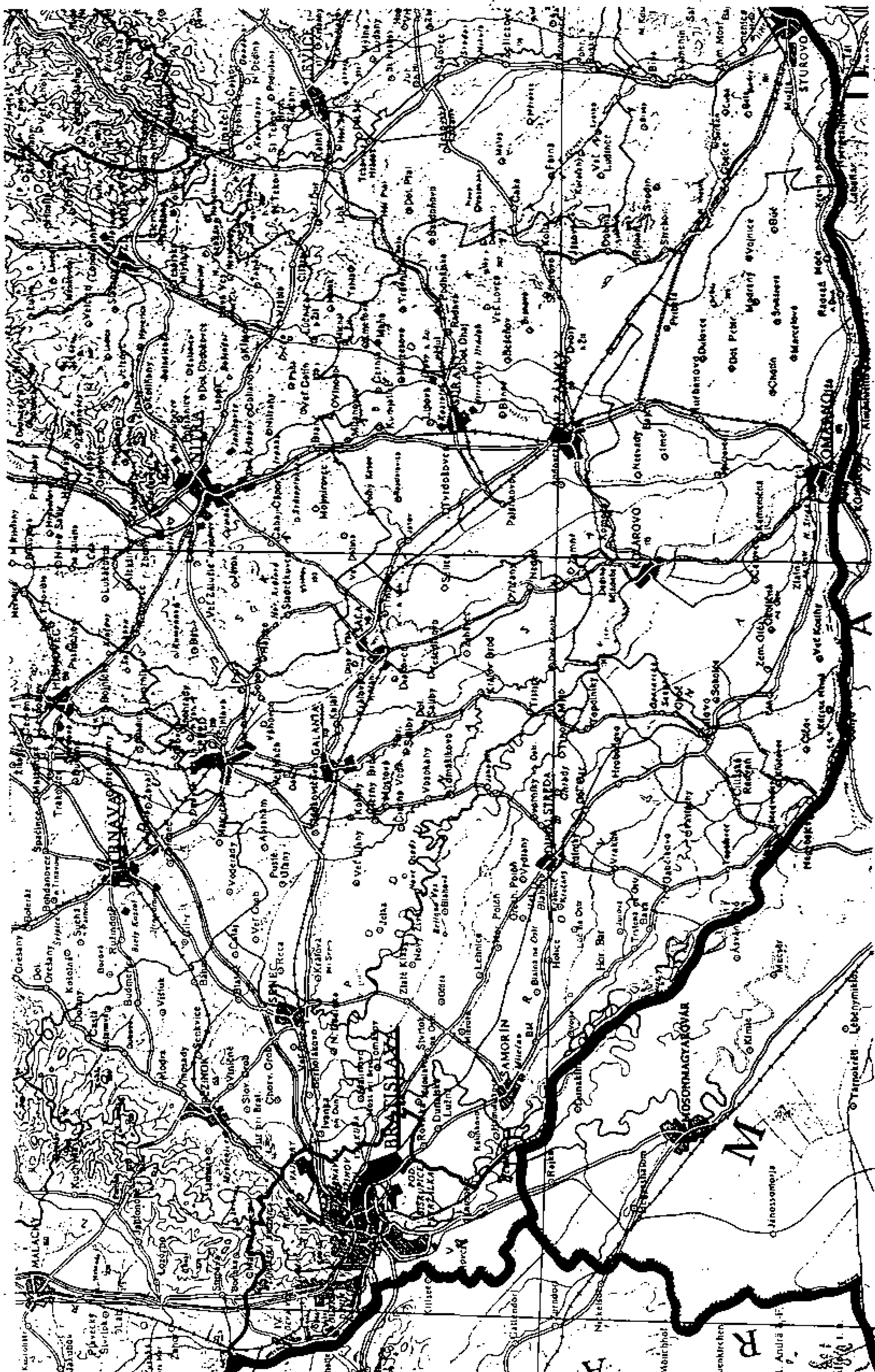


Fig. 1.1: Map of the Danubian Lowland

represented by clays, sandy clays, fine sands, sandstone, all of relatively very low permeability.

The depression originated in the Pannonian era and developed up to the end of Pliocene. It was a subsidence by bending, partly compensated by subsidence along faults. The depression has a dish - like brachysynclinal structure without respect to the pre-Pannonian basement. In the north side, the depression is bordered by the Carpathians Mountains and in the south it ends southwards from Danube in the Mosoni - Danube area. At this border the Danubian sediments change into less permeable sediments of rivers Lajta, Rabca and Raba. The thickness of the complex of interest, Quaternary - Rumanian era river Danube sediments, ranges from 5 to more than 450 m.

The Danube is a dynamic river with its considerable natural water flow and high water level fluctuation. On Bratislava gauge station, the minimal, average and maximal measured flow rates are 570, 2025 and 10254 m^3/s with the amplitude of water level fluctuation more than 8 meters. The river bed consists mainly of extreme permeable gravel and coarse sand. The hydraulic gradient slope downstream from Bratislava ranges from 0.03 to 0.04 % and downstream from Gabcikovo from 0.01 to 0.03 %. This gradient and the high flow rate determine the coarse composition of the grain size characteristics for the river bottom sediments, which are nearly without particular organic matter.

The river Danube creates an intercontinental delta downstream from Bratislava, passing granite threshold connecting the Alps and the Carpathians, which means, that the river is flowing on its own sediments and is lying above the surrounding area. This is the reason, why the river Danube recharges the aquifer during the whole year. In the past, ground water level was near under the surface and the Danube was divided into numerous meanders and river branches (Fig. 1.2). Compare historical maps.

The main characteristics of the area can be summarized as follows:
- a low lying, gently sloping plain area;
- weak surface layer formed by fine humid materials and soils, with variable thickness from tens of centimeters up to three meters;
- thick alluvial aquifer (the river Danube gravel deposits) with thickness from 5 m up to over 300 m, with great variability of particle size distribution and extremely high hydraulic conductivity (between 0.01 and 0.0001 m/s) intercalated by fine lenticular sands and meander deposits;
- continental climate of Central - European type, with well differentiated meteorological seasons; rainfall ranges from 500 to 700 mm/year; temperature from -15 up to over 30° C;
- river conditions of Alpine - continental type, affecting the aquifer through direct recharge;
- wide river meanders with dynamic water regime with changing water levels and with regular flooding;
- unique and valuable fauna and flora resources;
- ground water is affected quantitatively and qualitatively by the Danube water;
- in the upstream part of the area, the river Danube water infiltrates into the aquifer throughout the whole year.

Main resources of the territory are:
- intensive and diverse agriculture, using irrigation in the upper part and drainage in the lower part of the area;
- intensive floodplain forestry;

Fig. 1.2: Map of Bratislava (Preszburg) with the Danube branches (from 1712)

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- water supply works of large capacity;
- spread livestock breeding;
- industrial activities, mainly in the field of food and wood processing, important chemical and petrochemical complexes;
- extreme large ground water resources which are in danger of agricultural and industrial pollution and degradation;
- riverside woods, vegetation and fishery;
- tourism;
- large water power potential;
- international ship water way and harbor;
- natural and ecological resources.

1.1. GEOLOGICAL CONDITIONS

The survey of geological conditions was performed since the half of the 18th century. Results of the survey and research are presented mainly in the geological maps issued in the 1:200000 scale, the sheets of Bratislava - Vienna, Nove Zamky - Calovo, Nitra and in various geological monographs. New knowledge was obtained during the survey for the construction of Gabcikovo - Nagymaros hydropower station scheme, by the survey of geothermal waters and geothermal energy, within the ground water resources research, protection and exploitation, etc. At least 30 deep wells and geothermal wells were drilled which verified younger parts of sediment content of Danubian Lowland depression (Quaternary, Rumanian, Dacian age). Apart from this, a lot of shallower wells, but deeper than 100 m, were drilled during the hydrogeological and engineering geological survey. We would like to quote Hungarian hydrological magazine Hidrologiai Közlönyi 3/1990 in which is stated, that to find out geological structure in Hungarian part of area of interest was drilled 400000 regular meters of drill work.

Evidence of joined comprehensive elaborate of investigation results is in the report: "Joined Agreed Project, Comprehensive documentation - basis engineering geological research, part 0-7-1.1" elaborated in year 1978 both in Slovak and Hungarian language and it is owned by both sides.

A systematic investigation of Quaternary sediments of the Danubian Lowland has been performed at the Geological Institute of Dionyz Stur in Bratislava. A summary is presented e.g. in the "Explanation of the geological map of the SE part of the Danubian Lowland 1:50000 scale" [18]. A number of geological works performed during the engineering geological and hydrogeological survey for the Gabcikovo - Nagymaros scheme contributed to the special engineering and ground water purposes. Since 1989, a program "Danube Region Environmental Geology - DANREG" is performed. Results of this program will give a complex knowledge of geological - environmental situation of the region. The final report is supposed to be elaborated in 1995. Since 1992, the PHARE Project "Danubian Lowland - Ground Water Model" [2, 3] is performed. Also this project will be completed in 1995.

In Pannonian, the sea (the Caspian brackish lake) covered the area to the NW up to Vienna gate over the Vienna basin. Throughout the Pannonian vertical movements repeated several times, causing local regressions and transgressions and synsedimentary activity of faults is apparent. The Danube, as a major river with many tributaries, originated in the age of upper Pliocene - Rumanian and it was following the regressing sea. This is related to the tectonic movements, mostly the rising of Alps and Carpathians. The last orogeneous phase, between Pliocene and Pleistocene, is particularly important. Following the regressing sea, a river network in the end of the upper Pliocene begins to form in the bottom and middle part of the Danubian Lowland [13]. The fresh water flowing lakes had originated, in which bed load and suspended load began to sediment, brought by the Danube and its tributaries. Sedimentary material originated from the rising Alps and Carpathians. Originally, the ancient Danube was entering the Danubian Lowland through the Kärnten gate, later it penetrated the Lower Carpathians mountain range by Devin, at the place, where a transverse faults pass, in between which a small depression called Devin gate was created.

In the end of the upper Pliocene, the Danube made its way to the Great Hungarian Flat between Nagymaros and Visegrad. In the central and lower part of the Danubian Lowland, a lacustrine - fluvial conditions of sedimentation were being created with littoral sedimentation of coarse - grained sediments as well, and sublittoral sedimentation of fine - grained sands and mud, which is dependent on the flow velocity in lakes. At the beginning, this occurs as a result of the Pannonian sea regression by a gradual transformation to brackish or even fresh - water conditions in the bordering parts, and later, in relation with rising of the Hungarian Central Mountains, to a lake - fresh water conditions. As an evidence of this, the alluvial terraces above the Danube by Esztergom may be mentioned. A relative subsidence of the Danubian Lowland continues in Quaternary as well, but since Mindelian age, without lacustrine - fluvial conditions, because the Danube was quick enough with filling up of the subsiding area with gravel - sand fluvial sediments, even an alluvial cone was created, rising over the surrounding surface.

The Rumanian sediments themselves (upper Pliocene) respond to the sediments of the ancient Danube, which settled into the lacustrine environment. They are called, in the work [15], the "Gabcikovo sands". Parallel with them, further to the east, the "Kolarovo formation" is found, which settled in a more peaceful conditions with sediments transported from the Carpathian's area. Sedimentation of "Gabcikovo sands" in a lacustrine conditions is proved [15] by the grain - size difference in comparison to the Danubian gravel - the fluvial Danubian gravel is very coarse - grained, 10 - 17 cm, the gravel of the "Gabcikovo sands" is fine grained to a middle grain size. Besides of this, the Danubian gravel is usually colored by limonite, proving the presence of oxidizing conditions, but the color of "Gabcikovo sands" and fine gravel ranges from gray to green - gray without this limonite coating, which proves presence of anoxic conditions of a calm lacustrine sedimentation. There is an apparent discordance between the lacustrine sedimentation of "Gabcikovo sands" and the Danubian gravel [15], and an intensive erosion of previous sediments after the regression of lakes. Certainly, in the Danubian Lowland, there exist river alluvial sediments of the Danube and its tributaries, mostly of the Vah and Nitra rivers, and river sediments settled in a lacustrine conditions as sediments of rivers' deltas. Besides of these, there are the sediments of littoral and sublittoral zone, and this all is influenced by the gradient of surface and its changes within the relative subsidence of the depression center, and by the petrographic consistence of rocks, from where the fluvial material was transported. All these influences are finally shown up in the hydraulic conductivity and grain - size specific surface of the complex in relation to position and depth.

In the area of interest on the west side, there is a lacustrine sedimentation of "Gabcikovo sands" and gravel in Rumanian, which was settled mostly by the ancient Danube and the Carpathians ancient streams, and simultaneously, on the eastern side, there exist a lacustrine sedimentation of "Kolarovo formation", settled by the Carpathians ancient streams (Vah, Nitra). To these sediments, the fluvial - lacustrine Danubian sediments are deposited discordantly in the Gabcikovo depression, and a shallow - lacustrine or river lacustrine sedimentation of the "Kolarovo formation" continues on the east side until the Mindelian period. The commencement of Mindelian was simultaneously followed by uplifting and subsiding tectonic processes. In the western part, a river sedimentation of a massive alluvial cone begins to prevail, and in the east, the Danube is shifted to north and east and begins to flow to the Hungarian flat through the area, as it is known nowadays.

The border between the Danubian fluvial - lacustrine and lacustrine sediments and the lacustrine sediments of "Kolarovo formation" passes from Sala via Calovo to Cicov. This border is very approximate because the individual kinds of sedimentation were mutually alternating and overlapping. We remind, that in the Danubian sedimentation area, the lacustrine sediments called the "Gabcikovo sands" settling approximately until the upper Mindelian, continue into a shallow lacustrine and river - lacustrine sedimentation of "Kolarovo formation". The shallow lacustrine and fluvial - lacustrine sedimentation continues, in fact, in the lower Vah stream area until nowadays while, in the Zitny ostrov area, a typical river sedimentation of the Danubian gravel continues creating alluvial cone, the so called continental delta.

1.2. HYDROLOGY AND GROUND WATER

Long-term hydrological development of the Danube region in the past was influenced mainly by river regulations, straightening of bed, closing or raising the entrance threshold of meanders. River regulation works, exploitation of sand and gravel, construction of river dams upstream from Vienna altered the bed-load balance. The bed-load transport via Bratislava was diminished and the river bed erosion increased. Investigation showed the substantial deepening of the river bed and the trend to further erosion of the river bottom. This caused a long-term lowering of water level in the Danube which resulted also in long-term lowering of ground water levels not only in the riverside areas, but on the whole area under consideration.

The Danube inundation riverine area (floodplain area - Fig. 1.3 - part of inundation saved in pre-dam conditions, in Austria it is called "Au"), contains a floodplain vegetation, especially forests, which have been largely influenced by deepening of river bed and thus lowering the ground water table and extremely influenced by unnatural closing of entrance thresholds of meanders and river branches (Fig. 1.4). It is noticeable that vegetation is suffered from shortage of water and the character of forest have been changed. The inundation wood vegetation as well as the riparian and aquatic plant families are affected and threaten to lose their typical "Au" character changing continuously from oxidizing to reducing conditions of "polders" with stagnating water or without water. The result consists in unnatural sediments of reduction conditions in closed river branches (Fig. 1.5). River banks have been fortified and the contact with the river branches have been destroyed. The Danube is more or less straighten artificial canal, self-cleaning ability of river is reduced. Inundation is not washed out, organic sediments arise and large parts of ground water are degraded (e.g. locality Dobrohost, where waterworks of capacity of 10 m^3/s was previously proposed and now abandoned because of large contents of nitrite and ammonium salts). This process would continue if the hydrological conditions of the Danube were not changed.

Ground water of a large part of the Danubian sedimentation area is of oxidizing conditions and of a high quality. Save yield was estimated at 20 m^3/s and approximately about 4 m^3/s

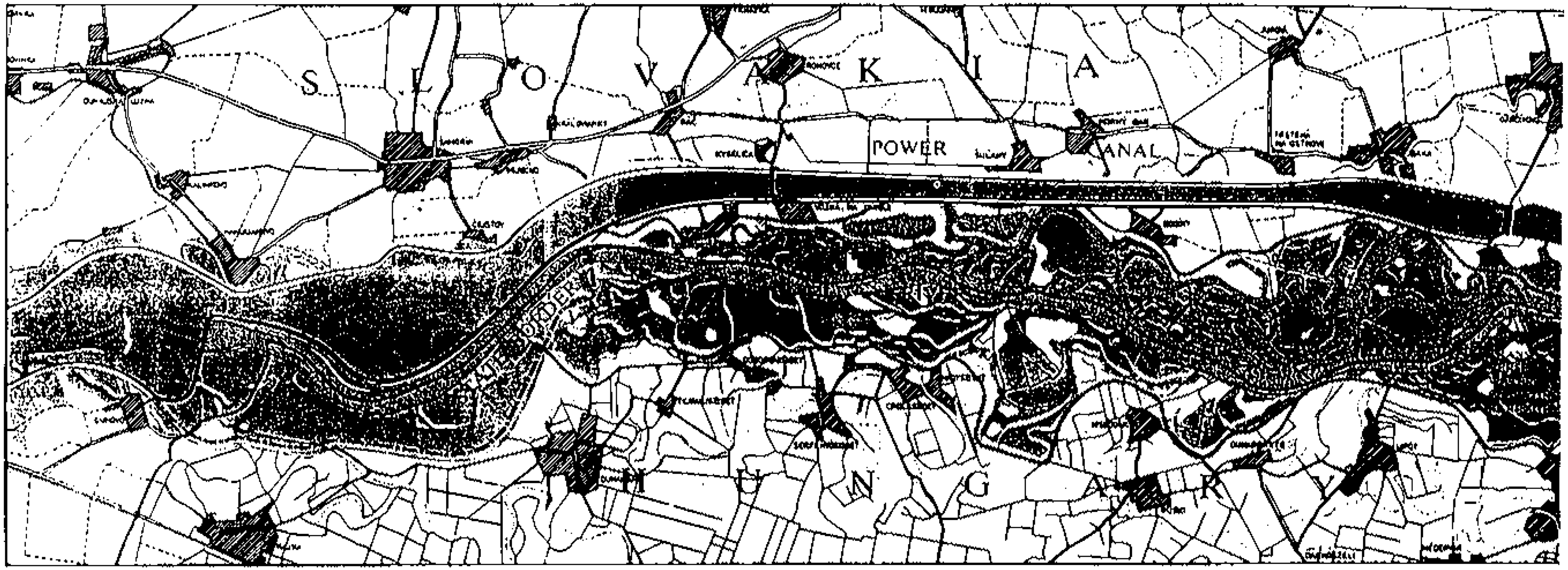


Fig. 1.3: Meanders and riverside woods

figure omitted

figure omitted

Fig. 1.4: Closure of river branch in Hungary

figure omitted

Fig. 1.5: Sediments in river branches with previously stagnant water

of this ground water is used for water supply directly without treatment (only chlorinating of water is used).

Decreasing of ground water level influenced the agriculture in the past. Not to lose the crops, irrigation was introduced. Introduction of irrigation means larger contamination of ground water, need of larger quantity of fertilizers and other agrochemical products. Under irrigation conditions the possibility of direct ground water contamination is much larger.

Agricultural activities are leading to contamination and degradation of ground water. The main problems are nitrate and pesticides, leaching of organic matter into aquifer, changing an oxidation state to reduction one, pollution by fuel, oil, etc., concentration of manure, sewage and other wastes and improper tillage and irrigation practices.

1.2.1. Regime of Discharge and Water Level in the Danube

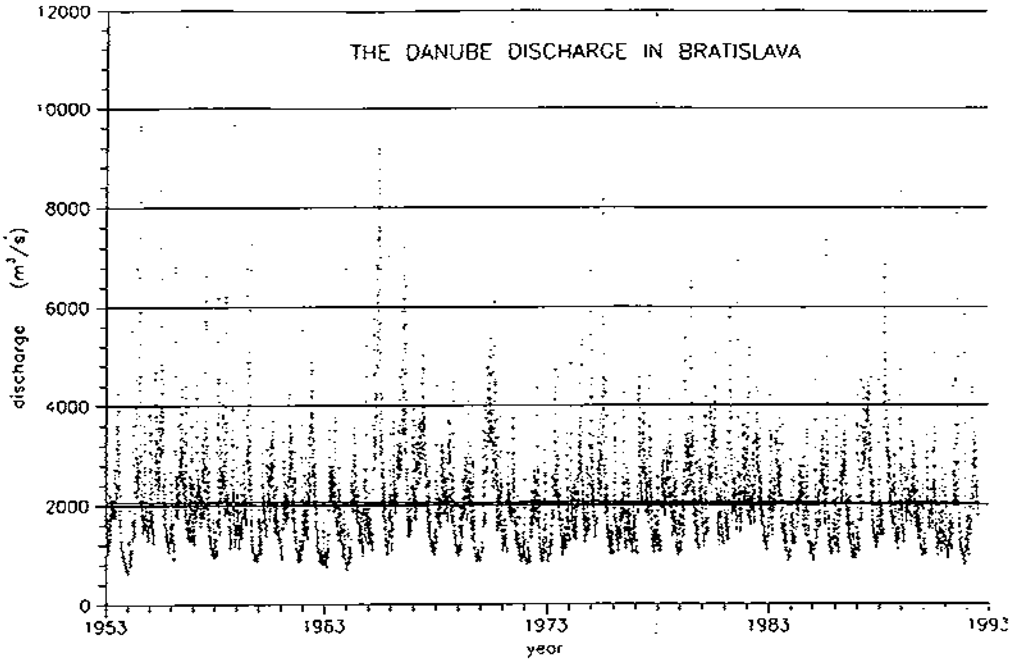
Regime of discharge and water level in the Danube is represented by discharge and water level fluctuation at gauging stations. The Danube discharge in Bratislava and Komarno in the period of 1953 - 1993 is presented in Fig. 1.6. The water level in the Danube measured in Bratislava, Gabcikovo, Medvedov and Komarno is presented in Figs. 1.7, 1.8. From the first view it is evident, that the discharge is more or less stable and water level is continuously decreasing. To express better the long-term development of discharge and water levels, the linear regression line is plotted. Equation of the linear regression is of the form

$$h = a * ((y - 1953) * 365.25 + d + c) + b \qquad (1)$$

where y is year,
d - number of day in the year,
a, b, c - parameters of eq. (1).

Table 1.1: Parameters for calculation of discharge and water levels using eq. (1)

Station	rkm	item	a	b	c
Bratislava	1868.7	disch.	-0.00175812	2099.86	19357
Bratislava	1868.7	level	-0.000119725	134.68	19357
Rusovce	1855.9	level	-0.000100193	128.013	1827
Gabcikovo	1819.6	level	-0.0000185326	115.213	1824
Medvedov	1805.4	level	-0.0000960211	112.638	9495
Klizska Nema	1792.4	level	-0.000104016	110.316	9495
Zlatna na Ostrove	1779.2	level	-0.0000891445	108.808	12782
Komarno	1767.1	disch.	-0.00681133	2406.99	12782
Komarno	1767.1	level	-0.0000571844	107.436	12782



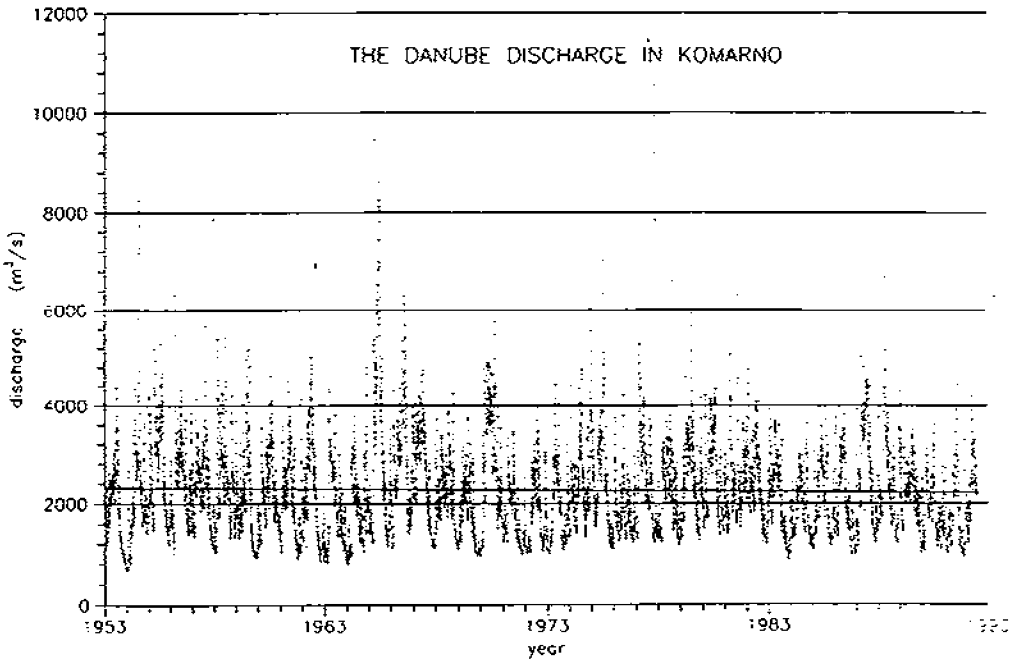


Fig. 1.6: The Danube discharge in Bratislava and Komarno

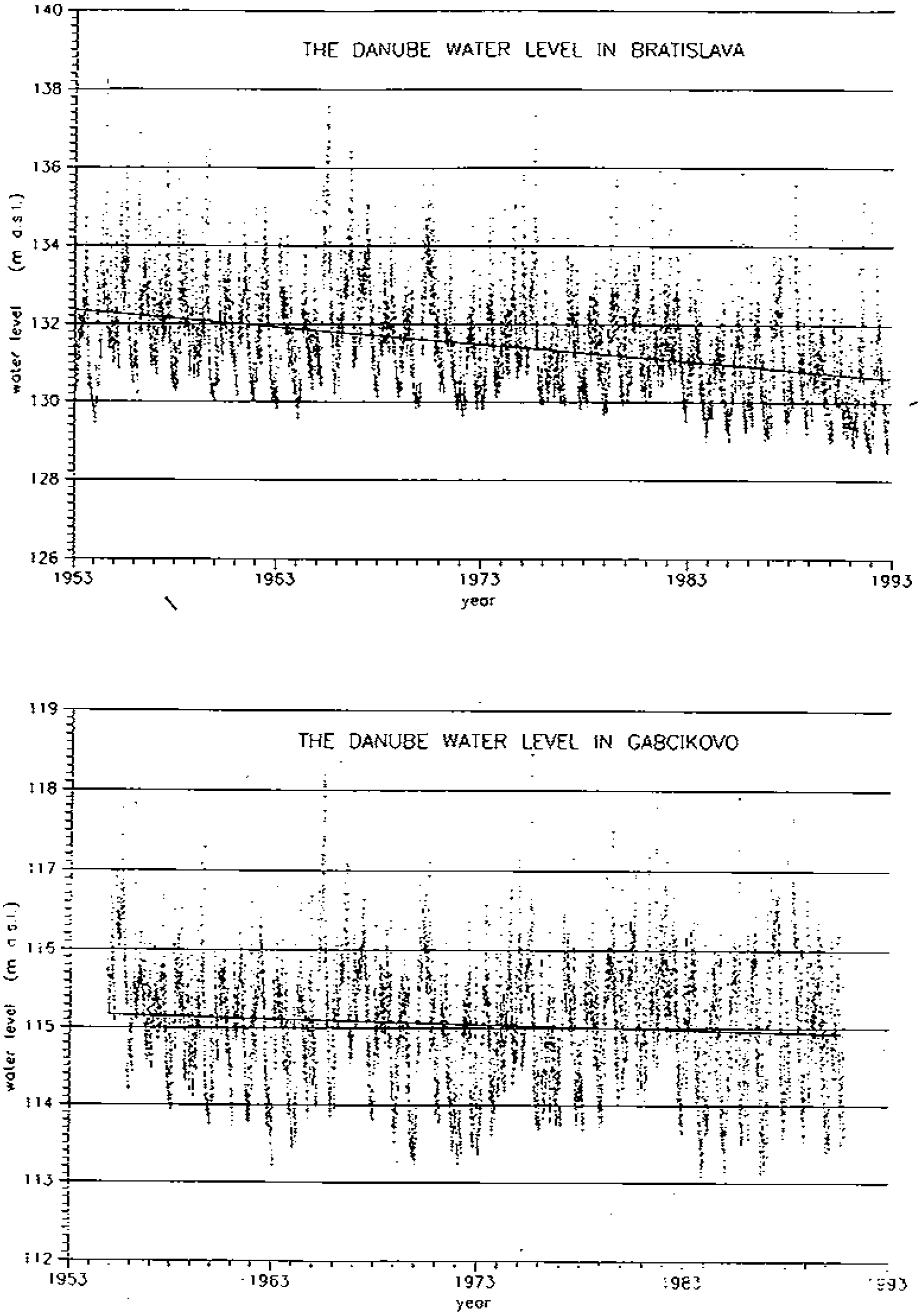
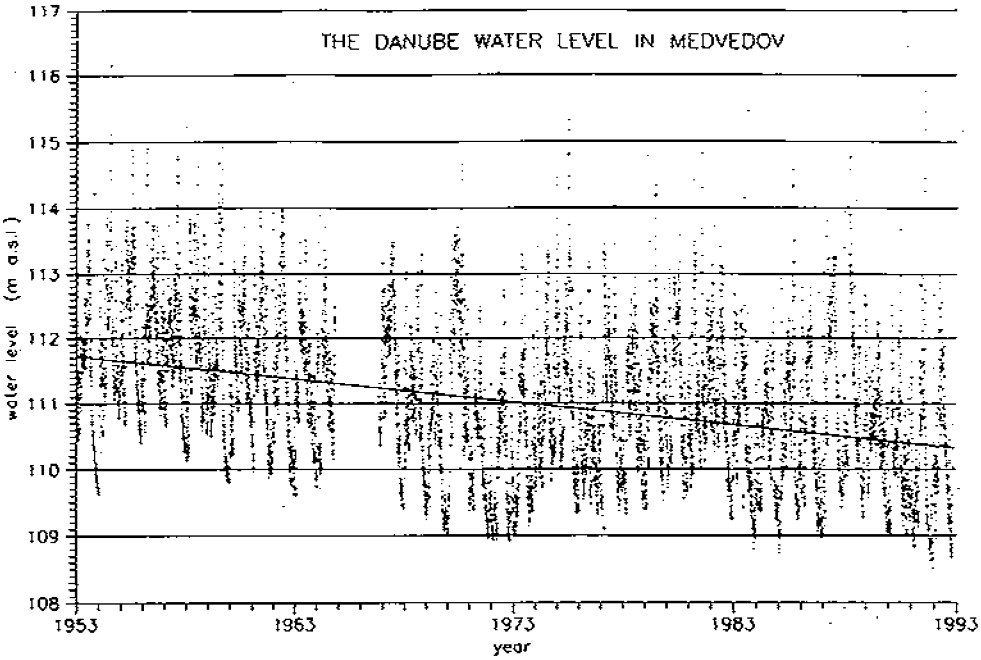


Fig. 1.7: The Danube water level in Bratislava and Gabcikovo



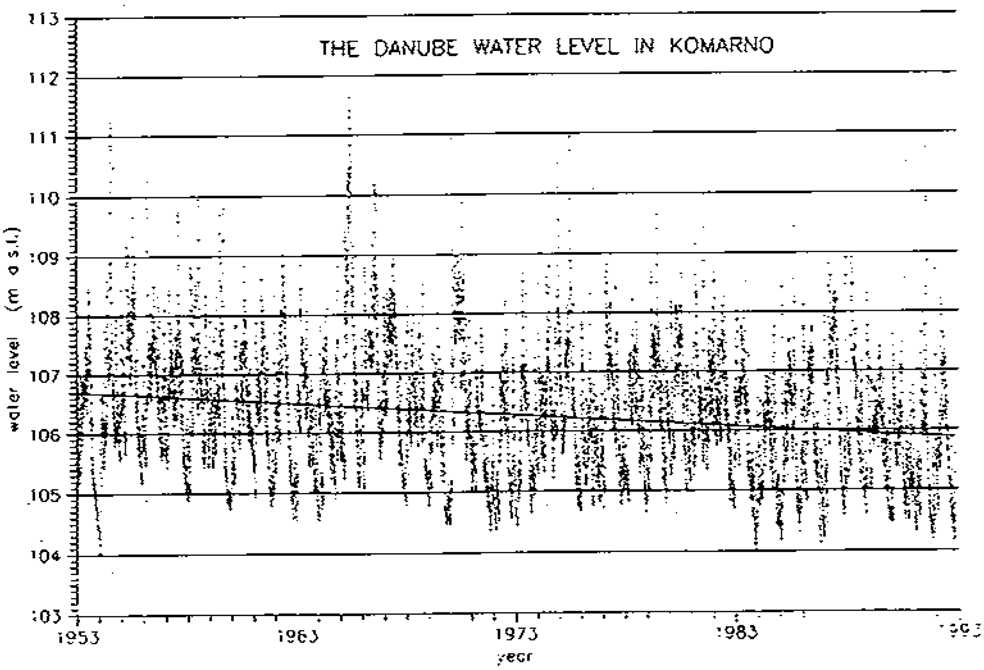


Fig. 1.8: The Danube water level in Medvedov and Komarno

Discharge and water levels, calculated by eq. (1) are considered for referential ones. Reference water levels for the years of 1963 and 1993 and their differences are given in the Table 1.2.

Table 1.2: Computed reference values of discharge and water levels for various gauging stations

Station	rkm	item	1.1.1963	1.1.1993	difference
Bratislava	1868.7	discharge	2059.40	2040.14	19.26
Bratislava	1868.7	level	131.93	130.61	1.32
Rusovce	1855.9	level	127.47	126.37	1.10
Gabcikovo	1819.6	level	115.11	114.91	0.20
Medvedov	1805.4	level	111.37	110.32	1.05
Klizska Nema	1792.4	level	108.95	107.81	1.14
Zlatna na Ostrove	1779.2	level	107.35	106.37	0.98
Komarno	1767.1	discharge	2295.04	2220.41	74.63
Komarno	1767.1	level	106.50	105.87	0.63

Decreasing of the discharge is very small and therefore the drop in the water level is due to deepening of the river bed.

Decrease of the water level in the Danube is one of the factors yielding to decrease of ground water level, decrease of infiltration rate and it is changing the ground water flow.

Decrease of water level in the Danube together with closure of river branches, because of navigation, was the main long-term negative factor upon the riverside forests and vegetation.

1.2.2. Ground Water Level Regime

The ground water level regime is manifested by its fluctuation, usually measured in regular intervals in hydrogeological wells (wells, piezometers). There is a basic network for observing ground water level fluctuation on the territory of the Danubian Lowland, where the Slovak Hydrometeorological Institute (SHMU) performs continuously or weekly measurements (Fig. 1.9). Similarly, the water stages and discharges on the Danube, Little Danube (Maly Dunaj), Vah, and in chosen canals are processed.

Examples of ground water level fluctuations are presented in following figures. The SHMU well No. 685, situated close to the Danube river channel within the floodplain area, is shown in Fig. 1.10. The ground water level fluctuates in direct dependence upon the Danube river fluctuation. Water level fluctuation in the SHMU well No. 612, occurring in the lower part of the Danubian Lowland, can be seen in Fig. 1.10. Water level rising during the flood in 1965 is clearly visible. The typical example of changes of different effects is presented in Fig. 1.11. There is shown the ground water level fluctuation in some observation wells situated in various distances from the Danube and the fluctuation of the Danube water level.

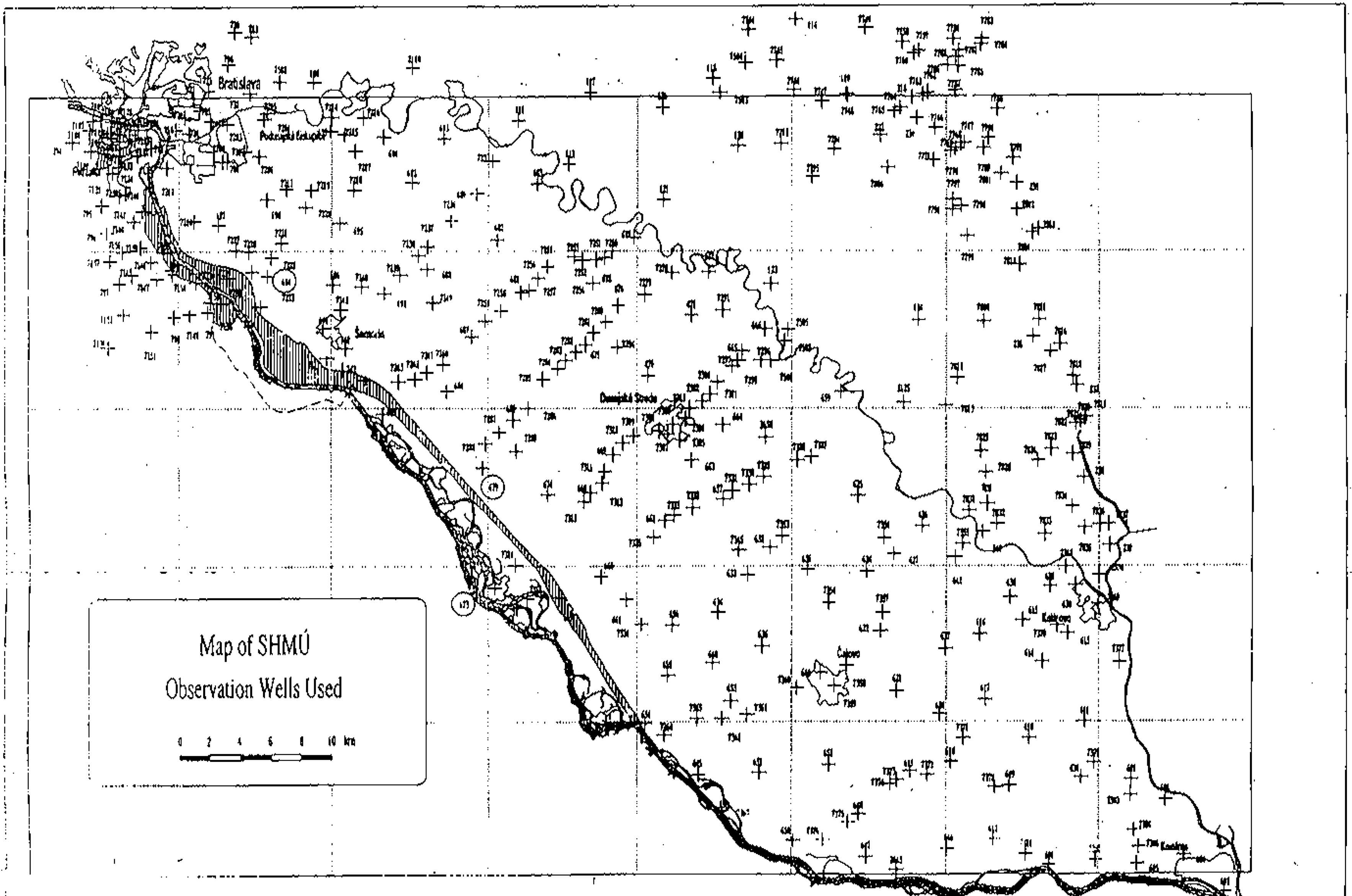


Fig. 1.9: Map of ground water observation wells of SHMU

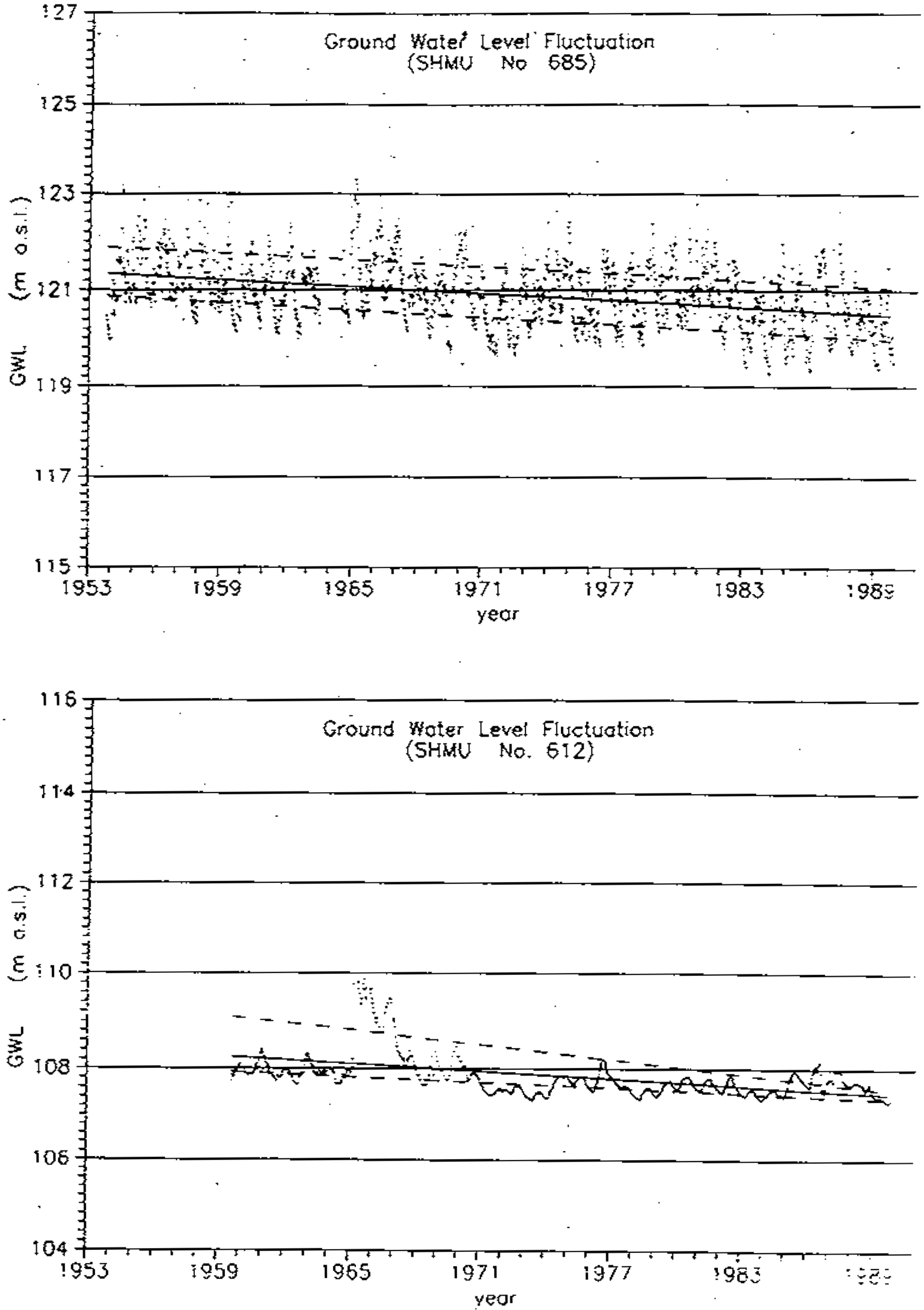


Fig. 1.10: Ground water level fluctuation in the SHMU wells No. 685 and 612

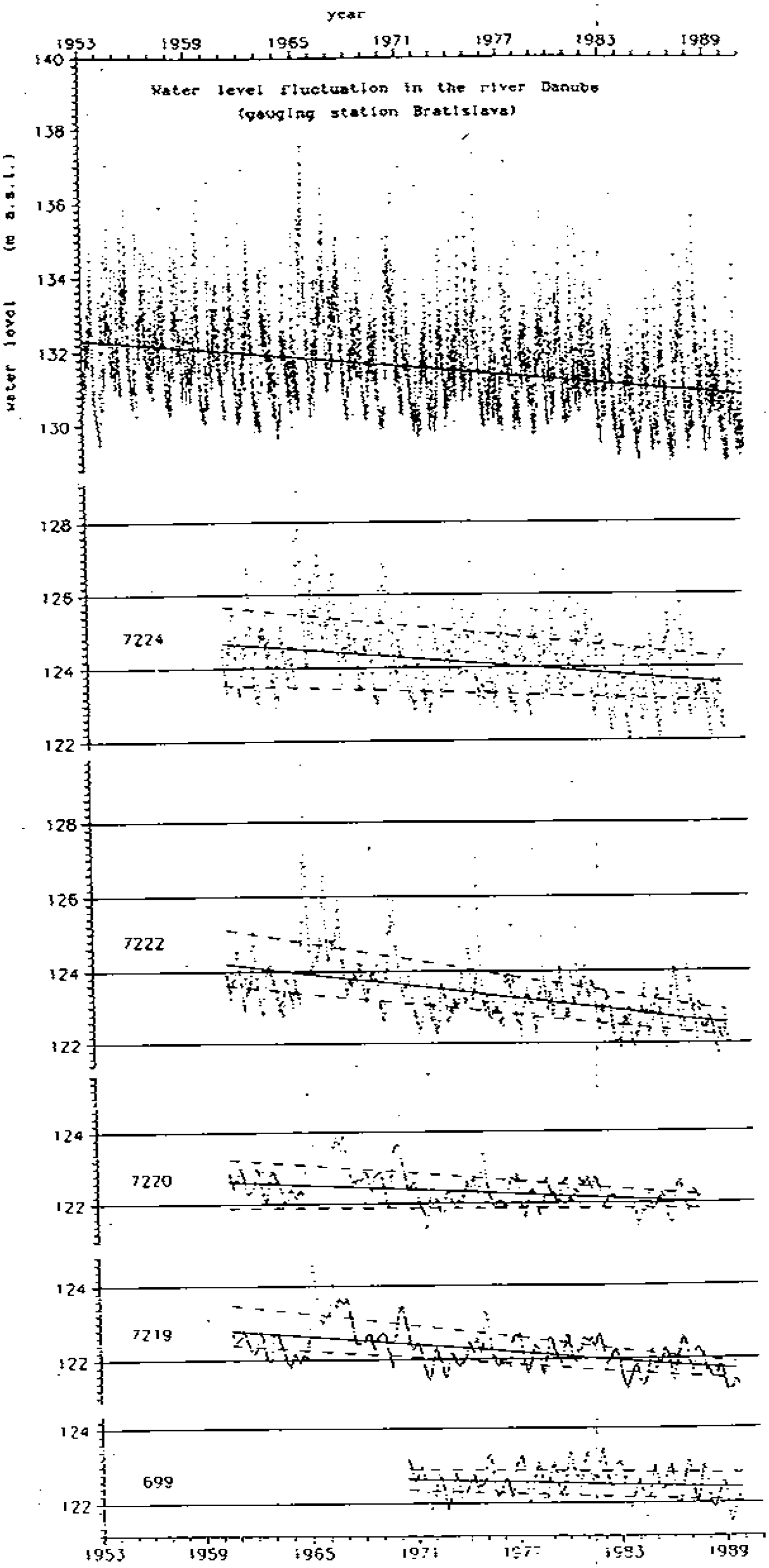


Fig. 1.11: Water level fluctuation in the Danube and ground water level fluctuation in the SHMU wells across the area

It can be seen in the region close to the Danube (SHMU well No. 7224) that the ground water level fluctuation corresponds with the water level fluctuation in the Danube. In a large distance (SHMU well No. 699), the fluctuation is strictly dependent upon the season of the year and the relationship between precipitation, snow melting, and evaporation. There exists a transition zone in which the effects of the Danube or precipitation/evaporation are more or less influencing ground water level fluctuation.

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In Figs. 1.10, 1.11 it is shown the linear regression line, representing the drop of average water level in dependence upon time in a long-term period. Above and below this line there are lines (dashed) representing the linear regression of points, situated above and below the average line. The range between the upper and lower dashed line represents the average ground water level fluctuation. Such expression of observed values confirms a gradual ground water level decreasing on a large part of the territory and at the same time, it shows the changes in amplitude of ground water level fluctuation within a long-term period. It is evident, that there are many circumstances influencing the ground water regime and that the application of the linear regression is not an ideal method for the evaluation of the changes in regime of ground waters in time. Such data processing was aimed only at the documentation of the long-term trend of changes of the ground water level fluctuation regime.

The average ground water level, represented by the linear regression line for a concrete time (date), is considered as a reference water level, from which the water level changes within a long-term period may be deduced. The values of the water levels in the SHMU wells (Fig. 1.9) for the years 1960 and 1990 were used for drawing up the maps of ground water level contours (Fig. 1.12), the map of difference lines (Fig. 1.13) and the map of ground water depths below the surface (Fig. 1.13). We also draw the attention to the influence of the second water source near Podunajske Biskupice and to the effect of the hydraulic protection well system surrounding refinery Slovnaft (Fig. 1.12) and to the substantial decrease of ground water level downstream of Bratislava (Fig. 1.13).

A considerable decrease of ground water level is evident in the upper part of the Danubian Lowland downstream of Bratislava during the last 30 years. For comparison, a map of ground water level contours at low water stage in 1954 is shown (Fig. 1.14), [12].

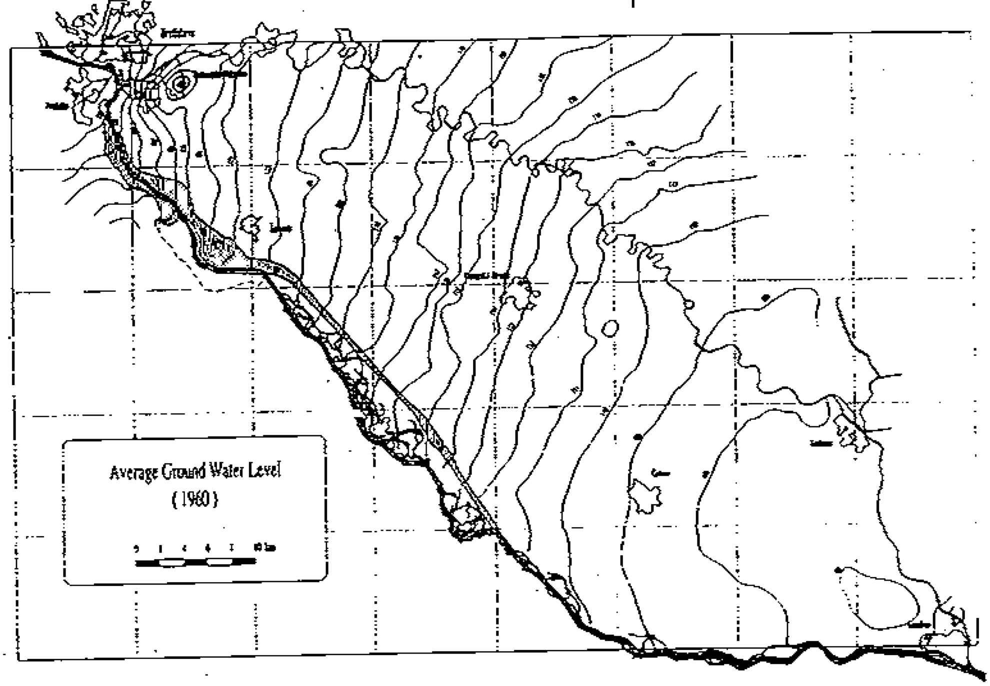
1.2.3. Ground Water Level Fluctuation Regime

The annual sums of weekly ground water level differences were computed (since the measurements have been performed weekly). The map of the summary annual amplitudes of ground water level fluctuation is shown in Fig. 1.15. The thick line in Fig. 1.15 is an approximate distance from the Danube where the water level fluctuation in the Danube influences ground water level fluctuation. Behind this boundary, ground water level fluctuation is caused by infiltration - evaporation relationship.

1.2.4. Influence of Ground Water Regime Changes

1.2.4.1. Influence of Ground Water Level Changes upon Agriculture

The hydrological and ecological regime in the area is subjected to a long-term trend of river bed erosion and decreasing of ground water levels.



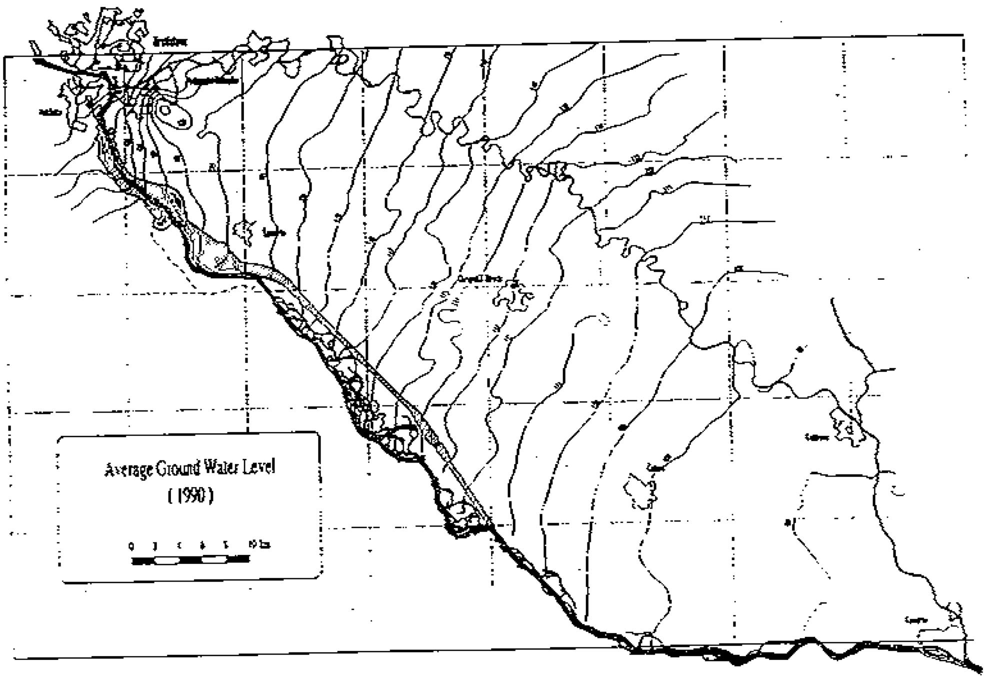
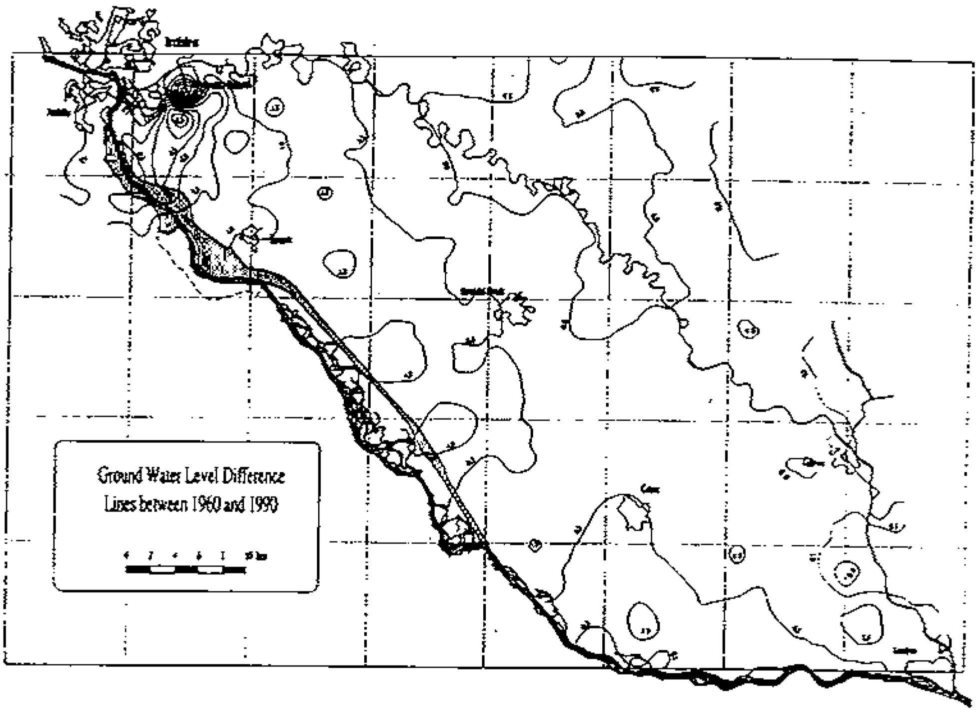


Fig. 1.12: Ground water level contour lines in 1960 and 1990



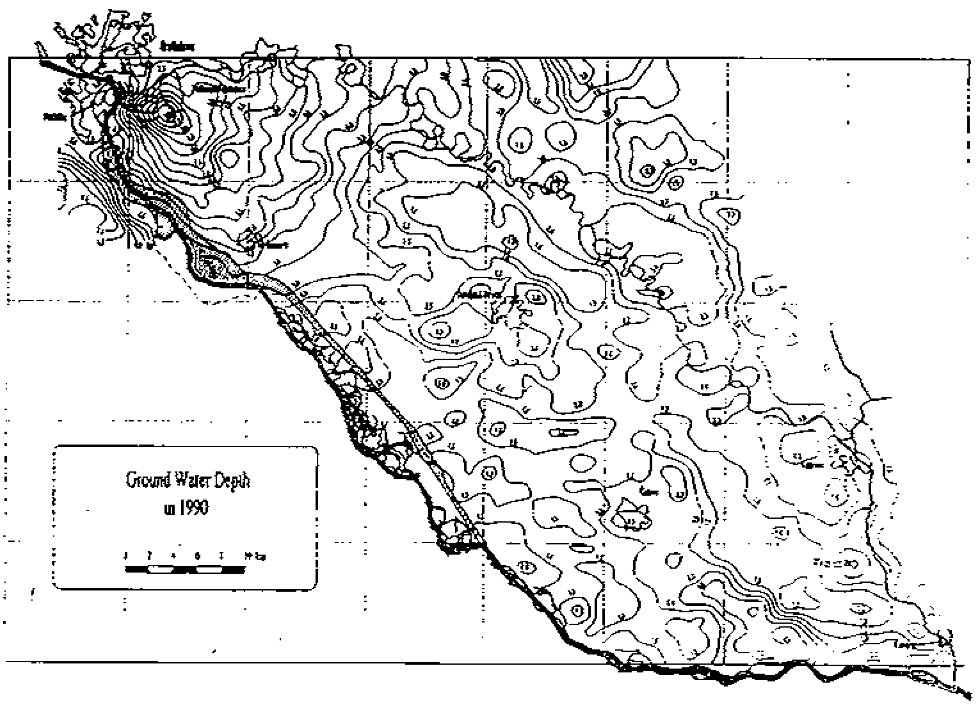


Fig. 1.13: Ground water level difference lines between 1960 and 1990 and ground water level depth in 1990

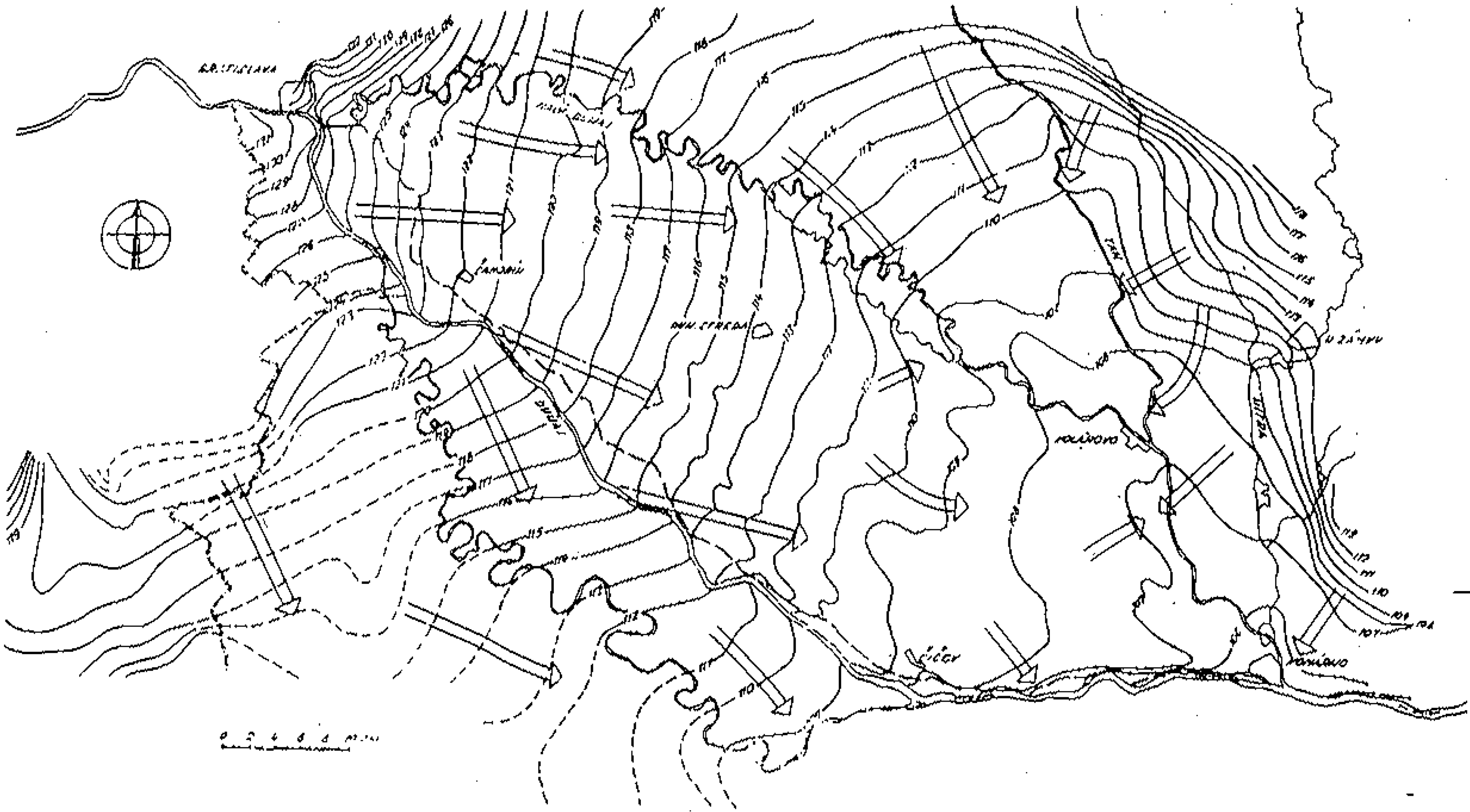


Fig. 1.14: Ground water level lines in SW part of the Danubian Lowland - low water stage, January 6, 1954 [12]

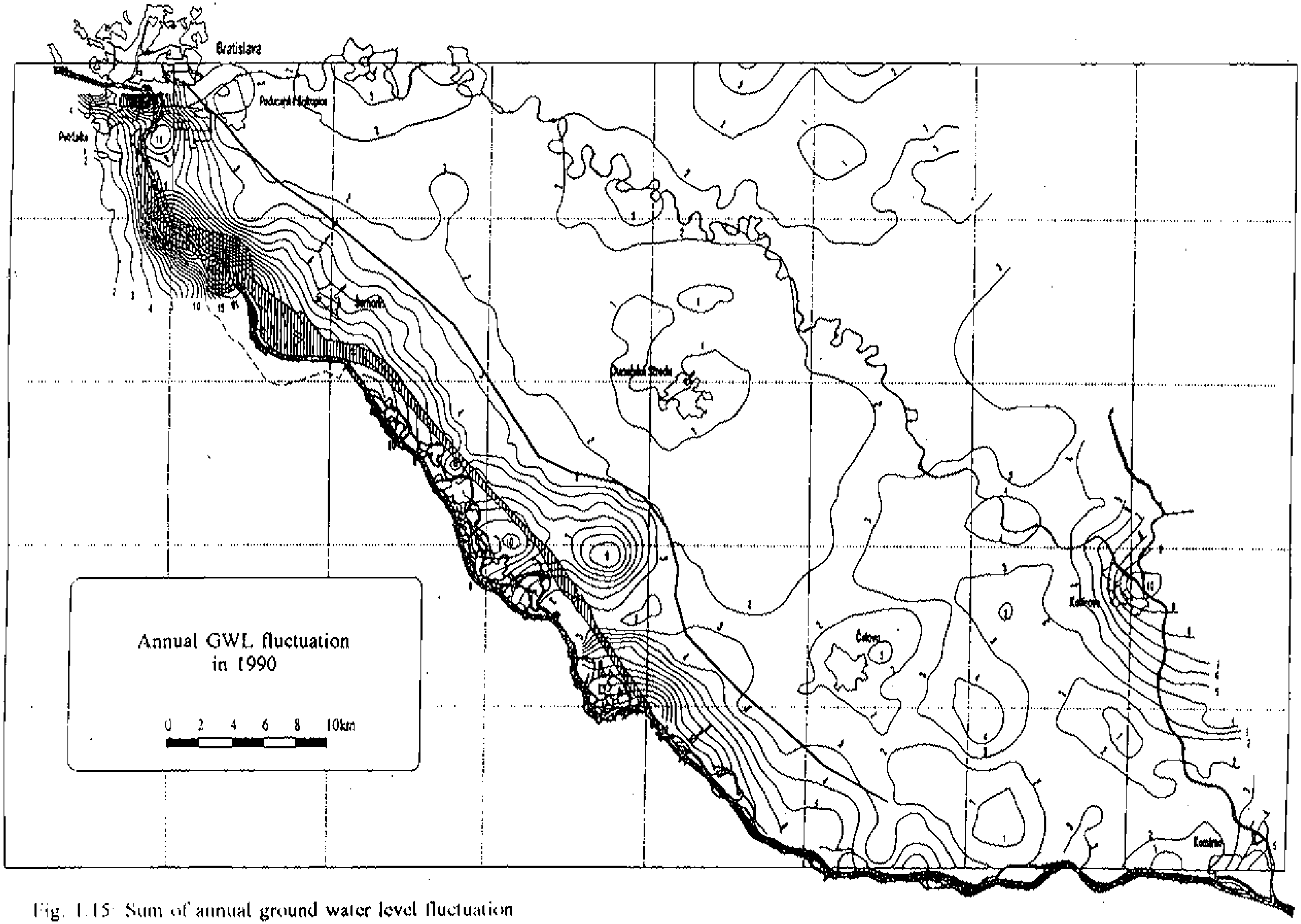


Fig. 1.15: Sum of annual ground water level fluctuation

The annual rainfall (500 - 700 mm) is much smaller than the need of water supply to the vegetation, especially during the summer season. This extra water supply was possible in the past throughout the area by vertically upwards flow in the capillary zone from the ground water table to the root zone. The necessary conditions for this are that the ground water table is not too deep and that no gravel layer is located over the ground water table. The pre-dam conditions are characterized by measured ground water level equipotential lines (Figs. 1.12 - 1.14).

However, due to the decrease in ground water levels during the past few decades, especially after the second world war, it has been necessary to make artificial irrigation for the agriculture. Thus, on the Slovak side, a comprehensive network of surface water canals has been developed for irrigation purposes. However, artificial irrigation has its disadvantages as compared to the natural situation because the downwards water flux causes a considerable leakage of nitrates, organic components, pesticides and other chemicals into the ground water.

1.2.4.2. Influence of Ground Water Level Decrease in Inundation upon Forestry

In the past, the measures taken for the navigation, constrained the possibilities for the development of the Danube and the floodplain area. The pre-dam trend with lowering of the Danube water level, endikements, cutting off the side branches upstream and fortification of the main channel has stressed the biotic communities substantially during the last decades. As a result of past ground water decrease (typical example is the SHMU well No. 673 situated at the village Bodiky, Fig. 1.16), some area of soft alluvial forests have been turned into hard alluvial forests. The latter were often cultivated with poplar and white willow. Furthermore, it is estimated that large part of the originally forest is not alluvial forest any longer. In addition, forestry has replaced many natural forests by plantation, where introduced cultivars of poplar have been used. Due to anthropogene effects, the dynamics and structure of alluvial forest were considerably disturbed and made the invasion of Solidago, Aster and Impatiens species possible.

Percentage of discharge in the Danube and its river branches, before cutting off and closing the river branches, is shown in the Table 1.3. The first number in the table is discharge in the main stream of the Danube, the number in brackets is the discharge throughout the river branches. It can be seen that e.g. from rkm 1833 to 1816, in the area of Gabcikovo, the discharge in the river branches was before the closing the river branches approximately 20 % of discharge in the Danube in Bratislava, also by low discharges. In the opposite, a short time before damming of the Danube the flow in some river arms started by discharge in Bratislava from 2500 - 3500 m^3/s. The flow in almost all river branches occurred when the discharge in the Danube was over 3500 - 4500 m^3/s. The main difference between the conditions in late 1950's and pre-dam conditions is, that in the far past the main river branches were supplied with water all the time but in pre-dam conditions less than 78 days in a year.

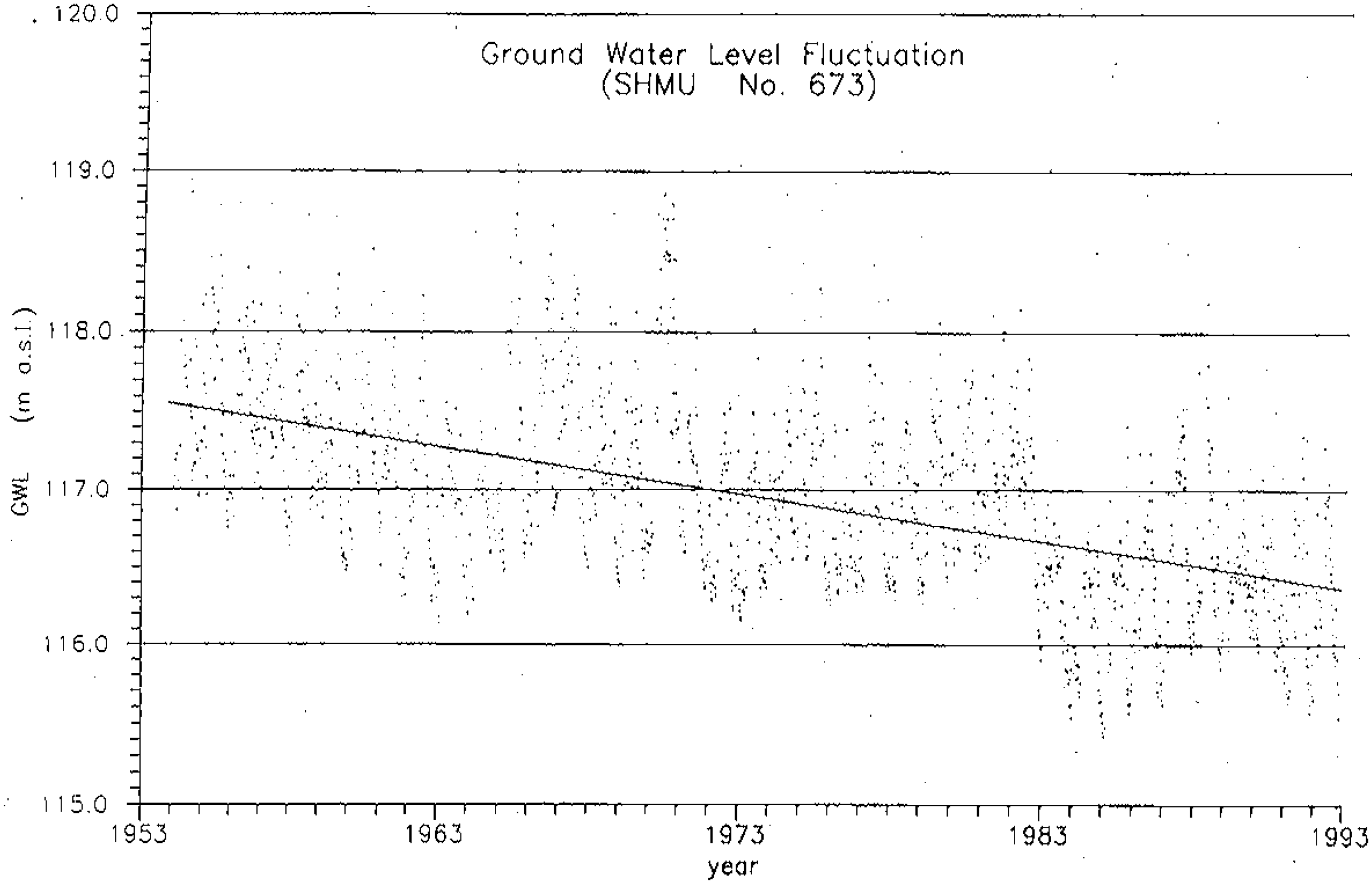


Fig. 1.16: Ground water level fluctuation in the SHMU well No. 673

Table 1.3: Percentage of discharge in the Danube and her river branches (Dub, Duba, Szolgay in [10])

		17.1.1961	21.9.1960	20.-22.6.1961	16.-17.5.1955
		Discharge in Bratislava (m^3/s)			
		1005	1958	2998	4002
	rkm	(%)			
Hrusov	1842.40	99 (1)	97 (3)	83 (17)	68 (32)
Sulany	1833.10	76 (24)	74 (26)	62 (38)	65 (35)
Baka	1825.00	88 (12)	96 (4)	78 (22)	67 (33)
Gabcikovo	1821.07	65 (35)	82 (18)	66 (34)	51 (49)
Istragov	1816.85	84 (16)	84 (16)	76 (24)	64 (36)
Palkovicovo	1810.40	99 (1)	85 (15)	68 (32)	63 (37)
Medvedov	1806.00	99 (1)	99 (1)	89 (11)	92 (8)
Klucovce	1802.37	99 (1)	99 (1)	90 (10)	99 (1)

1.2.4.3. Influence of Ground Water Level Decrease upon Water Resources

The city of Bratislava is supplied with water from the wells situated near the Danube at various places. Some of them are in the position where thickness of the gravel and sand sediments is very low. Pospisil and Kucera [17] estimated deep erosion of river bed in various places at the Danube (Table 1.4).

Table 1.4: Erosion of the Danube river bed (1964 - 1990)

Locality	rkm	decrease (m)	thickness of aquifer (m)
Sihot	1875	1.18	10 - 17
Pecensky les	1871	0.77	8 - 14
Bratislava - limnigraph	1868	0.45	8 - 15
Rusovce - Ostrovne Lucky	1856	0.41	15 - 45
Cunovo	1855	0.95	45 - 100

At locality Pecensky les, Pospisil [16] estimated the decrease of ground water inflow towards the system of wells of 30 - 40 % between the years 1973 - 1991. At the locality Rusovce -

Ostrovne Lucky, Pospisil and Kucera [17] estimated the shift of watershed divide towards Cunovo further from the Danube.

1.2.4.4. Influence of River Bed Erosion

The ground water level decreasing can be also studied with respect to geological conditions downstream of Bratislava. Fig. 1.7 shows that the Danube bed erosion is progressing. The basic problem creates the subsidence of the Danube bottom with respect to the geological interface between the gravel of the Danube sediment deposits and sub-surface sands of the Neogene age. Problems caused by erosion are well visible in Fig. 1.17, where the geological profile, worked out by the enterprise IGHP, is demonstrated in the site of planned subway under the Danube.

Thus the progressing process of the Danube bed erosion has not only a negative impact on present ground water level decreasing, on decreasing of the infiltrating amount into the Danubian Lowland region, but also on the possibility of a substantial erosion acceleration downward from the granite threshold upstream from the Bratislava castle, in places from the Old Bridge down to the winter harbor in Bratislava. It is emphasized, that the most significant factor of erosion is the water flow velocity and by influencing this velocity it is possible to directly influence the erosion and sedimentation processes.

Similar problems are known and described by Austrian water researchers Kresser [6], Zottl [8] and Prazan [7] and the cuttings from their articles are enclosed (see Appendix).

There is the imminent danger of the Danube river cutting into the Neogene sediments and consequent substantial acceleration of erosion, further ground water level decreasing and, naturally, also decreasing of well yields, especially in the region close to Bratislava. Thus, prevention of further erosion of the river bed and successive improvements (rising of the bottom) are more than advisable.

1.3. FORECASTING OF GROUND WATER LEVEL WITHOUT GABCIKOVO HYDROPOWER STATION

From the long term ground water level measurements based on statistical analyses, a long-term drop of ground water level was estimated. Based on the data evaluation, the extrapolation for the future was made. It means, that the forecasted ground water levels expressed in equipotential lines will be reached under conditions, that the processes yielding to ground water level decrease would continue without changes. According to our opinion, the river bed erosion will be speeded up after construction of hydropower station in Vienna Freudenau. In the Fig. 1.18, there is shown the real reference ground water level before damming the Danube in so-called pre-dam conditions in 1992. The forecasted ground water levels in 2022 are in Fig. 1.18. This means extrapolation 30 years after damming the Danube. It is evident that the forecasted changes, decrease of ground water level, are from all points of view, and especially from the point of view of ecology, very negative.

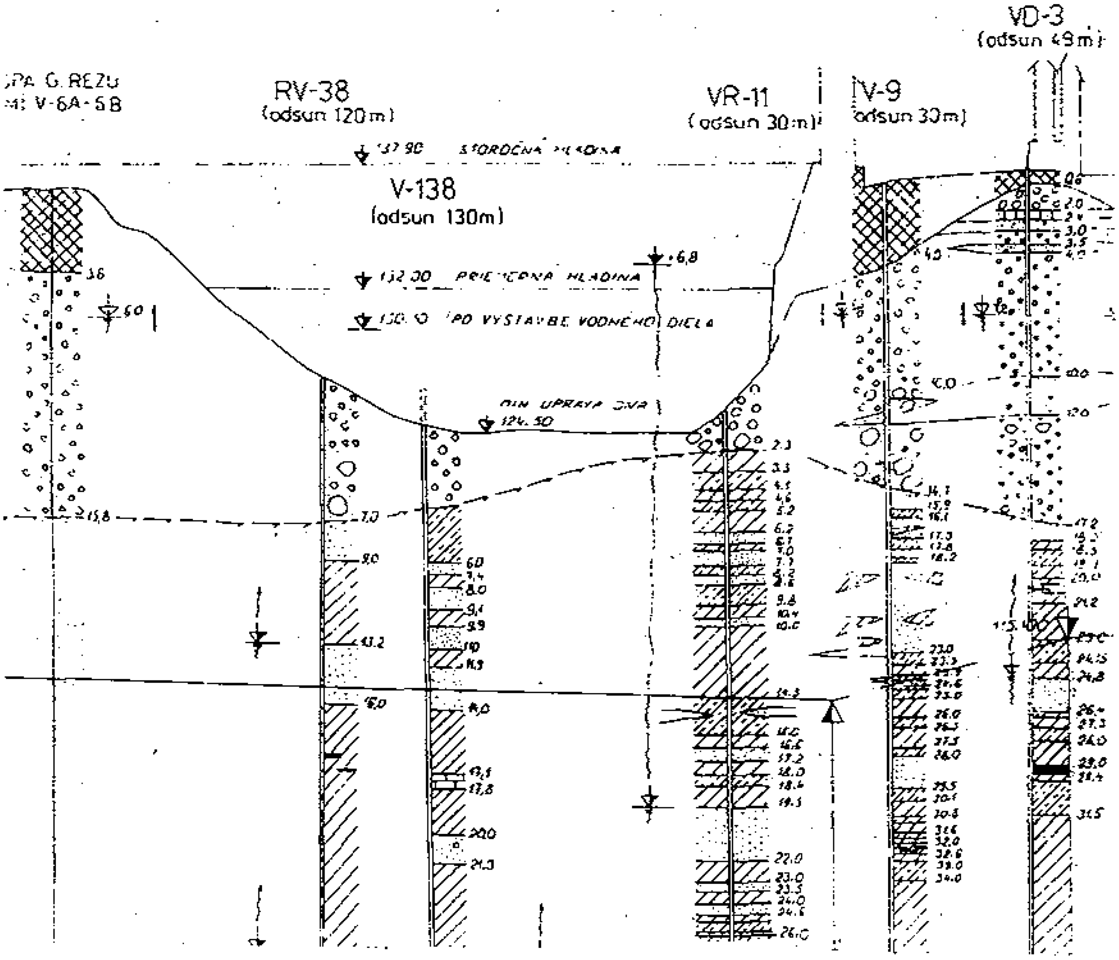


Fig. 1.17: Geological profile downstream of the Old Bridge in Bratislava

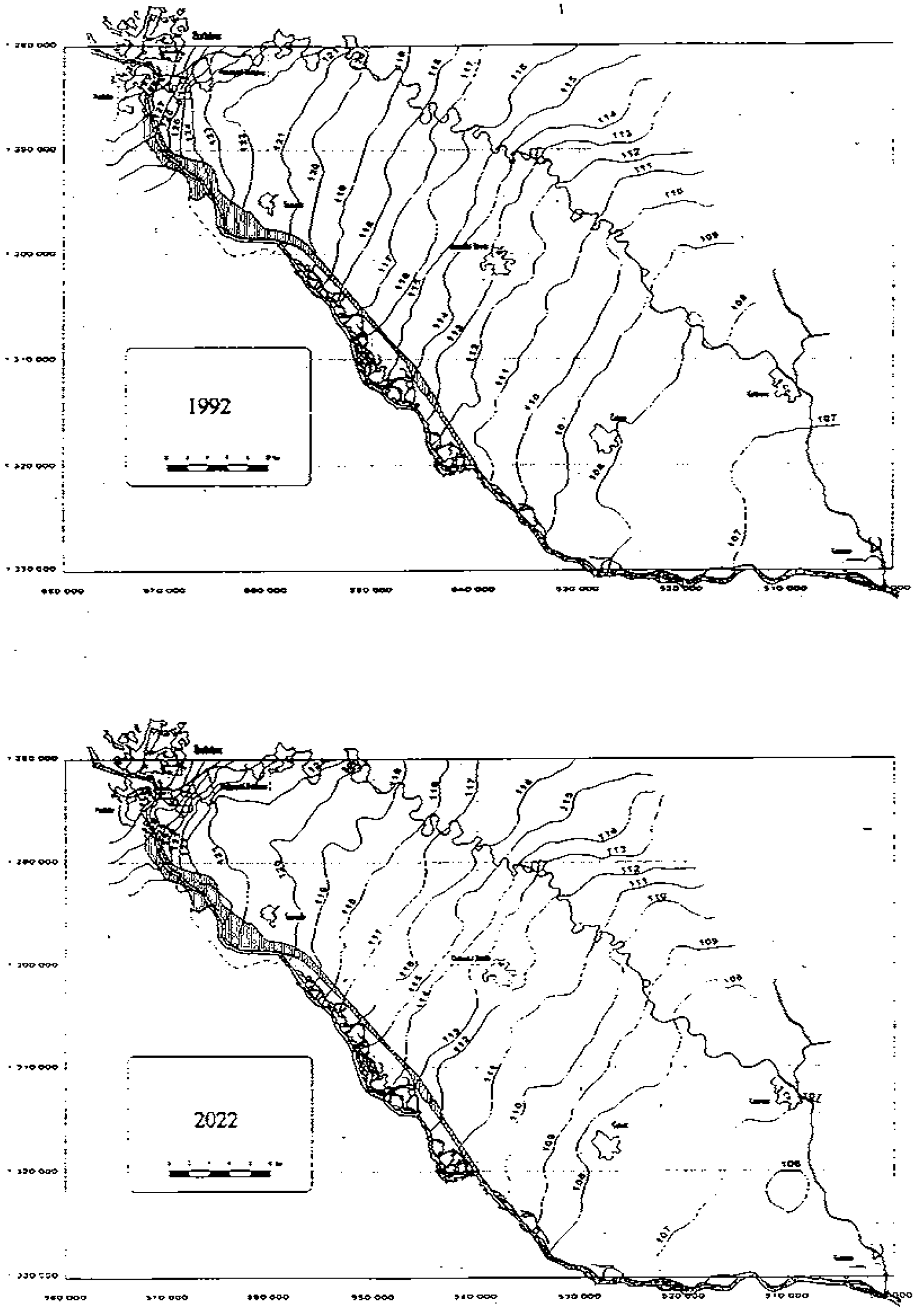


Fig. 1.18: Reference ground water level equipotential lines in 1992 and forecasted reference ground water level equipotential lines in 2022 (for pre-dam conditions)

1.4. INTERPRETATION OF CHANGES AFTER DAMMING THE DANUBE

1.4.1. Interpretation of Changes 6 Months after Damming the Danube

The influence of damming the Danube can be seen on 3 typical chosen piezometers. Fig. 1.19 represents water discharge in the Danube starting at the time of pre-dam conditions. In Fig. 1.19 there is shown the date of the damming the Danube (October 24, 1992) and starting the filling up the river arms in inundation on the Slovak territory (May 5, 1993). Typical well, not far away from the reservoir, the SHMU well No. 694 (Fig. 1.19, see situation in Fig. 1.9) shows eminent increase of ground water level just after damming the Danube. The SHMU well No. 673 (Fig. 1.20), situated in inundation near the river Danube, shows after damming the Danube the decrease of ground water level and increase of ground water level after filling up the river arms. The SHMU well No. 679 (Fig. 1.20), situated behind the power channel, shows decrease of ground water level after damming the Danube and visible increase of ground water level after filling up the river arms. It is evident the impact of not only the damming the Danube but also of the filling up the river arms.

To show the regional impact of damming the Danube and filling up the river arms, the equipotential lines were drawn for both cases. From the SHMU wells, the ground water level equipotential lines were drawn for the date of April 28, 1993 (Fig. 1.21). Reservoir was filled up but the river branches in inundation were still empty. Using prediction of water levels for the situation without filling up the reservoir, the equipotential lines for the same date were constructed (Fig. 1.21). The difference lines, constructed from these two figures, give to us a general overview about changes in ground water level (Fig. 1.22). On wells, situated near the reservoir, there is the increase of ground water level and in opposite, on wells, situated near the intake channel leading to the power plant, there is a temporary decrease of ground water level until some remedy measures are realized.

1.4.2. Interpretation of Changes 8 Months after Damming the Danube

Influence of the filling up the river arms in inundation (May 1993) can be seen on the SHMU well No. 673 (Fig. 1.20), which is situated between the Danube and intake channel. Similar situation is on the SHMU well No. 679 (Fig. 1.20) behind the intake channel.

The main difference between 6 and 8 months after damming the Danube is caused by the filling up the river branches in inundation on the Slovak territory (May 5, 1993). To express the situation after 8 months after damming the Danube (June 30, 1993), the ground water level equipotential lines based on the measured SHMU wells are shown in Fig. 1.23. Using prediction of water levels for the situation without damming the Danube, equipotential lines of ground water level were constructed (Fig. 1.23). Comparing equipotential lines, the difference lines of ground water levels are presented in Fig. 1.24. Fig. 1.24 represents the changes of ground water levels on 30 June 1993 in comparison with the conditions without the damming the Danube. From the figures it is clear that the damming the Danube and filling up the river branches have increased ground water levels on the whole territory including the inundation approximately to the state 30 years ago.

Except this, it is clear that the ground water levels are very sensitive upon the filling up the river branches in inundation. This means that river branches are one of the management tools for ground water level optimization. The changes of ground water level, measured on the SHMU well No. 679 in the second half of June, show the good response on higher water

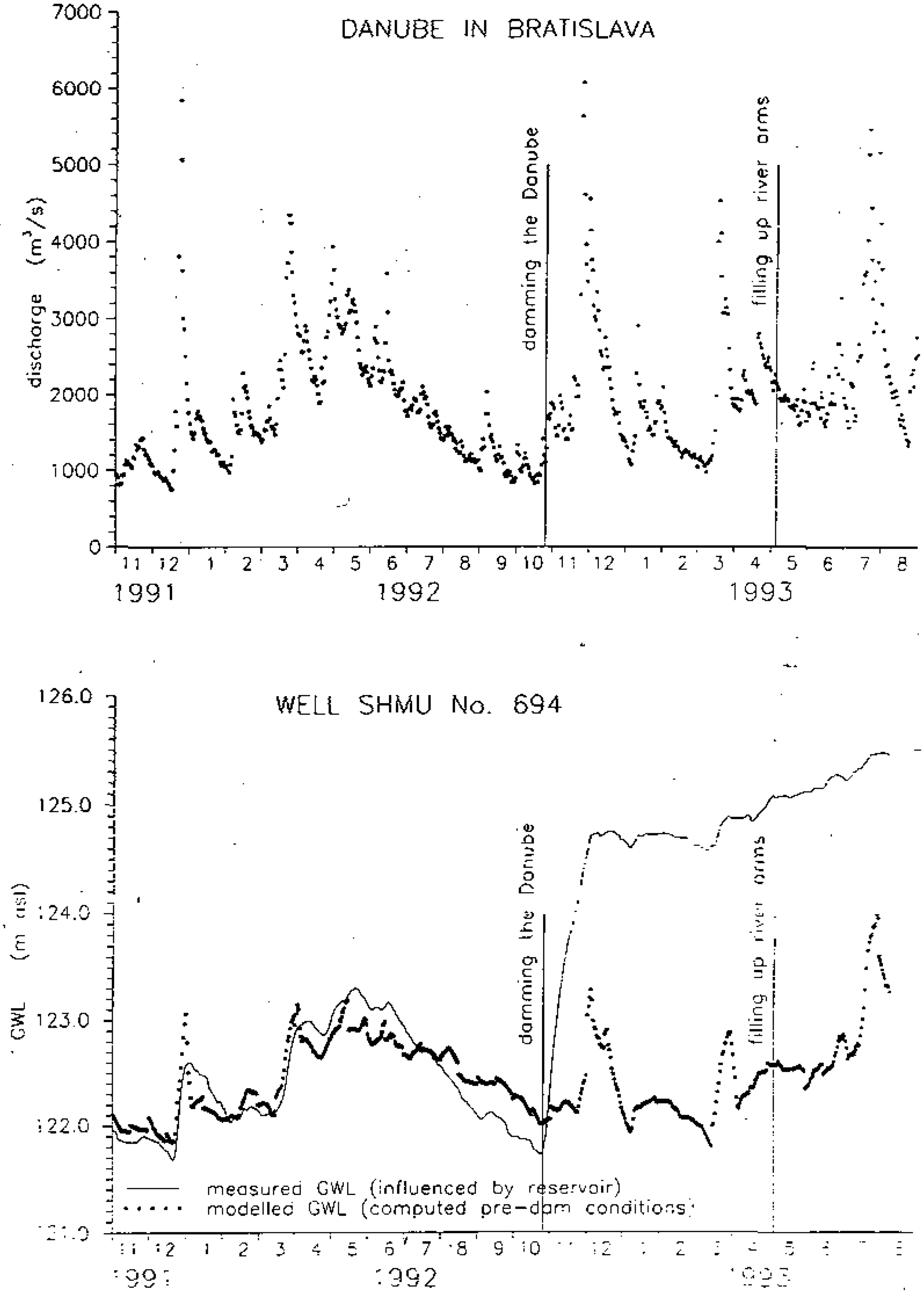
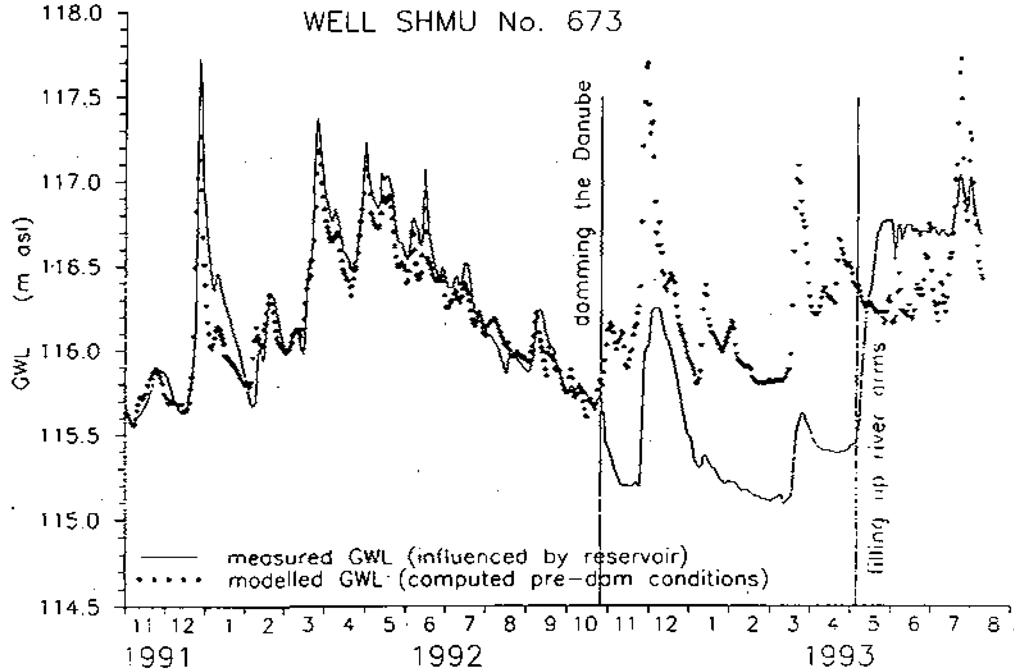


Fig. 1.19: Discharge in the Danube in Bratislava and measured and modeled ground water levels in the SHMU well No. 694



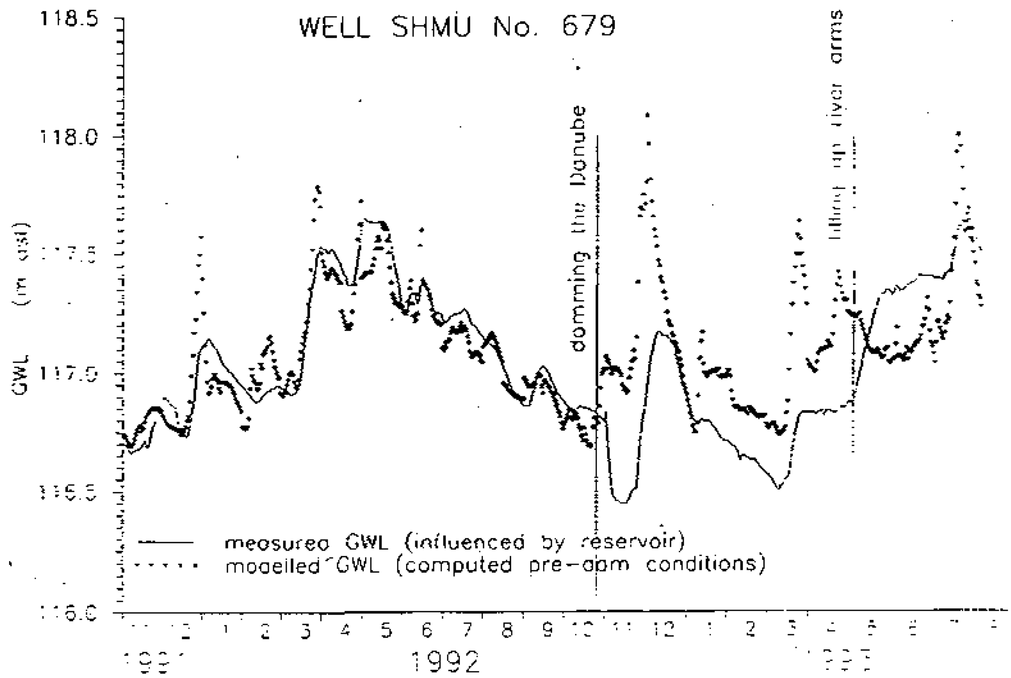


Fig. 1.20: Measured and modeled ground water levels in the SHMU wells No. 673 and 679

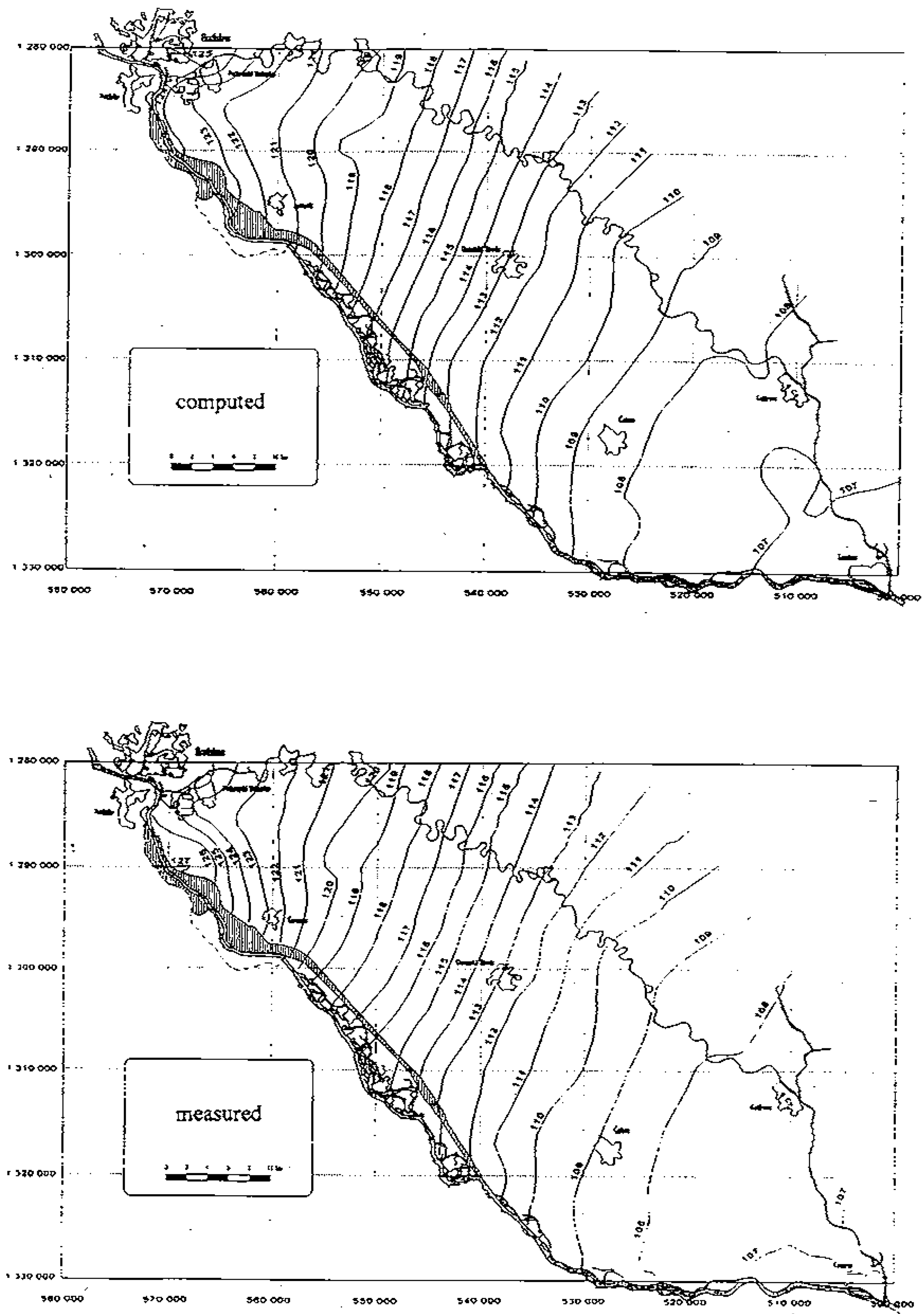


Fig. 1.21: Ground water level equipotential lines computed for pre-dam conditions and measured (April 28, 1993)

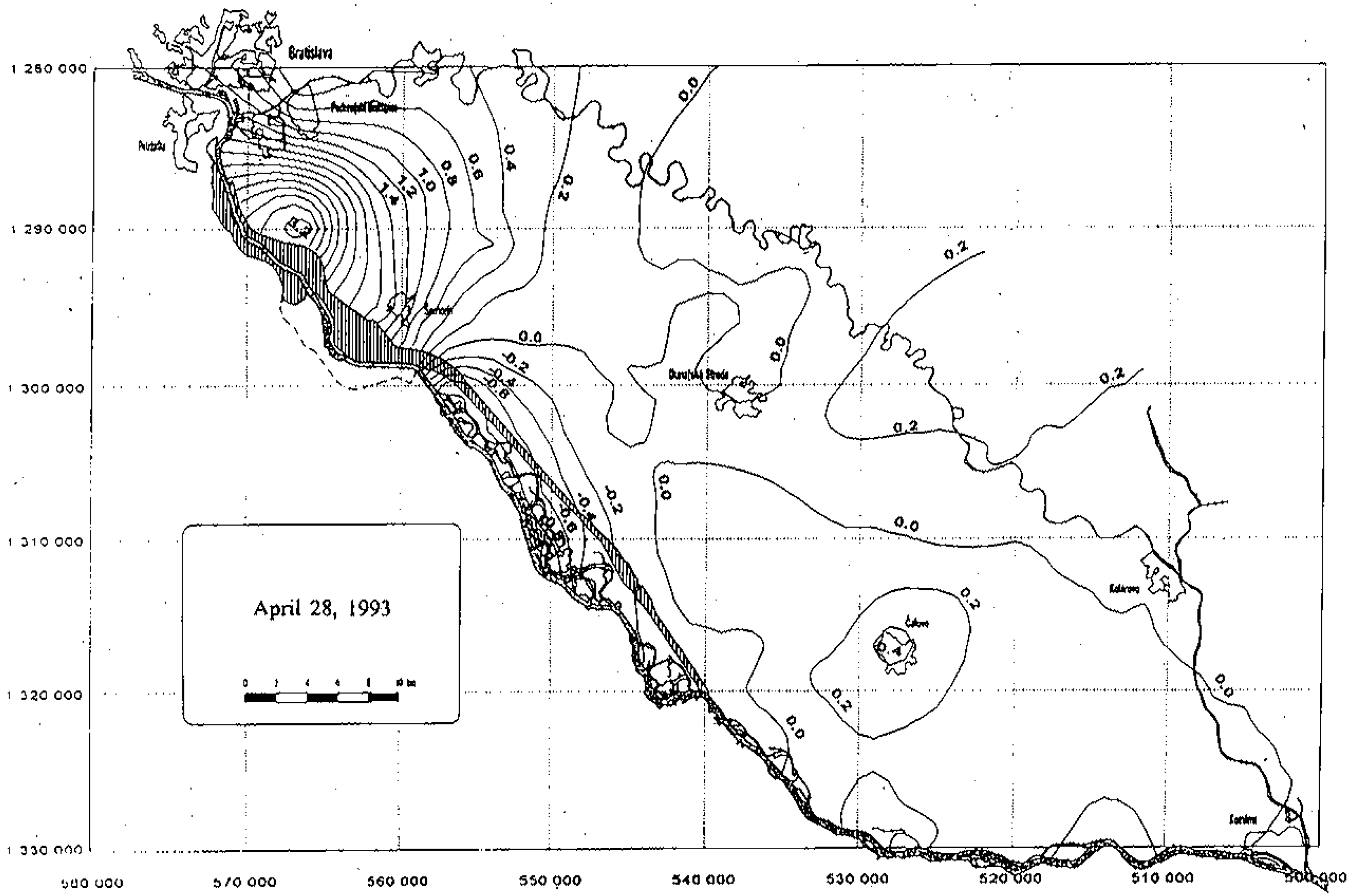


Fig. 1.22. Increase of ground water level 6 months since damming the Danube

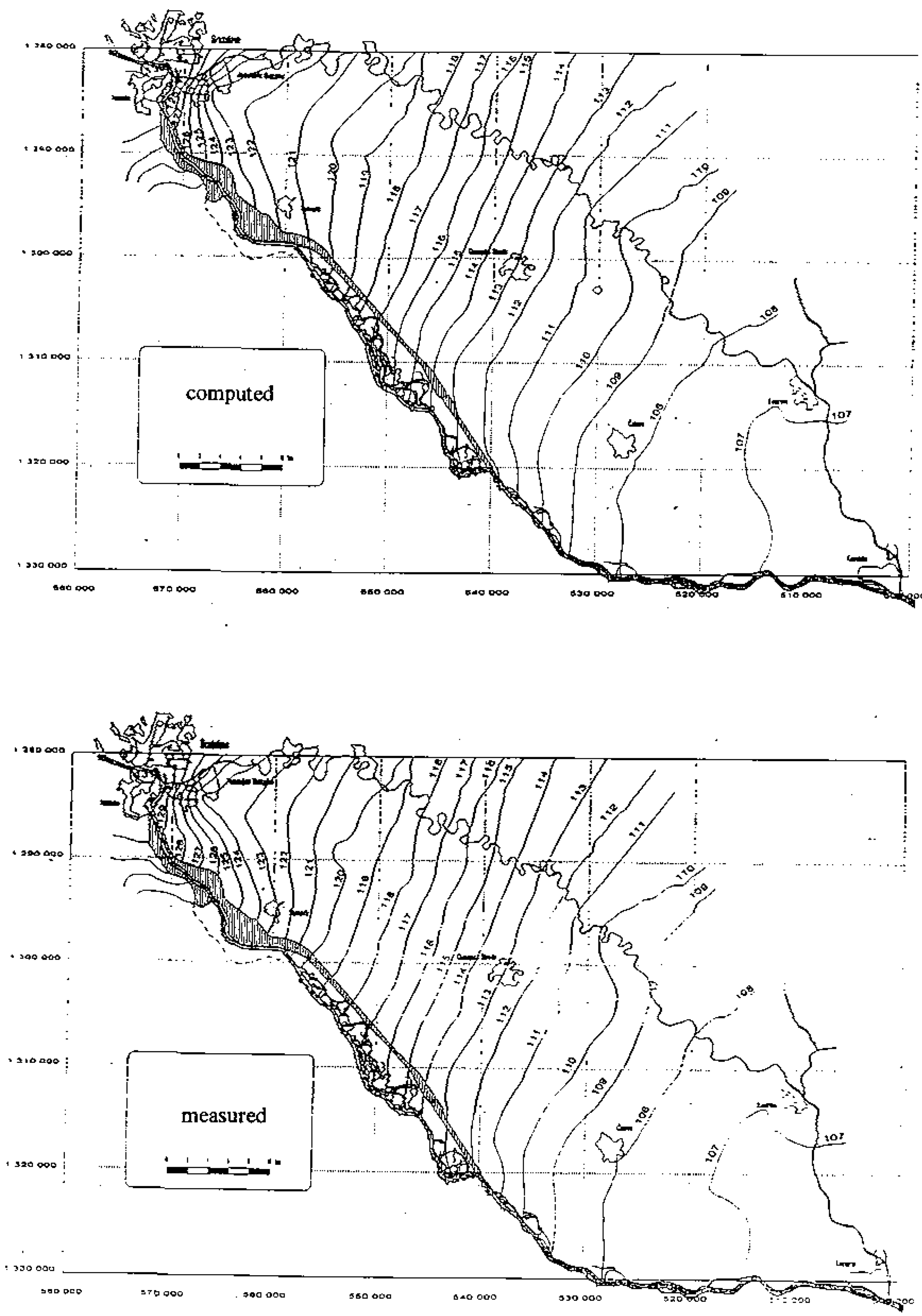


Fig. 1.23: Ground water level equipotential lines computed for pre-dam conditions and measured (June 30, 1993)

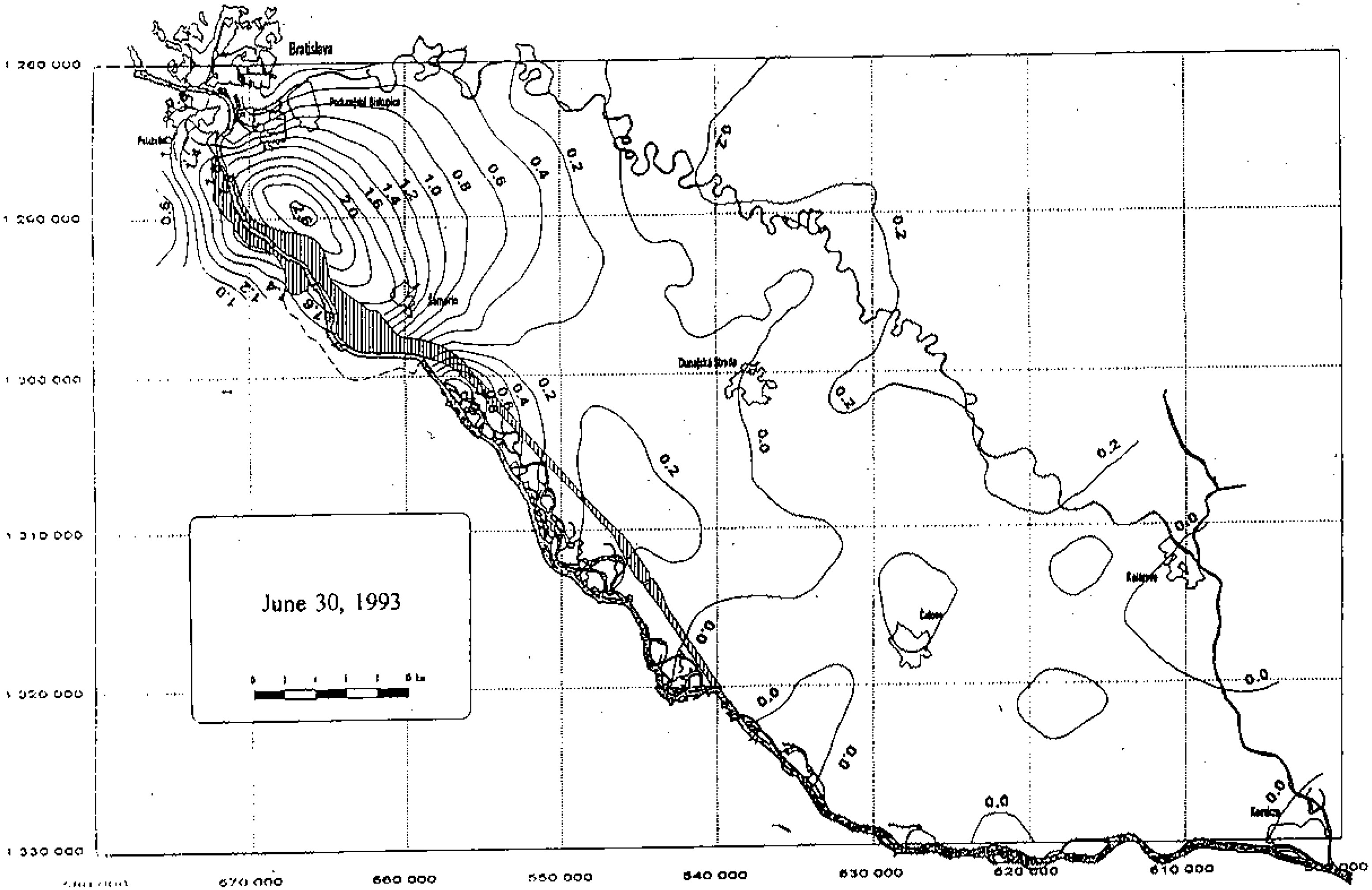


Fig. 1.24: Increase of ground water level 8 months since damming the Danube

levels in the Danube (part of discharge was led through the weir in inundation to the Danube) and confirm that the future construction of small underwater weir in the Danube would act as an additional important means for optimizing ground water levels. The underwater weirs are important not only for the ground water level optimization but also for diminishing the difference between ground water level and water level in the Danube and for better mutual interconnection between the Danube and the river branches from the point of view of fish and ecology.

1.5. WATER QUALITY

1.5.1. Surface Water Quality

The river Danube water quality is evaluated from the point of view of oxidizing - reduction conditions [25]. Following example of evaluation is based on analyses of the water quality taken at the municipal waterworks Sihot in Bratislava.

Concentration of Cl^- and SO_4^{2-} depends on discharge and is presented in Fig. 1.25.

Contents of O_2 and COD(Mn) is in Fig. 1.26. From the figure it can be seen that the trend is in the direction of improvement of water quality from the point of view of recharge of aquifer and river bank infiltration.

Concentration of NO_3^- and NO_2^- is shown in Fig. 1.27. It is shown an increase in nitrates. The maximal contents of nitrites is up to 0.3 mg/l.

The general improvement of the water quality in the Danube is because of improvement and capacity of biological purification plants at the Danube, especially Vienna's main purification plant, which was put into operation in 1980, the Schwechat's refinery and Slovnaft's refinery purification plants and Bratislava's purification plants on both sides of the Danube. Some additional information about the Danube water quality is given in Appendix in PERSPEKTIVEN.

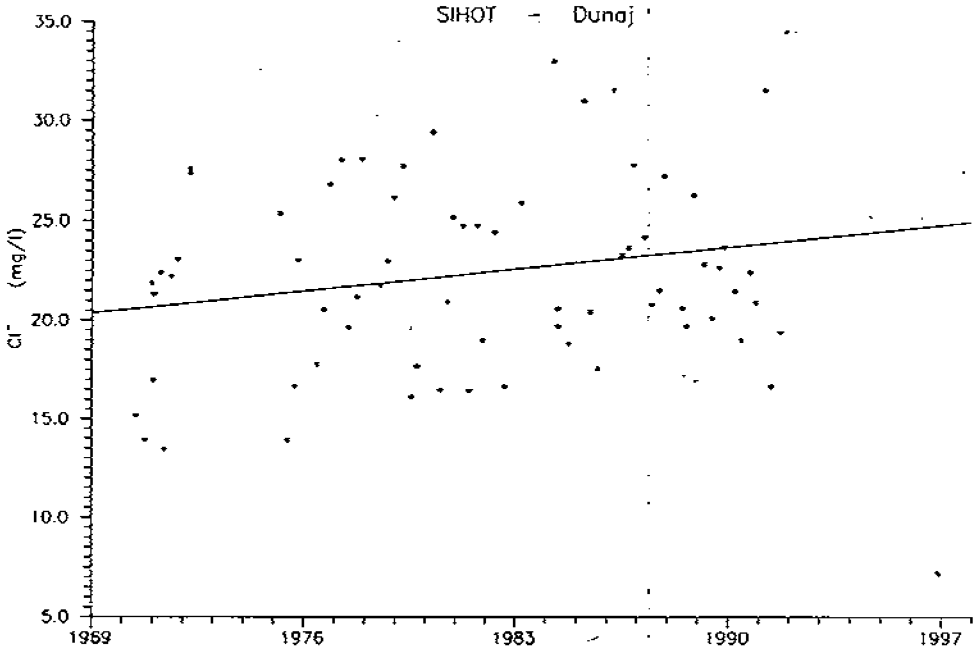
The changes in the Danube water quality since 1960's could be seen when comparing publications [26, 10] with [8, 9].

1.5.2. Ground Water Quality

Aerobic biodegradation is an important mechanism for saving ground water quality. Redox reactions may often be key mechanism controlling the migration of toxic and inorganic wastes in the sediments and in the ground water. Ground water in water supply areas is still of excellent quality and mostly of oxidizing conditions in the Zitny ostrov area. The main goal is to save the favorable oxidizing conditions mainly in the area used for water supply.

Ground water quality, since damming the Danube, is carefully monitored and evaluated in regular reports. In [28] there is evaluation of ground water quality from October 25, 1992 to December 31, 1993. The main results of this evaluation are:

1. In ground water, which is used for municipal water supply, in no case the values, according to the Standards CSN 75 7111, were exceeded



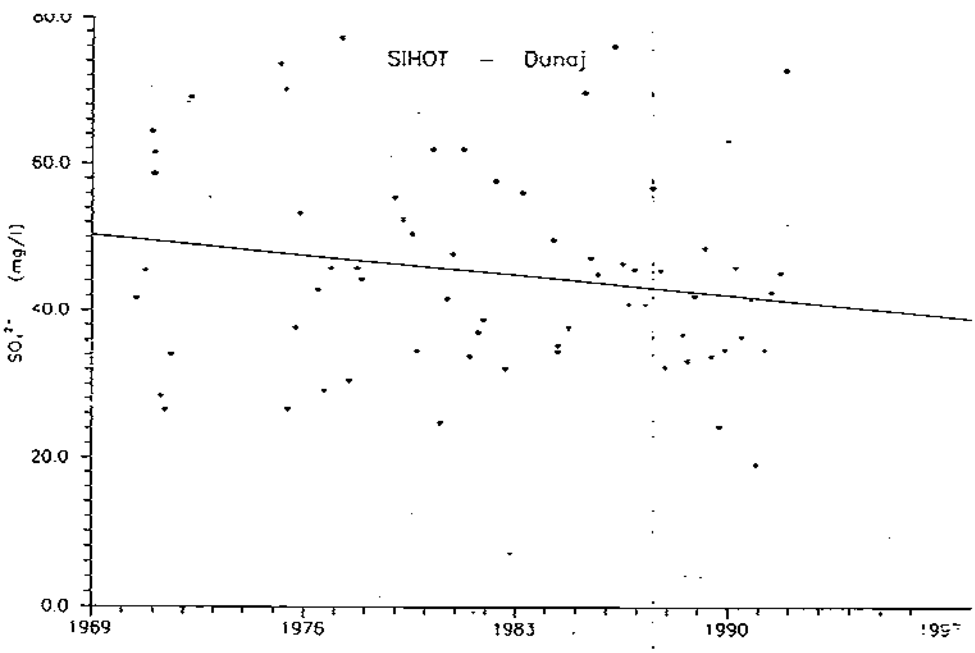
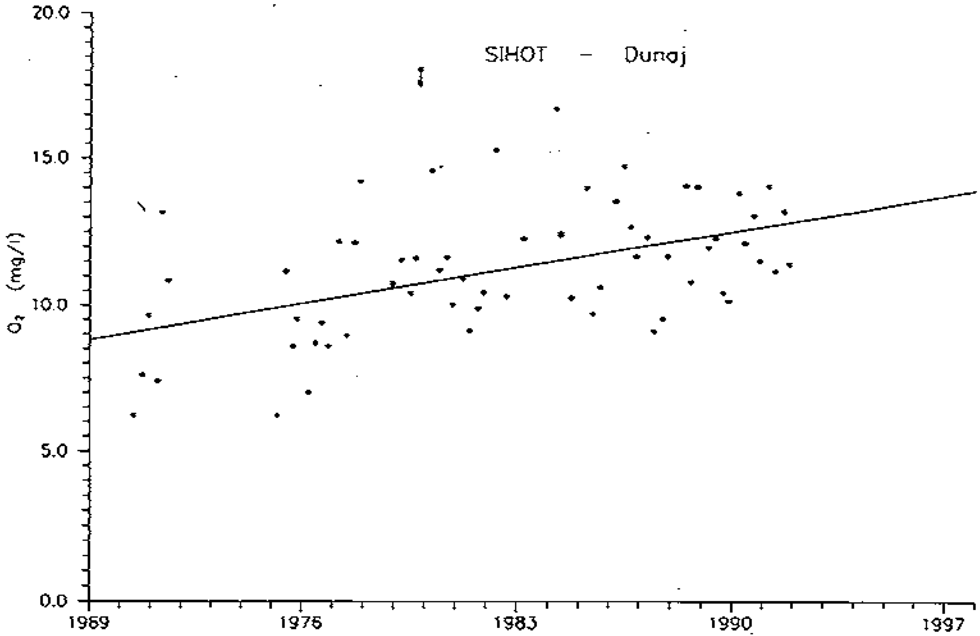


Fig. 1.25: Trend of concentration of Cl^- and SO_4^{2-} in the Danube water



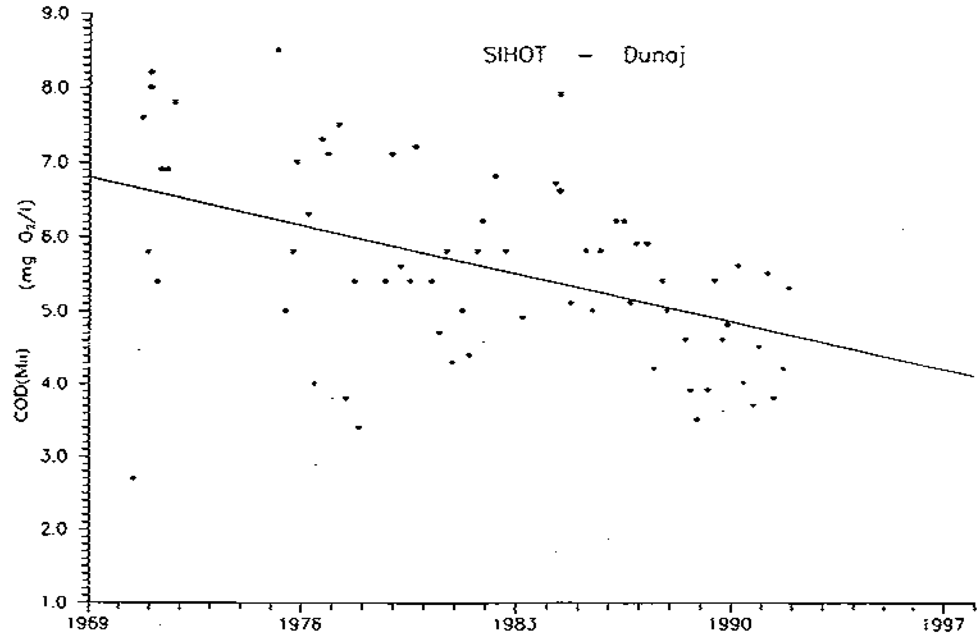
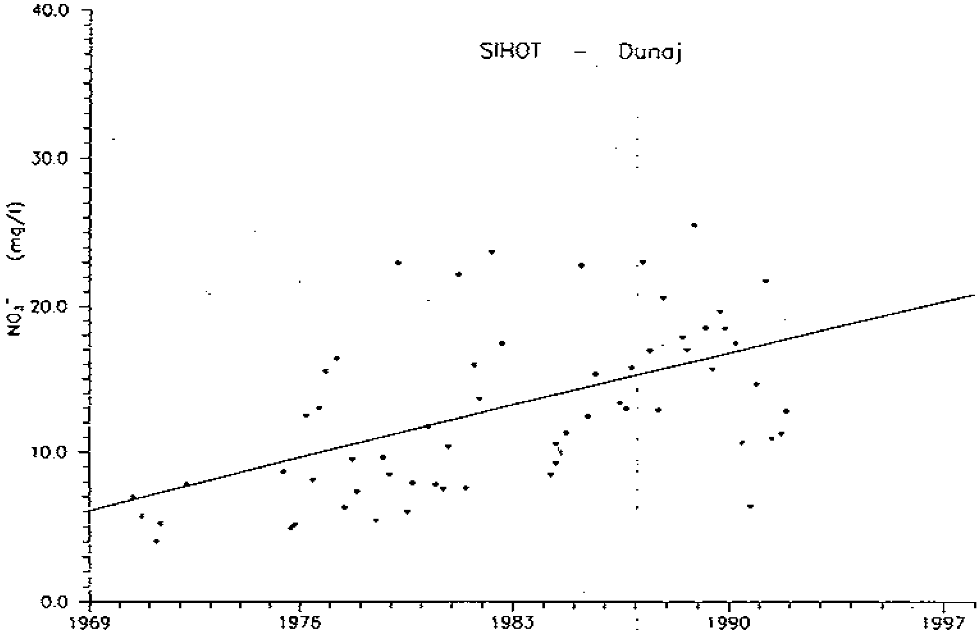


Fig. 1.26: Trend of concentration of O_2 and COD(Mn) in the Danube water



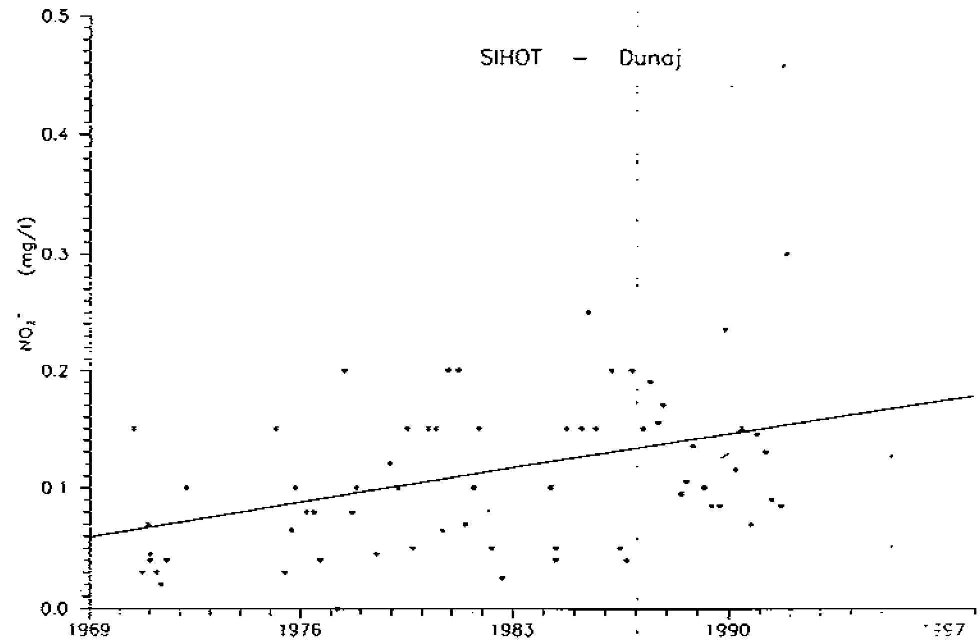


Fig. 1.27: Trend of concentration of NO_3^- and NO_2^- in the Danube water

2. The basic chemical type of ground waters stayed nearly unchanged in the whole period, the range of fluctuation of the contents of dissolved substances and the changes of the contents of inorganic macropollutants do not go out of range in the long-term trends
3. The most significant changes of chemical composition (which can later affect the ground water quality especially in the vicinity of large water supplies situated in the riverside zone of the Danube at the Zitny ostrov area) occur in oxygen regime.
4. In spite of the more exceeding of water quality indicators (mainly in the first phase of filling up the reservoir), there were positive changes in the development of water quality (especially in the right riverside zone of the Danube - in the vicinity of the water supply Rusovce - Ostrovne Lucky - Mokrad).
5. The hydrogeochemical changes which were monitored, in general confirmed that the ground water quality is unchanged or in some places it is possible to evaluate improving in ground water quality. This improvement is not necessarily definite. Further monitoring is required.
6. Changes in the surface water quality are not significant. The slide changes are in oxidizing conditions and microbiological indicators.
7. In the power channel and tailrace channel the water quality is similar as in the reservoir at Samorin.

1.6. QUALITY OF SEDIMENTS

Complex evaluation of sediments is summarized in [24]. In the database, there is 186 analyses of sediments and 3 analyses of suspended load from the river Danube, taken before damming the Danube. Except this, there is 37 analyses from the last survey in the framework of Project PHARE. Sampling places in the last survey were situated in the areas where there is possible recharge of aquifer and in the areas where the ground water is flowing towards possible places of future ground water extraction. Places of sampling are shown in Fig. 1.28. 8 samples were analyzed in two laboratories, in the Netherlands and in the Slovak Republic. Results are given in the Table 1.5. Based on the evaluation of the expert from the Netherlands, Mr. J. Griffioen, the results could be summarized as follows:

- in the area of Gabcikovo reservoir, the sediments are not evidently contaminated
- sediments are not contaminated by organic contaminants
- in spite of higher contents of heavy metals in sediments analyzed by the method of total decomposition, the situation is not worrying because a large part of the heavy metals in the sediments is in the form of stable rock minerals (e.g. Cu, Ni)
- contents of some metals in oxidizing conditions is in river sediments in Alpine - Carphatians geological conditions high and it does not mean a pollution.

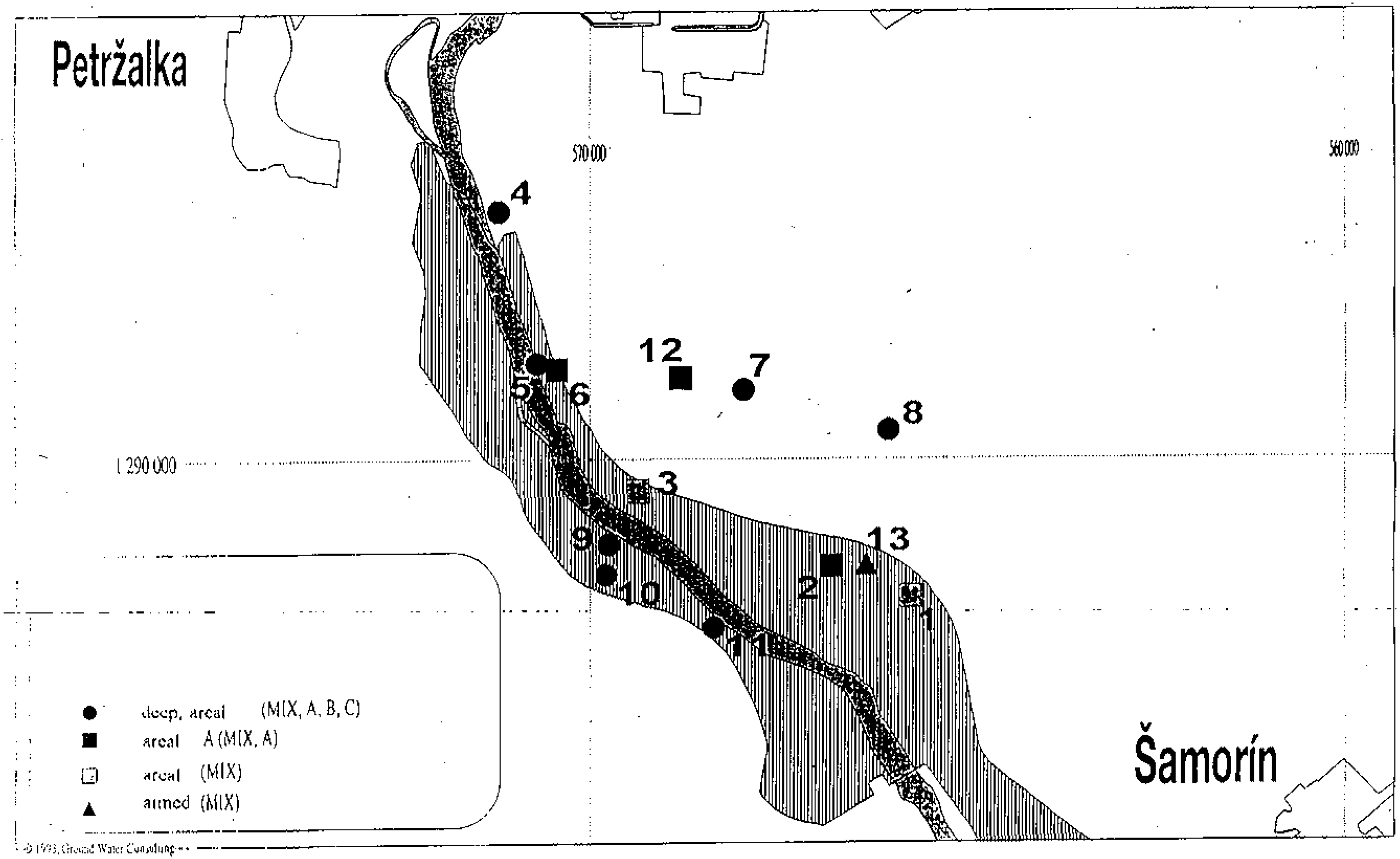


Fig. 1.28: Schematic map of places of sediment sampling in the framework of Project PHARE

A. OMEGAM, H.J.E. Wenckebacheg 120, 1096 AR Amstredam, Holandsko
B. Chemický ústav PriF UK, Mlynská dolina pav. CH-2, 842 15 Bratislava, Slovenská republika

NA - not analyzed
ND - not detected

ukazovateľ (mg/kg)	2/A		4/A		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
$CaCO_3$ (%)	21	22,7	20	23,8	19	20	20	18,6	24	25,6	27	26,9	18	18,4	22	23,4
TOC (%)	2,4	1,1	4,3	1,1	1,5	2,3	1,8	0,4	1,7	1,1	6	1,8	2,6	1,1	4,3	2,2
Dry Rest (%)	82	83	80	80	86	88	91	93	90	92	75	77	86	88	81	83
Mineral Oil	< 50	20	< 50	20	< 50	ND	< 50	ND	< 50	ND	< 50	20	< 50	20	< 50	ND
Cr	25	52	31	61	22	50	18	37	22	41	33	61	23	55	41	72
Ni	22	30,5	25	36	19	24,5	17	22	20	26	27	37,5	18	23	35	45,5
Cu	19	25,2	31	33,8	19	22,1	13	17	17	20	31	36,3	16	19	32	37,4
Zn	45	58,5	77	107	44	55,5	33	47	35	49	74	95,2	42	55	69	87
Cd	< 0,6	0,33	< 0,6	0,48	< 0,6	0,41	< 0,6	0,28	< 0,6	0,36	< 0,6	0,36	< 0,6	0,32	< 0,6	0,44
Mn	420	518	520	594	380	525	300	400	370	493	520	585	400	558	620	698
Fe	18000	23750	21000	23250	16000	17500	13000	19000	17000	20250	22000	24375	15000	19500	29000	30375
EOX	< 0,1	< 1	< 0,1	< 1	< 0,1	< 1	< 0,1	< 1	< 0,1	< 1	< 0,1	< 1	< 0,1	< 1	< 0,1	< 1
naphtalene	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND
acenaphthylene	0,3	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND
acenaphthene	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND
fluorene	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND
phenantrene	< 0,1	ND	< 0,1	0,08	< 0,1	ND	< 0,1	ND	< 0,1	ND	0,1	0,09	0,2	ND	< 0,1	ND
anthracene	< 0,1	ND	< 0,1	0,02	< 0,1	ND	< 0,1	ND	< 0,1	ND	< 0,1	ND	0,2	ND	< 0,1	ND
fluoranthene	0,01	ND	0,1	0,1	0,03	ND	<0,01	ND	<0,01	ND	0,13	0,05	0,54	ND	0,02	ND
pyrene	0,01	ND	0,08	0,1	0,03	ND	<0,01	ND	<0,01	ND	0,1	0,04	0,39	ND	0,01	ND
benzo(a)pyrene	0,01	ND	0,06	ND	0,02	ND	<0,01	ND	<0,01	ND	0,07	ND	0,2	ND	0,01	ND
chrysene	<0,01	ND	0,05	0,03	0,02	ND	<0,01	ND	<0,01	ND	0,07	0,02	0,19	ND	0,01	ND
benzo(b) fluoranthene	0,01	ND	0,06	ND	0,02	ND	<0,01	ND	<0,01	ND	0,07	ND	0,21	ND	0,01	ND
benzo(k) fluoranthene	<0,01	ND	0,03	ND	0,01	ND	<0,01	ND	<0,01	ND	0,03	ND	0,09	ND	<0,01	ND
benzo(a) anthracene	<0,01	ND	0,05	0,03	0,02	ND	<0,01	ND	<0,01	ND	0,06	0,02	0,26	ND	0,01	ND
dibenzo(a,h) anthracene	<0,03	NA	<0,03	NA	<0,03	NA	<0,03	NA	<0,03	NA	<0,03	NA	<0,03	NA	<0,03	NA
benzo(ghi) perylene	<0,03	ND	0,04	ND	<0,03	ND	<0,03	ND	<0,03	ND	0,05	ND	0,1	ND	<0,03	ND
indeno(1,2,3-cd) pyrene	<0,03	ND	0,05	ND	<0,03	ND	<0,03	ND	<0,03	ND	0,06	ND	0,11	ND	<0,03	ND
PAHs (EPA sum)	0,34	ND	0,5	0,36	0,15	ND	< 0,4	ND	< 0,4	ND	0,7	0,22	2,5	ND	0,07	ND

Table 1.5: Comparison of chemical analyses of sediments

2. FROM THE HISTORY OF ORIGIN OF WORKING GROUP OF INDEPENDENT EXPERTS EU

2.1. FACT FINDING MISSION (October 27 - 31, 1992)

After unsuccessful bilateral negotiations between Hungary and Slovakia concerning Gabcikovo - Nagymaros Project, EC Commission (now EU - European Union) invited Czecho-Slovakia and Hungary for a trilateral meeting at Brussels on October 22, 1992. During the negotiations, Czecho-Slovakia handed over the Aide-mémoire, the substance of which was that during the work of the tripartite commission ("Working group of independent experts on Variant C of the Gabcikovo - Nagymaros project"), Czecho-Slovakia would not divert water from the common riverbed and only navigation would be transferred to the Czecho-Slovak territory. Aide-mémoire confirmed that damming of the Danube was not a definite solution, if conclusion of the tripartite commission would prove the principal negative ecological impacts of the Gabcikovo scheme. Hungarian delegation refused proposals contained in Aide-mémoire and conditioned the establishment of tripartite commission by interruption of works leading to the damming of the Danube. This requirement was unacceptable, because of technical reasons and necessity of anti-flood protection and navigation. Czecho-Slovak delegation expressed readiness to receive independent experts who could evaluate the real situation and the earnestness of its proposal. After this unsuccessful trilateral meeting at Brussels the damming of the Danube had been started on 24 October 1992 and on 27 October 1992 the Danube was dammed.

In connection with these talks, the EC Commission has sent a Fact Finding Mission to the area of Gabcikovo project. The mission carried out an on-site inspection of the ongoing work on Tuesday afternoon, October 27, 1992. The mission from the EC Commission consisted of the following three persons:

- Mr. Jens Christian Refsgaard - team leader, Denmark
- Mr. Jan M. Van Geest, Director Infrastructure, DHV, The Netherlands
- Mr. Jesper T. Kjelds, Computational hydraulics engineer, Denmark

<u>Terms of References of the Fact Finding Mission</u>

1. To make an on-site inspection of the ongoing work.
2. To assess the need and urgency of the ongoing work in light of potential flooding risks for damage to already constructed parts.
3. To assess the immediate consequences/impacts of the ongoing work relating to:
    - Navigation
    - Hydrological aspects
    - Environment
4. To assess the irreversibility of the ongoing activities and to assess the cost for restoring status quo.
5. To establish when works on the Danube can be stopped without risks for existing structures or floods.
6. To establish whether and when the Danube waters can go back into the existing bed after the present works have been finalized and the artificial canal filled up. To indicate flows and dates of possible realization.

7. The results of the consultancy must be communicated to Mr. Benavides and Mr. Giunti as soon as possible. Mr. Giunti should receive daily briefing from Mr. Refsgaard on the progress of investigation.

The United Kingdom, in the capacity of the President of the EC Council at that time, came in this situation with a new initiative. During the summit of the prime ministers of the Visegrad group (Hungary, Czecho-Slovakia and Poland) with the Premier of the United Kingdom, John Major, the trilateral negotiations were held in London on 27 - 28 October 1992. There was decided to put together a new Fact Finding Mission composed of one expert from each of the three parties. The following three experts have been appointed to constitute the Fact Finding Mission:

CEC:	Mr. Jens Christian Refsgaard, Chief Hydrologist, Danish Hydraulic Institute, team leader of the Fact Finding Mission
CSFR:	Univ. Prof. Igor Mucha, Faculty of Natural Sciences, Comenius University
Hungary:	Dr. Péter Bakonyi, Managing Director, VITUKY Consult Rt, Budapest

The Mission met in this constellation the first time on 29 October 1992 in Györ. It carried out an on-site inspection of the ongoing work on 30 October 1992 and held the concluding meetings in Bratislava on 30 - 31 October 1992. The Agreed Minutes (see in Appendix) from trilateral negotiations in London were used by The Fact Finding Mission as the Terms of References.

General results of the Fact Finding Mission including the London Agreed Minutes in the original Terms of References are as follows:

- In a possible flood situation some of the not yet finished structures might be damaged depending on the peak and duration of the flood. **To meet the design flood criterion $Q_{0.01\%,year}$ the Phase 2 of Variant C has to be completed** (Fig. 2.1). Although not direct related to works of Variant C, the most flood endangered reach of the Danube in the Area of interest is the left hand side between Palkovicovo (rkm 1811) and Medvedov (rkm 1806).
- As a consequence of the ongoing works **the Danube discharge is separated in two parts. One part supplied the power canal leading to Gabcikovo which serves as the navigation channel as well. The other part of discharge is directed into the existing Danube bed through the by-pass weir. The water management possibilities are restricted until the various parts of the hydraulic structures are fully completed.** After completion of Variant C, the full complex of structures can provide comprehensive possibilities for regulation of the discharges both by low discharge and flood situations.
- **The major environmental impact is related to the ground water resources and to the ecology.** The effect on floodplain ecology is a result of both the lowering of ground water table and a less frequent inundation of the flood plain. Thus the environmental impacts of reducing the discharge in the Danube are negative, unless proper remedial actions are taken. CSFR has included a budget of 2.4 billion CSK for construction of underwater structures as part of Phase 2 of Variant C. **There are indicated some possible remedial measures, e.g. small underwater weirs, gate operation, interconnection of Danube river bed with river branches, adding some material into the river. It is stressed, that such remedial measures are possible to be made because the navigation takes place in the power canal instead of the existing Danube bed in this reach of the Danube.**
- Immediate impacts observed in Hungary are included. **Closure of the Danube resulted in decrease of discharge.** On 24 October 1992 the discharge was 800 - 900 m^3/s. On 28 October 1992 the discharge was 227 m^3/s at Rajka and 356 m^3/s at Dunaremete. Due to

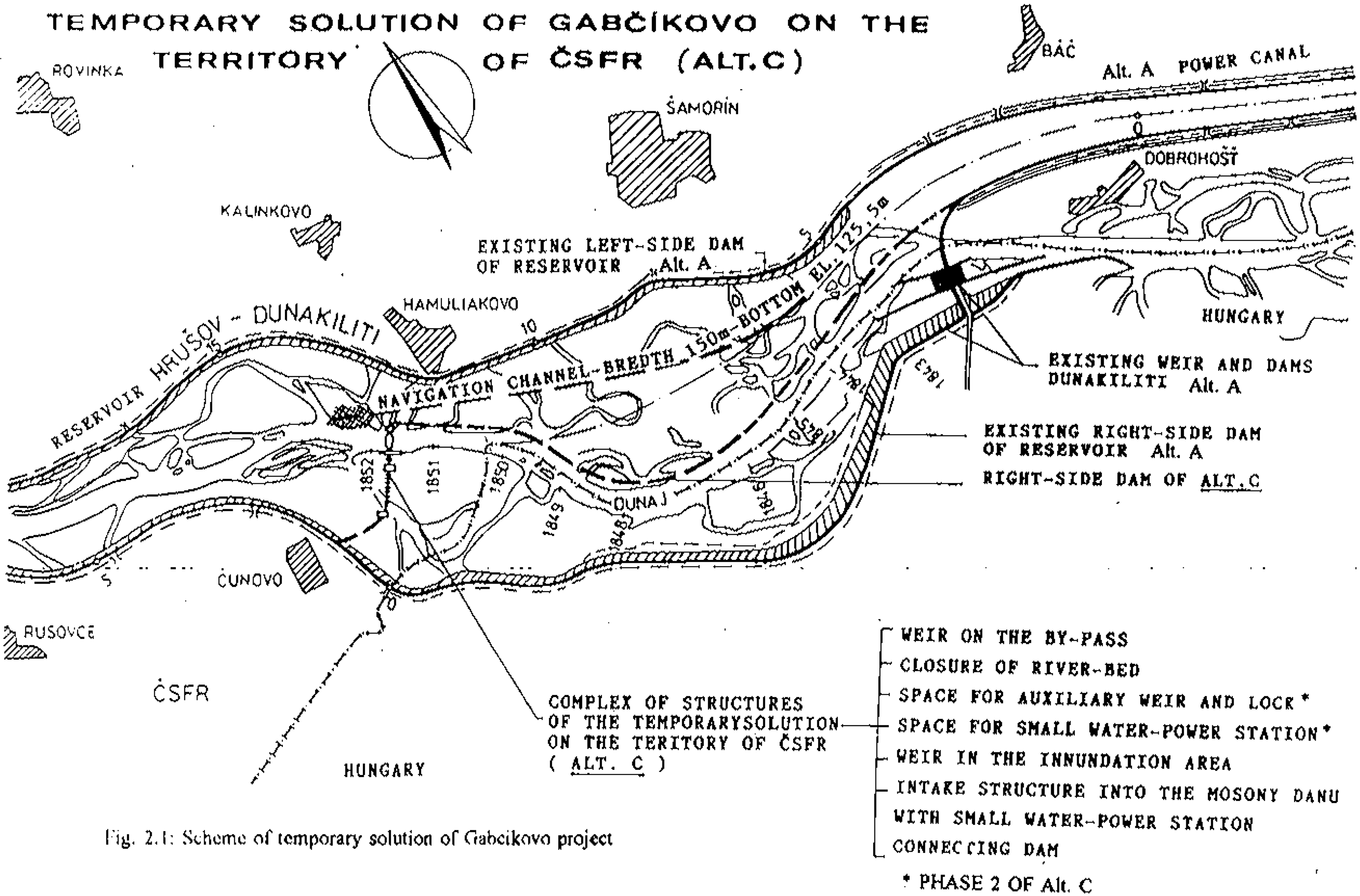


Fig. 2.1: Scheme of temporary solution of Gabcikovo project

the sudden drop of the discharge, the water level decreased in less than 4 days by 3 m at rkm 1850 and by 2.4 m at rkm 1825, according to Hungarian measurements (which is according to Hungarian rating curve exaggerated (Fig. 2.2)).

- Some effects of water level decrease are: **the side branches have been cut off from the main channel, the water from the downstream part of the side branches disappeared immediately, the ground water table has decreased, the river training structures at some places slid into the Danube, the water disappeared from the ports as in Asványráró, Dunaremete, Dunakiliti, the ecological balance of the side branches has become disturbed.**
- As a consequence of the ongoing works, the navigation route in the existing Danube navigation channel has been closed. Instead the new navigation channel and power canal with the navigation locks at Gabcikovo are being opened. The immediate impact of the ongoing works is the disruption of navigation for the period from October 23 to November 3, 1992. **When the navigation channel is operational the navigation should be improved as compared to the previous situation, because the water depth will be larger than in the existing Danube and ships will save a part of the energy required for transport.**

<u>Irreversibility of Ongoing Activities</u>

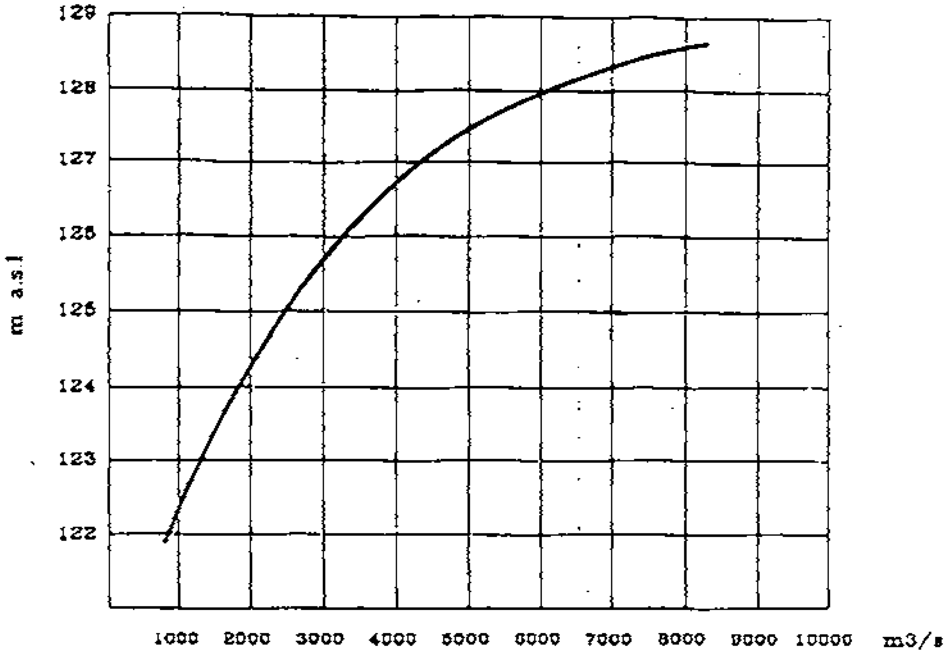
In principle, the ongoing activities with Variant C could be reversed. The structures, excluding some of the underground parts could be in theory removed. The costs of a such removal are roughly estimated to at least 30 % of the construction costs. There will be negative environmental effect during the demolition of the structures and the deposition of the waste material. It is therefore relevant to evaluate under which circumstances the Variant C structures could have only insignificant effects. Such **"functional reversibility" is possible for a scenario like this: "if the Dunakiliti weir and the other structure on Hungarian territory are being operated according to the original plans the gates in the Variant C structures can be kept fully open and will not have any significant effect."**

<u>General Remarks Written by Fact Finding Mission</u>

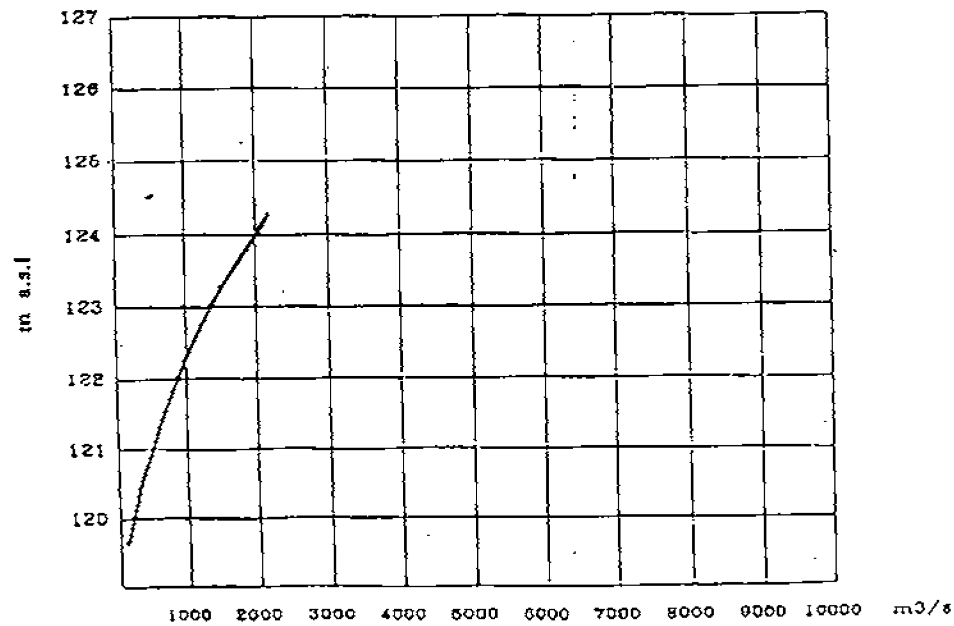
Finally, it is important to emphasize that the **environmental conditions in certain respects are deteriorating today due to river bed erosion and thus lower ground water tables.** The decline is varying from approximately 2 m over the last 30 years near Bratislava to approximately status quo near Komarno. Thus, the riverside vegetation is slowly drying out resulting in significant changes in vegetation species, etc. The conditions for agricultural water supply through capillary rise from low ground water tables are no longer good enough and hence more irrigation is required. It is realized that sudden changes as a consequence of e.g. the Gabcikovo - Nagymaros project will occur immediately, and that it will take some time until a new ecological balance develops. However, **the "status quo" situation in pre-dam conditions is neither a stationary nor a natural situation, but rather a slower transition from one cultural landscape to another one, with the inherent consequences of this on the ecological conditions.**

DISCHARGE RATING CURVE

at Rajka rkm 1848.4



Before the damming of Danube



After the damming of Danube

Fig. 2.2: Discharge rating curve

Scenarios

Scenarios, based on the London Agreed Minutes, that the project will be stopped at the date specified by the EC Commission, are as follows:

I. The work will be stopped for a period no longer than one month.
II. The work will be stopped for a period up to three months.
III. The work will be stopped for a period of one year.

Scenarios, based on the London Agreed Minutes, that the whole quantity of water will be maintained in the old Danube riverbed, are as follows:

A. The "whole" quantity of water is directed into the Danube.
B. The main part of the water is diverted to Gabcikovo.
C. A combination of A and B.

All the scenarios were evaluated. The mission believed, that it would be possible to define more optimal scenarios maintaining the major part of the advantages of A and B and at the same time not containing the main disadvantages of A and B. In addition to the above, it is emphasized, that a more final optimization with full weight to the ecological conditions most likely includes a range of regulation measures within the flood plain area itself.

It is evident that no scenario and no date to stop the work was proposed.

2.2. WORKING GROUP OF INDEPENDENT EXPERTS (November 9 - 23, 1992)

As a follow-up to the London Agreed Minutes, a Working Group of six independent experts was established. The Working Group was composed of the following experts:

CEC: Mr. Jens Christian Refsgaard, Chief Hydrologist, Danish Hydraulic Institute, Denmark, Team Leader

Mr. Jan M. Van Geest, Director DHV Environment and Infrastructure, The Netherlands

Mr. Johann Schreiner, Director, Norddeutsche Naturschutzakademie, Germany

Professor Dr. Heinz Löfler, Head of Zoological Department, University of Vienna, Austria

CSFR: Professor Dr. Igor Mucha, Faculty of Natural Science, Comenius University Bratislava

Hungary: Professor Dr. Gabor Vida, Head of Department of Genetics, Eötvös L. University, Budapest

The Working Group consists of hydrologist, water works engineer, ecologist, zoologist, ground water specialist, geneticist. It means generally that **the group consists of one technician, two water specialists and three members of natural sciences dealing with ecological problems.**

Terms of References

The scope of work of the Working Group of Independent Experts was expressed in the letter sent by the CEC on 29 October 1992 as follows:
The Working Group will:
i) Make an on-site inspection of the structures of Variant C and describe the state of work;
ii) Assess the need and urgency of these structures in the; light of the potential flooding risk, including the risk of causing damage to already constructed parts;
iii)Assess the (immediate) consequences/impacts of these structures relating to:

* Environment, covering:
    - Erosion and Sedimentation in River and River Reservoir System
    - Surface Water Quality
    - Ground Water Regime
    - Ground Water Quality
    - River and Flood plain Ecology
* Hydrological and water management aspects and
* Navigation

The assessment will be based on an outline of existing (pre-dam) conditions and trends.

iv)Assess the reversibility of these structures and assess the cost of restoring the status quo ante, i.e., the situation existing prior to the construction of the dam;
v) Make suggestions for (urgent) measures and, if necessary, studies to be (under) taken to improve the present conditions.

2.2.1. Working Material Prepared by Slovak Expert

Working material was prepared in separated report [C]. The main goal of this working material was the identification of the hydraulic system under the condition of the hydropower station Gabcikovo, called as Variant C and outline the possible optimal and beneficial use of the Danube water for various interests. Report includes:
Outline of state and present trends in the area

* Geological conditions
* Long-term impacts and trends in the area
* General ecological requirements
* Erosion and sedimentation in river system
* Surface water quality
* Ground water regime
    * Trend of ground water level depth
    * Ground water level fluctuation
    * Ground water quality
* River and floodplain ecology
* Conditioning factors for recovering of inundation floodplain
* Trends in the past
* Navigation
    * Capacity, number of boats of navigation company CSPD Bratislava
    * Navigation conditions
    * Problems on the section Bratislava - Komarno

Immediate and potential long-term consequences/impacts of the Gabcikovo Varian C and outline of possible remedial measures impact of reservoir of hydropower station on ground water levels

- Hydrology and water management
    - Forecasting of ground water levels
    - Immediate impacts of Variant C on ground water levels
    - Immediate impacts of Variant C on Danube water levels from Cunovo to Sap
- Environment
- Improvement of navigation conditions after finishing of Gabcikovo dam
    - Time saving
    - Saving of energy
    - Improvement of depth in harbor of Bratislava
    - Increment of turnover
    - Problems of navigation at the place where the Danube and outlet canal are joining
- Possible remedial measures
    - Hydrology and water management
    - Environment
    - Navigation

Except this, two scenarios have been elaborated:

- Water management scenario based on requirements of the Slovak Ministry of Environment
- Scenario based on treaty between Republic of Hungary and Czech and Slovak Federal Republic

Detailed monitoring of discharge, water levels, ground water levels and ecological factors were proposed. It was stressed that all measurements are carried out on both sides according to agreed monitoring system.

2.2.2. *Main Results of the Working Group Report*

From the ecological point of view, the following statements are interesting in the Executive Summary.

The hydrological and ecological regime in the area is subject to **a long-term trend of river bed erosion, decreasing water levels and associated ecological changes.** This is caused by a variety of reasons, above all the **large river regulation works,** which implied deliberate **unnatural cutting off and bundling of river branches into one main, straightened and heavily fortified channel for navigation.** In spite of this basically negative trend the floodplain area with its alluvial forests and the associated ecosystems still represents a very **unique landscape of outstanding importance.**

In the past, the measures taken for the navigation constrained the possibilities for the development of the Danube and the floodplain area. Assuming the navigation will no longer use the main river over a length of 40 km a unique situation has arisen. Supported by technical measures the river and the floodplain can develop more naturally.

Variant C Structures and Status of Work

In both countries the original structures for the Gabcikovo scheme are completed except for the closure of the Danube river at Dunakiliti and the installation and testing of turbines.

Variant C (Fig. 2.1) consists of a complex of structures, located in Czecho-Slovakia within the area of the original (according to treaty) Variant A.

The hydropower station is designed for peak power production. At the time of Working Group activity five turbines (from 8 planned) and generators have been installed.

The floodplain weir and the bottom protection **were originally designed for use only in flood situations** (few days per year). During the Working Group activity this design has been modified to allow its daily use as a result of the London Agreed Minutes and a good will and flexibility of CSFR. Along the Danube right bank a spillway was under construction and the downstream bed would be protected with additional 100000 m^3 stone. (The unexpected high flood in November - December 1992 eroded the area between the floodplain weir and the planned spillway along the Danube right bank and the construction is no more realizable.)

The intake structure at entrance to the Mosoni Danube and supply canal on Slovak territory with capacity 25 m^3/s had been constructed.

An intake structure located in the power canal allowing for a maximum intake discharge of 234 m^3/s to supply a river arms and the floodplain downstream the Dunakiliti weir on Slovak territory is completed.

The road on side of the right side dams connecting Bratislava with three villages lying between power canal and the Danube is under construction.

Assessment of the Need and Urgency of the Structures

The designed flood discharge for the project of Variant C (Phase 1 and Phase 2 of construction) is based on 10000-year flood occurrence, risk of occurrence of such flood is 0.01 % within a year. For the construction period, usually larger risk is accepted. The flooding risk of stopping the work depends on the season period during which the work will be stopped and the level of finalization of structures. Stopping the work in summer period needs higher finalization or the risk is much higher. Although not directly related to the works of Variant C, the most flood endangered reach of the Danube in the area of Gabcikovo - Nagymaros system of water works is the left-hand side between Palkovicovo (Sap rkm 1811) and Medvedov (Medve rkm 1806) due to extensive siltation and lack of dredging (problem of erosion upstream of Palkovicovo when dredging without of decrease of flow velocities, see solution in common project of Gabcikovo - Nagymaros).

The Gabcikovo complex can regulate the discharge between 80 m^3/s (discharge for navigation and ship locks) and 5200 m^3/s which is the maximal discharge in power canal. Upon completion the weirs of the Phase 1 of Variant C can regulate discharges between 0 and 6100 m^3/s. **After completion of Phase 2 of Variant C, the full complex of structures can**

provide comprehensive possibilities for regulating the discharges, both in low flow and flood situations.

Reversibility of Variant C

In principle, the Variant C could be reversed. The structures, excluding some of the underground parts like sheet piling and injections, could be removed in theory. The cost of removing the structures are roughly estimated to at least 30 % of the (nowadays) construction costs. There will be negative environmental effects during the demolition of the structures and the deposition of the waste materials. It is therefore relevant to evaluate under which circumstances the Variant C structures could have only insignificant and very local hydraulic effect if they are not fully removed. Such "functional reversibility" is possible for a scenario like:

- If the Dunakiliti weir on Hungarian territory is being operated according to the original plans, the gates in the Variant C structures can be kept fully open and will not have any significant effect. However, in this case it should be evaluated, whether it is desirable to maintain the riverside forest on the Hungarian side for the 7 km reach between the two structures by not using the area as a full reservoir. In such case it may be necessary to operate both sets of structures.
- If the Danube closure is removed and the "whole" discharge is routed back to the Danube.

States and Trends in the Area

In general, large monitoring programs are carried out and large data bases exist for both the Slovak and Hungarian areas.

Before the 18th century, the Danube split downstream of Bratislava. Near Bratislava it was partly a braided river with many small islands as a result of progressive sedimentation where the Danube entered into the plain. It was a meandering river system. Large changes occurred in 19th century, when the first regulation works started. Within several decades of instability and retrogressive erosion of other meanders, the system changed into braided river. With the past endikements, the original zonation in vegetation towards higher grounds and associated forests was largely 'diked' out of the natural system. Most of the higher, no longer flooded soils, were converted into agricultural lands. These river regulation works led to deliberate and natural cutting off and bundling of river branches into one main, straightened and heavily fortified channel for navigation. The cut off branches are only activated at higher discharges.

Within the river branches many small weirs and dams were build, so most of them behave like cascade systems at low discharge. Some are continuously overflowing while others may have dried and some sections are with stagnant water depending upon ground water level.

The main river channel has been significantly lowered due to erosion caused by a combination of several factors. In some places the river bed has been lowered more than two meters, leading to lowering of ground water levels, drying out part of river branches and less flushing of most river branches. The lowering of the riverbed during the past 30 years has been particularly larger between Bratislava and Rajka (1.5 m). The quantity of suspended and bed load on the Danube under Bratislava shows a decreasing trend.

The **quality of the Danube water** can be categorized as 1st class regarding to the majority of components, 2nd class with regard to orthophosphate, nitrite, BOD, pH and 3rd class with regard to bacteria and some heavily degradable substances such as hydrocarbons. **Parameters for oxygen contents and organic carbon show slightly improving trend,** while deteriorating trend exists for nitrite and some heavily degradable materials. **Surface water quality is well suited for river bank infiltration which is the major source of water supply along the Danube between Bratislava and Budapest.**

The water quality of the side branches differs from that of the main Danube channel due the lower velocities and periods and places with stagnant water. This negative trend has been observed with high pH, high organic matter and low oxygen contents.

Ground water regime is to large extent determined by the permeability of the main river channel and the variations in river water level. Between Bratislava and Komarno 10 - 20 m^3/s of water infiltrates on Slovakian side and 8 - 9 m^3/s on the Hungarian side. Due to a very large permeability of aquifer, the ground water flow velocities are very high (1 - 3 m/day). The depth of **ground water shows a trend of decrease around 2 m near Bratislava to about zero at Komarno in the last 30 years.** This decrease is due to erosion of the river bed. An important feature is the large ground water level fluctuation.

The **ground water quality** in the area dominated by the **infiltration from the Danube is generally in a good state.** The quality abstracted from the wells located close to the Danube is generally excellent. For the areas further away from river, where the ground water infiltrated partly in agricultural and industrial areas, there are some problems with ground water pollution.

The ongoing pre-dam trend with lowering of the Danube water level, changes in the character of the flood peaks, endikements, cutting off the side branches upstream and fortification of the main channel **has stressed the biotic communities substantially during the last decades.** As a result of past ground water decrease, some areas of soft alluvial forests have been turned into hard alluvial forest. The latter was often cultivated with poplar and white willow. Furthermore it was estimated that approximately 200 ha of the originally more than 2000 ha are not alluvial forest any longer. In addition, forestry has replaced many natural forests by plantations, where alien, introduced cultivars of poplar have been used. Due to anthropogene effects the structure and dynamics was considerably disturbed and made the invasion of Solidago, Aster and Impatiens species possible.

Compared to other reaches of the Danube human impacts have until now not been as large as elsewhere. As the original type of alluvial forest almost completely disappeared from Europe, the significance of Szigetköz from the point of view of conserving Europe's natural heritage is of outstanding importance. Similar situation is on the Slovak side in inundation between Dobrohost and Palkovicovo.

However, partly due to the decrease in ground water tables during the past decades it has been necessary to make artificial irrigation for the agriculture. However, artificial irrigation has its disadvantages as compared to the natural situation, because the downward water flux causes a considerable leakage of nitrates and chemicals used in agriculture.

Negative influence of ground water decrease can be still seen in areas close to Bratislava.

Immediate Impacts of Damming the Danube

After the closure of the Danube, the major part of discharge has been diverted to hydropower station. The reduced discharges have led to significant decrease in river water tables, 2 - 3 meters according to Hungarian measurements. **Most of the river arms had no flows at the time just before the closure of the Danube due to low flow season.** However, many of them are open at their downstream connections to the main river and had therefore **stagnant water due to backwater effects.** In all cases the water levels of the river arms has been negatively affected.

The discharge in the Mosoni Danube in Hungary has increased.

The following three factors have had some immediate impacts on ground water regime:

- increase in ground water levels in areas near the reservoir, positive effect
- decrease of ground water levels in areas near the river downstream the closure, negative effect
- higher discharge and water levels in the Mosoni Danube and increase in ground water levels in nearby areas, positive effect.

These effects are spreading to larger areas with time, and in some areas are superimposed and to some degree counterbalancing each other. This is the case in upper part of Szigetköz downstream from Rajka. In some villages in dug wells of limited depth (less than 2 m below ground water level) the drop in ground water level resulted in drying out of some wells. In areas where the ground water abstraction is done from deeper wells, including the bank filtration schemes, no immediate effects on ground water availability have occurred.

Analyses of ground water quality have not indicated so far any impact.

Closure of the Danube has influenced the Danube seriously. There is **reduction of discharge for a reach of about 40 km to an extreme low level.** This causes a huge **immediate damage to all water organisms, especially those living in the side branches.** If the situation will continue until the beginning of the vegetation period, most of the fauna and flora depending on floodplain ecosystem condition will be heavily damaged and may have resulted in the loss of essential portions of populations and thus in reduction of genetic diversity and thus adaptability. (To lower the immediate effects, some measures are in progress, e.g. putting the discharge into river branches and increasing the water level in the Danube.)

Upstream the dam the river changes to an impounded lake with significantly smaller flow velocities. Thus, the river system will change on this reach its character, there will be loss of reophil organisms.

Construction of dam interrupted migration of fish and many species of water insects, so they cannot reach their reproduction zones upstream.

Hydrological conditions for agriculture and forestry have changed (mostly neutral and positive changes).

The new channel and locks represent an **improvement of the navigation.** On the Danube downstream the closure, navigation except small vessels has become impossible. Thus Hungary has lost 40 km of international navigation route.

Variant C created changes in landscape character upstream the dam as well as downstream. **As a substitute the lake (through-flowing reservoir) has been created as a new element in the landscape.**

2.2.3. Possible Remedial Measures Proposed by Working Group

The construction of Variant C causes large impact on the environment. Working Group describes a **list of possible measures** ranging from substantial changes of Variant C to small additional measures.

Division of this chapter is generally divided in the area of reservoir and the area downstream from reservoir. Some other possible measures are mentioned in addition.

<u>Restoration the Floodplain inside of Reservoir Area</u>

Between the left and right side dikes floodplain ecosystems could be restored **to a pre-dam conditions** to a great extent between Bratislava and Rajka, **by removing the closure of the Danube.** In addition, suitable measures can be taken to allow navigation through the navigation canal and to stop the erosion in the Danube. **This statement is according to the London Agreed Minutes with the proclamation of 95 % of discharge into the original river bed. Technically it is not possible to remove closure and to allow navigation through the navigation canal.** For division of water is always necessary some structure on the Danube and it is necessary to rise water level at the entrance of the navigation canal at least to 128.5 m asl.

<u>Remedial Measures for Floodplain downstream Reservoir</u>

It has to be the aim **to restore the dynamics of water and substrate to the conditions similar the natural conditions.** This implies the splitting of the Danube discharge to navigation canal and the Danube. This can be done by managing discharge that way, that the typical water level hydrograph with flood periods and periods with low water level is achieved. In the report it is added that this can be achieved perhaps in the average at a slight level. Using all management possibilities it is possible to achieve better conditions, or conditions similar not only to the pre-dam conditions, but conditions few decades before pre-dam conditions. Management tools are:

- **division of discharge**
- **underwater weirs or other small structures**
- **management of intake structures by Dobrohost and at Dunakiliti**
- **measures inside of inundation**
- **interconnection the Danube and river branch system.**

There exists a technical help for starting natural processes. During the last decades the channel system (the Danube and river branches) was changed to a quite unnatural stage. **The Danube discharge nearly as high as in the pre-dam conditions would not be sufficient to improve the ecological situation compared to October 1992. Measures could be taken to reduce river sole erosion and to start natural processes.**

Shallow underwater weirs in the main channel situated in front of river branches could increase the water level and ensure that the ground water table will not be lowered.

Removing the thresholds between the main channel and the side branches will then enable splitting up the discharge so that the flow velocity and the pulling power will reduce.

Removing the fortifications from the banks of the main channel will allow the river to saturate its bed load deficiency by lateral erosion.

All these measures together will initiate natural processes that guarantee a sufficient ground water recharge, a high diversity of ecosystems and a reduction of river sole erosion.

These statements of the Working Group are very important. The Working Group sees in the lateral erosion positive influence in opposite to the Hungarian specialists. They included as negative effect that some parallel training structures and other river training works have slid into Danube. The Working Group explicitly expresses that the Danube discharge nearly as high as in the pre-dam conditions (this means the well known 95 %) would not be sufficient to improve the ecological situation in comparison to October 1992. In Executive Summary page iv is clearly stated that "**In the past, the measures taken for the navigation constrained the possibilities for the development of the Danube and the floodplain area. Assuming the navigation will no longer use the main river over a length of 40 km a unique situation has arisen. Supported by technical measures the river and the floodplain can develop more naturally**".

If the priorities will be not given to starting natural processes, but rather to guarantee sufficient ground water levels and/or continuous water supply to side branches (the well known 95 %), technical supply method as small inlets/outlets could be pointed out.

To avoid the bed erosion downstream the dam, dredged gravel from the reservoir can be added. After completion of Phase 2, the spillway weir can help to manage erosion/sedimentation problems.

To reduce river sole erosion it is possible **to build belts of concrete and fortify river bed** in reaches, where sole erosion is observed.

<u>Other Remedial Measures</u>

Other remedial measures are mentioned as:

- fish passes
- shape measures in reservoir
- optimizing floodplain habitats
- prevention of negative impacts on infiltration of water in aquifer.

At some places the mentioned measures have been realized. There are the shape measures by Cunovo and Rusovce, hydraulic structures in reservoir, velocity ensure in reservoir, discharge from power canal into inundation, some fish passes and the others.

2.2.4. Various Water Management Scenarios

Summary of impacts for different scenarios is included in Appendix I of the Working Group Report.

Scenario A: 95 % of average discharge to the Danube
Scenario B: Main part of water to Gabcikovo
Scenario C: According to water levels and discharges planned by the Slovak Commission for Environment
Scenario D: Danube redirected to the former bed
Scenario E: Step by step solution

Scenario A means that 95 % of water should flow into the Danube and some water into power canal for navigation.

Scenario D means pre-dam condition and progress of pre-dam development. This scenario is long-term negative and is taken as the basis for comparison of other scenarios, therefore all items in Appendix I for Scenario D have value of zero.

Scenario B means scenario without remedial measures and with minimal discharge into Danube.

Scenario C means scenario with remedy measures and ensure of water levels analogue to discharges presented by the Slovak Commission for Environment.

Scenario E is step by step solution proposed by CEC experts.

It is interesting to compare pluses and minuses in the Table in Appendix I. It seams, that the best solution is the Variant C with Scenario C. (Scenario D is not using the Variant C and Scenario A is using the Variant C only for navigation and not for hydropower production.)

From the Table in Appendix I of the Working Group Report it can be read that from Scenario C it is expected progressive changes in water level developments, regime of fluctuation similar to pre-dam conditions, lowering of water velocities in the Danube, proper development of floodplain dynamics, positive impact on the Mosoni Danube, positive impact on sedimentation in Bratislava (stopping the erosion and starting the sedimentation), negative effect of sedimentation in reservoir (fine sediments), progressive better situation by Palkovicovo (Sap), unknown changes of water quality in reservoir, but probably better in the Danube, generally progressive better ground water regime near reservoir, within floodplain and on area behind floodplain, no changes in ground water quality, better condition for agriculture near reservoir and no changes downstream and for floodplain forestry, improving navigation in navigation canal, reduction of navigation in the Danube (for small vessels), production of hydropower.

It is interesting to compare this impact assessment with real situation. Ground water regime has improved all over the area on the Slovak side. On Hungarian territory has improved close to the Mosoni Danube and under the Cunovo and Rajka. Negative impacts are to be seen in inundation. This is because the intake structure in Dunakiliti on Hungarian territory has not been put into operation and because small underwater weirs have not been constructed. Ground water quality is generally without changes, with slightly improvement at water work Rusovce - Ostrovne Lucky. There is improvement by water supply of Maly Danube and irrigation canals and general improvements for agriculture and forestry, especially downstream from Bratislava. Surface water quality is still not evaluated, but there are no significant changes. Effect of sedimentation is still not measurable. Erosion under Bratislava has stopped. There is improvement by navigation and by entrance into the Bratislava harbor. Some other aspects are just under evaluation and an additional monitoring supported by CEC is before starting.

2.2.5. Explanation

The whole report is influenced by the London Agreed Minutes. In spite of this, in the whole report there is no once used the word "catastrophe" or "ecological catastrophe". In the opposite, there is stated long-term negative development of the area from various points of view, there is defined the pre-dam situation in inundation area and the river branches. There is description of various scenarios, influenced mainly by London Agreed Minutes, with the more or less proper and realistic evaluation in Appendix I. This part of report was signed by all members of Working Group including Hungarian and Czechoslovak experts.

In Chapter 9 in the report [B] there is recommendation of the CEC group of experts. This recommendation is not signed by Hungarian and Czechoslovak experts. Czechoslovak expert denied to sign the recommendation because of using the London Agreed Minutes as a basis for water management and not mentioning the treaty on construction and operation of Gabcikovo - Nagymaros water works. Except this, according to the situation of the location, the Czechoslovak side was aware on not realistic technical possibilities to fulfill this proposal. Because of denying of Hungarian side to realize underwater weirs and not signing the recommendation, we were aware of possibility of repetition of the "case story" of London by confirmation of putting 95 % of water in the former river bed. This means that the first phase, Scenario A, would be prolonged by not constructing underwater weirs probably into infinity as a status quo for the International Court of Justice.

The evaluation of this report was the meeting between the CSFR, Hungary and EC on Gabcikovo - Nagymaros Project held in the Brussels on 27 November 1992. All participants agreed that the Working Group of independent experts (November 9 - 23, 1992) has prepared the report of high quality (see Agreed Minutes of the meeting given in Appendix). In the Agreed Minutes there is no remark on maintaining of 95 % of discharge into the old Danube, there is no requirement to stop the work and no definition of catastrophe is used. The result of the meeting was the proposal to submit the dispute to the International Court of Justice.

2.3. FIELD INSPECTION AT THE GABCIKOVO CONSTRUCTION SITE (May 24, 1993)

In order to provide an update of the situation, described in the working group report of November 23, 1992 [B], a field inspection was carried out according to the scope of work in the Terms of References of the Commission of the European Community, as follows:

1. Describe the ongoing construction activities (scope and time schedule) in the region and assess preliminary the aim and objectives of these activities in terms of protection of the environmental and ecological resources.

2. Assess the current discharge and establish the discharge in the last three months. Identify, if any, discrepancies in the discharge data provided by the Hungarian and Slovak sides.
3. Preliminary assessment of the environmental/ecological consequences (including the impact on ground water quality and level) of the deviation of the Danube since October 1992.

The inspection team was composed of two experts:
- Mr. Jan M. van Geest, Director DHV Environment and Infrastructure, The Netherlands (team leader)
- Mr. Johann Schreiner, Director, Norddeutsche Naturschutzakademie, Germany.

2.3.1. Main Results of the Field Inspection

In the report there is described the status of ongoing work in comparison to previous field inspections.

On the Slovakian flood plain area the remedial measures have nearly all been carried out according to the design of original project. Dams, weirs and spillways have been constructed and the branches filled with running water.

On the Hungarian flood plain area the digging of a water inlet canal has just started. Due to uncertainties caused by vague aims and objectives **there are no clear plans. A closure of the Danube near Dunakiliti** in order to set up the water level **and to use the water intake structure of the Dunakiliti works, is a point of discussion.**

In terms of protection of environmental and ecological resources the aims and objectives of these works are assessed by the inspection team as follows:
- It is not necessary to complete the construction works on the inundation weir.
- If more water should be directed to the old Danube bed, **it is necessary to strengthen the tail protection of the inundation weir** or at least behind a number of openings of the weir. It is also necessary to protect part of the banks of the newly created winter-bed and of the newly created summer-bed. It is not the Slovakian government's objective to prepare the river bed for daily use. It is possible to carry out these works in a few months.
- Under the present circumstances **it is very useful to complete the works in the Slovakian floodplain. The branches are filled with running water.** However not all structures allow migration of species of fauna.
- **It is urgent to build irrigation works in the Hungarian floodplain.** It is also **urgent to build dams or underwater weirs in the Danube** in order to increase the Danube water level in front of the intake structure belonging to the Dunakiliti complex.
- Opening of the road in August this year serves neither any environmental nor any ecological aim, but it is urgent from a human point of view.

One structure of the Phase 2 works is a spillway with a sill level which is the same as the river bed level and a high discharge capacity.

This **spillway makes bed-load transport possible** and makes it possible to **cause floods in the old Danube area.** These two possibilities are very important from the ecological point of view.

Preliminary assessment of the environmental and ecological consequences of the deviation of the Danube since October 1992 have been done.

2.4. WORKING GROUP OF MONITORING AND WATER MANAGEMENT EXPERTS FOR THE GABCIKOVO SYSTEM OF LOCKS (September 8, 1993 - December 1, 1993)

Based on negotiation among EC representative and the State secretary of the Hungary Republic and the Slovak Republic, "Establishment of a Group of Monitoring and Water Management Experts for the Gabcikovo System of Locks" had been realized on 26 August 1993. The goal of the establishment of this Group of Experts is expressed in the Communiqué from the First Meeting held on 8 - 9 September 1993 in Bratislava (see in Appendix).

The Working Group was composed of the following five experts:

CEC:	Prof. Johann Schreiner (primus inter pares), Director, Norddeutsche Naturschutzakademie, Germany
	Mr. Jan M. van Geest, Director, DHV Environment and Infrastructure, The Netherlands
	Mr. Jens Christian Refsgaard, Chief Hydrologist, Danish Hydraulic Institute, Denmark
Slovakia:	Prof. Dr. Igor Mucha, Faculty of Natural Science, Comenius University, Bratislava
Hungary:	Prof. Dr. Gabor Vida, Head of Department of Genetics, Eötvös L. University, Budapest

The Group of Experts submitted two reports:

- Commission of the European Communities, Republic of Hungary, Slovak Republic. Working Group of Monitoring and Water Management Experts for Gabcikovo System of Locks. **DATA REPORT - Assessment of Impacts of Gabcikovo Project and Recommendations for Strengthening of Monitoring System**, Budapest, November 2, 1993.
- Commission of the European Communities, Republic of Hungary, Slovak Republic. Working Group of Monitoring and Water Management Experts for Gabcikovo System of Locks. **REPORT ON TEMPORARY WATER MANAGEMENT REGIME**, Bratislava, December 1, 1993.

In Appendix D of the second report in separate volume is the "Scenario submitted by the Slovak Expert" entitled: **REPORT ON TEMPORARY WATER MANAGEMENT REGIME, INDEPENDENT SCENARIO**, elaborated by Univ. Prof. Igor Mucha on behalf of Slovak Republic, Bratislava, November 28, 1993.

2.4.1. Review of the Main Impact Assessment

"In the past, the measures taken for the navigation constrained the possibilities for the development of the Danube and the floodplain area. Assuming the navigation will no longer use the main river over a length of 40 km a unique situation has arisen. Supported by technical measures the river and the floodplain can develop more naturally" (report [B], p. iv). This unique situation does not exist on any other Danubian hydropower work, because the Danube was "canalized" by fortified banks in all other hydropower construction sites.

Discharge

"Evidently, there is **no significant long term trend in the Danube discharge**" (report [E], p. 5) at Bratislava for the last 40 years. "Historical discharge data from the **Little Danube show a clear decreasing trend** from the mid 1970's to 1992. This is a result of a general decrease in Danube water level at Bratislava" (report [E], p. 5). "At Mosoni Danube historical discharge data exist from the mid 1980's onwards" (report [E], p. 5). Data are not included in Data Report (report [E]). According to our knowledge, discharge from the mid 1980's onwards at Rajka had been only occasional during high discharge in Danube.

Due to putting Gabcikovo hydropower station into the operation **"In the Old Danube the discharge has in 1993 been reduced to in average about 400 m^3/s corresponding to about 20 % as compared to the pre-dam conditions"** (report [E], p. i). This discharge is higher than originally projected discharge (50 m^3/s) according to the Treaty 1977. This means that only 72.5 % from discharge in Bratislava was used for hydropower production (report [E], p. 9), which is less than on other hydropower plants on the river Danube and the river Rhine. "As an effect of the project **the discharges in the Little Danube and the Mosoni Danube have been increased by 10 - 20 m^3/s, so that Mosoni Danube now permanently carries discharge"** (report [E], p. 56).

Surface Water Level

"Evidently, there is **a significantly decreasing long term trend in the Danube water levels** at Bratislava of about 1.5 m for the last 40 years" (report [E], p. 14). This trend is clear from Bratislava until Dunaremete.

"At Bratislava the water levels during low flow periods have **increased** by 1 - 2 m as compared to pre-dam conditions, i.e. to a **level corresponding to the situation 40 years ago**" (report [E], p. ii). This has solved the problems with river bed erosion at Bratislava and has ensured the ship entrance into the Bratislava harbor during the whole year around. This has ensured the higher discharge into the Little Danube and the permanent discharge of 20 m^3/s into the Mosoni Danube on Hungarian territory.

"In the upstream part of the Old Danube the 1993 **water levels have been reduced by 2 - 4 m as compared to pre-dam conditions,** and have thus reached a level 2 m below the lowest ever recorded values" (report [E], p. ii). "Scenario 3 consists in construction of some underwater weirs for increasing the water level in the Old Danube and for enabling interconnection between the main river and the branch system. Construction of underwater weirs is possible along with any discharge regime" (report [G], p. 48). "In addition, the characteristic natural dynamics of the water level fluctuation have been changed (reduced) significantly" (report [E], p. ii). "This could be influenced by implementation of improved operational rules for day-to-day water management" (report [G], p. 37).

Surface Water Quality

"Due to high oxygen content, low organic carbon contents and very small quantities of fine grained sediments the **surface water quality is generally well suited for river bank infiltration,** which is the major source of water supply along the Danube between Bratislava and Budapest. With exception of November - December 1992, when sudden changes of regime and a high flood event occurred, **no significant changes in surface water quality parameters as compared to pre-dam conditions can be detected after damming the Danube"** (report [E], p. 23).

Inundation Area

"The water quality of the side branches differs from that of the main Danube channel due to the much lower velocity and periods and places with stagnant water. In dryer years a negative trend has been observed with high pH, high organic matter and low oxygen contents" (report [E], p. 23). "**Until about 30 years ago the side branches carried a substantial part of the total discharge.** In the following years the connection between the river branches and the main river were closed in order to ensure high water depths for navigation. This resulted in a pre-dam situation with total lack of connection about half the year and full connection only about 20 days per year" (report [G], p. 17). "The pre-dam situation on the Hungarian side was similar to the pre-dam situation on the Slovak side" (report [G], p. 19).

In order to remedy situation after damming the Danube and the processes described above, "Slovakia has implemented a project with the following key elements:

- Intake of water at an intake structure in the power canal, at Dobrohost. Through a new canal this water is diverted into one of the river branches.
- Construction of a number of hydraulic structures in the side channels."

Using this "it is possible to regulate the intake of water from 0 to 140 m^3/s (234 m^3/s when the structure is completed)" (report [G], p. 17). (see report [G], p. 17 for details). "The system was taken into operation at the end of April 1993, and the discharge has since then varied between 10 and 70 m^3/s" (report [G], p. 17).

"According to the **experience from supplying discharge to the Slovakian branches** after May 1993, 70 m^3/s was apparently sufficient to clean the river bottom from mud at so many places that a very **significant infiltration to the ground water system started.** Correspondingly, such condition will be sufficient for biocenosis" (report [G], p. 27). As a result of the continuous discharge the water quality in side branches has improved.

"As a result of river regulation during the past 30 years merely a limited number of side branches succeeded in preserving virtual connection with Danube. Thus the pre-dam condition Hungarian side was similar to the pre-dam situation on the Slovak side. After damming the Danube the connection between the Danube and the side channels disappeared" (report [G], p. 19). "The water supply to the branch system on the Hungarian side presently comes from the outlet structure at Cunovo reservoir (22 m^3/s) and the right side seepage canal (3 m^3/s)". The originally projected and ready made outlet structure at Dunakiliti is not used for water supply. "**Unlike on the Slovak side** the velocities have not been high enough to remove the fine bed material ..." (report [G], p. 21) because of not sufficient water supply. Thus, **the higher discharge of the branch system on the Hungarian side could improve the state** to the better level as before the damming the Danube.

Sediment Transport and Sedimentation/Erosion

"The main channel has been significantly lowered due to erosion caused by a combination of several man made factors" (report [E], p. 24). "In some places the river bed has been lowered more than two meters since the 1960's, leading to lower ground water levels, occasional drying out of river branches and less flushing of most river branches" (report [E], p. 25).

"Most of the transported material of the river has already settled upstream in the reservoir" (report [E], p. 25). "For quantitative analysis few data exist enabling some tentative but no firm conclusions regarding the impacts due to the Gabcikovo Project". "No major net erosion and sedimentation in the Old Danube" will occur. "During some events sedimentation of fine material will take place. This fine material may be washed away during flood events" (report [G], p. 30, scenario - continuation of the present situation).

Because of measures realized on Slovakian territory "The river bed in **the main branches on the Slovakian side will continue to be free from mud,** so that good infiltration conditions exist" (report [G], p. 30).

"The river bed in **the main branches on the Hungarian side will continue to be clogged with fine material/mud** and prevent significant infiltration to the ground water system" (report [G], p. 31) until similar measures (as on the Slovak side) will not be realized. Such measures have been originally projected.

Ground Water Level

The trend over the past 30 years points out that "the ground water levels have decreased ranging from about 2 meters around Bratislava to about zero at Komarno. This decrease is due to erosion of the river bed" (report [E], p. 28).

"From the most recent map it is noticed that **the ground water levels on all the Slovakian territory have increased or have not been affected. The increase have mainly occurred in the upstream area close to the reservoir, i.e. in the area which has been most negatively affected by the long term trend of decreasing ground water levels**" (report [E], p. 34). "It appears that the ground water levels in Hungary have also increased close to the reservoir. In the middle of Szigetköz between Dunakiliti and Asvanyraro the ground water levels have decreased in areas close to the Danube" (report [E], p. 34).

Nevertheless in our opinion, the Monitoring and Data Report proved sufficiently that the ground water level on the Hungarian territory can be still improved to the better level as before damming up the Danube and i.e. by filling the branch system with water, similarly as it was done on the Slovak side.

Ground Water Quality

"In general **no ground water quality changes** can be identified after the damming the Danube. According to the Hungarian Data Report, no significant changes have been detected in the ground water quality" (report [E], p. 40).

Flora and Fauna

"It can be estimated that forestry and agriculture together with regulation measures in the Danube and construction of dikes have caused changes in flora and fauna in former times but the data base does not allow to analyze the long term trends for most of the taxa. On the other hand in some cases it provides a good basis for analyzing the trend in the past and for monitoring the development in the future" (report [E], p. 45).

For pre-dam conditions "long-term analysis with a good data base can be done with fish species. From 56 native fish species 4 are now extinct, 13 species were introduced by man" (report [E], p. 45).

Agriculture

"Due to the general decline of the ground water table in large parts of the area during the past 40 years the conditions for capillary water supply to the root zone have decreased and the irrigation water requirements have increased correspondingly" (report [E], p. 47).

"Due to the **increase of ground water tables** in large parts of the Slovakian area the conditions have improved. According to an estimate the requirements for irrigation from external sources is expected to decrease by about 25 % as compared to the pre-dam conditions" (report [E], p. 47).

Forestry

"As a result of the changes in ground water levels the forestry has been positively influenced in Slovakia and negatively in Hungary" (report [E], p. iii).

Electricity Production

"The Gabcikovo hydropower plant has produced 150 - 200 GWh/month in 1993. This corresponds to about **10 % of Slovakian's electricity consumption**" (report [E], p. ii).

Navigation

"The international navigation through the ship locks at Gabcikovo has functioned since its opening on 9 November 1992" (report [E], p. 55). This is surely an improvement of navigation and a positive impact from the point of view of development in the inundation area, decreasing the fuel consumption and exhales.

2.4.2. Review of the Scenarios

In the REPORT ON TEMPORARY WATER MANAGEMENT REGIME [G] five scenarios with different characteristics on discharge regime and remedial measures have been elaborated. All the five discharge regimes are dynamic and characterized by the below average values. The five scenarios and their most important impacts can be summarized as follows:

Scenario 0: November 1993 Situation

* Old Danube: 400 m^3/s
* Slovakian side branches: 40 m^3/s
* Hungarian side branches: 10 m^3/s

The key impacts are as also described in the Data Report:

* The environmental conditions on the Hungarian inundation area are bad due to lack of water.
* The flow velocities and water levels in the Old Danube are too low for providing suitable living conditions for typical flora and fauna.
* The lack of connections between the main channel and the side branches prevents migration of wetland species.

Scenario 1: Increased Water Supply to the Hungarian Side Branches

* Old Danube: 400 m^3/s
* Slovakian side branches: 50 m^3/s
* Hungarian side branches: 50 m^3/s
* 1 - 3 floods of more than 3500 m^3/s are expected to occur each year in the Old Danube.

The key impacts as compared to Scenario 0 are:

* Improvements of the environmental conditions for the Hungarian inundation area.

Scenario 2: Increased Discharge in Main River and in Hungarian Side Branches

* Old Danube: 800 m^3/s
* Slovakian side branches: 50 m^3/s
* Hungarian side branches: 50 m^3/s
* 1 - 3 floods of more than 3500 m^3/s are expected to occur every year in the Old Danube.

The key impacts as compared to Scenario 1 are:

* Improvements of the main river environment to a level where species requiring higher flow velocities (e.g. fish) have suitable living conditions.

Scenario 3: Construction of some Underwater Weirs

Scenario 3 is basically identical to Scenario 2 except for construction of a number of underwater weirs.

The key impacts as compared to Scenario 2 are:

* The connections between the main channel and the side branches on both sides are maintained or even improved as compared to pre-dam conditions.
* For discharge not exceeding 1000 m^3/s the flow velocities in the Old Danube are not sufficient for maintaining the typical flora and fauna.

Scenario 4: Full Capacity of Variant C Structures Used for Water Supply of the Main River and the Branches

In Scenario 4 as much water as technically possible will be diverted into the Old Danube and the side channels. However, this will technically not be possible until after the summer of 1996.

2.4.3. Review of some Recommendations and Assumptions

"None of the described scenarios can be recommended without modifications. Therefore the three EC members of the Working Group will recommend a **combination of elements from different Scenarios**". "In addition to the environmental aspects **also economical** aspects should be considered" (p. iii).

"Scenario 3 consists in construction of some **underwater weirs** for increasing the water level in the Old Danube and for enabling interconnection between the main river and the branch system. **Construction of underwater weirs is possible along with any discharge regime"** (p. 48). "Water level fluctuation could be influenced by implementation of improved operational rules for day-to-day water management" (p. 37). "A discharge of 3500 m^3/s twice per year will be enough to clean the river bed sufficiently for fine material deposited during low discharge conditions and to spread this material in the whole inundation area" (p. 25).

"To provide sufficient living conditions for typical fish species living in the Danube under pre-dam conditions a pattern of different flow velocities in the river bed is necessary. Flow velocities near the river bottom of at least 0.6 m/s must occur at several places all over the year" (p. 26). This is according to the study in the Austrian part of Danube. Quotation from the mentioned study (G. Zauner, 1991, Vergleichende Untersuchungen zur Ekologie der drei Donauperciden Schratzer, Zingel und Streber in gestauten und ungestauten Donauabschnitten, Diplomarbeit, Universität für Bodenkultur, Wien). "Unter 35 cm/s (7 cm über Grund) konnte kein einziger Streber nachgewiesen werden. Über 65 cm/s liess sich wiederum kein Streber mehr nachweisen".

In the inundation areas "a variation of the water level within 2 m will be enough to ensure the dynamic character including the flooding according to the pattern in pre-dam conditions" (p. 26). "Until about 30 years ago, the side branches carried a substantial part of the total discharge" (p. 17). At the Slovak side "it is possible to regulate the intake of water from 0 to at present 140 m^3/s" (p. 17), which is ensuring the necessary variation of the water level. This "according to the experience from supplying discharges to the Slovakian branches after May 1993, 70 m^3/s corresponding to a typical flow velocity in the main side channels of 0.1 - 0.3 m/s (cross-sectional average values) was apparently sufficient to clean the river bottom from mud at so many places that a very significant infiltration to ground water system started" (p. 27). This is much better than in the pre-dam conditions.

"To ensure ecological conditions which are as good as pre-dam conditions migration of wetland species between the main river and the side branches should be possible all over year in both directions. Migration can be made possible either through fish passes or through direct flows between the main river and the side branches during some periods" (p. 28).

3. COMMENTS TO THE WWF STATEMENTS ON THE EC EXPERTS' REPORTS

Note: the text written in *italic* is the quotation from the WWF paper "A New Solution for the Danube" [5].

*****

Introduction

WWF has been actively engaged in the Gabcikovo case since 1986. Several experts reported on the most important aspects of Gabcikovo. In January 1993, WWF submitted a joint NGO paper to the EC recommending much needed studies necessary to get a comprehensive overview of the benefits and negative impacts of the hydroengineering project on ecology, the economy, national/international law and on the social situation of the people affected.

The first Czechoslovak attempt to involve the EC and Hungarian experts into the optimization of water regime dates back to September 6, 1990 when the Czechoslovak plenipotentiary for construction and operation of the hydropower system Gabcikovo - Nagymaros submitted this proposal during negotiations with his Hungarian colleague. On 26 October 1990, the plenipotentiary sent a draft agreement on joint Czechoslovak and Hungarian co-operation on the EC PHARE program (see Appendix). Czechoslovakia has never received positive answer. The above mentioned EC PHARE program entitled "Danubian Lowland - Ground Water Model: Surface Water and Ground Water Model of Danubian Lowland between Bratislava and Komarno; Ecological Model of Water Resources and Management" has been subsequently carried out only on the territory of Slovakia [2, 3]. Dr. Emil Diester from the WWF was invited to the workshop at the beginning of this PHARE project, invitation was not accepted.

Working Group of Independent Experts [B] recommended "studies, monitoring and modeling as a basis for water management in 1993 and for the long term". Monitoring of the effects of the conditions after the closure of the Danube by Cunovo has been carried out by the Slovak Center of Monitoring at the Slovak Hydrometeorological Institute according to the original international Treaty from 1977 [4] and to the later proposals and projects of monitoring.

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The goal of the WWF paper "A NEW SOLUTION FOR THE DANUBE" is:

- *to give an independent, scientifically based review on the present situation in the Danube region affected by Gabcikovo*
- *to critically comment on the Reports of the EC Mission and*
- *to give recommendations for the future management of the river.*

WWF, having high competence on the Danube and in the Gabcikovo issue, considers it as its responsibility to produce this independent statement.

Today, circa 8,000 hectares of interconnected, mostly very valuable floodplain biotopes and the second largest drinking water reservoir in Europe for up to 5 million people can still

be saved. This makes this stretch of river between Bratislava and Györ unique at Central and West European scale and an ecological priority area.

It is the objective of our recommendations to prevent the continued, total destruction of this wetland and to develop a long-term, ecologically sound solution for the Danube.

Our aim is to discuss this WWF paper, its competence in the Gabcikovo issue and to clarify the WWF accusation of the Slovak Republic. The titles of the following chapters are identical with the WWF paper chapters.

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Brief Review of the recent Gabcikovo "history"

Following WWF's international law study (3), presented in Bratislava on 20 October 1992, this "Variant C" is illegal because it violates the international principles of good neighbourliness and of equitable utilization of shared resources. Also, Variant C violates several boundary agreements and does not constitute a legitimate response of CSFR or Slovakia to an alleged violation of the 1977 Treaty on Gabcikovo - Nagymaros by Hungary.

WWF is surely aware, that according to the **"Special Agreement for Submission to the International Court of Justice of the Differences Between the Republic of Hungary and the Slovak Republic Concerning the Gabcikovo - Nagymaros Project"** in the Article 2 is written:

(1) The Court is requested to decide on the basis of the Treaty and rules and principles of general international law, as well as such other treaties as the Court may find applicable,
(a) whether the Republic of Hungary was entitled to suspend and subsequently abandon, in 1989, the works on the Nagymaros Project and on the part of the Gabcikovo Project for which the Treaty attributed responsibility to the Republic of Hungary,
(b) whether the Czech and Slovak Federal Republic was entitled to proceed, in November 1991, to the "provisional solution" and to put into operation from October 1992 this system, described in the Report of the Working Group of Independent Experts of the Commission of the European Communities, The Republic of Hungary and the Czech and Slovak Federal Republic dated on 23 November 1992 (Damming up of the Danube at river kilometer 1851.7 on Czechoslovak territory and resulting consequences on water and navigation course).

To make such judgments it belongs to the International Court of Justice and not to the WWF. This is a clear evidence, that **WWF** and a group of *"independent scientists"* **is not independent from the point of differences between the Republic of Hungary and the Slovak Republic concerning the Gabcikovo - Nagymaros Project.**

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After its diversion, the "Old" river bed received only 10 - 20 % (200 - 400 m³/sec) of its water, while the "rest" was countinuously diverted into the turbines of the Gabcikovo powe

plant. The debatable, one-sided benefit comes in the form of electricity production. It involves numerous negative impacts on the hydrology and ecology of floodplains as well as on the social situation of local people.

Hydropower plants are in all countries constructed that way, that water is diverted into the turbines. Gabcikovo uses circa 70 % of water in average for energy production. Water of the Danube is in average used for:

Maly Danube	30 m^3/s	
Mosoni Danube	25	
seepage canals	8	
seepage into Danube	30	
Groundwater recharge	30	
Slovak inundation	40	
Hungarian inundation	40	(in preparation)
shiplocks	30	
by-pass weir, discharge into the old Danube	400	
turbines -electricity production	1392	
Long-term average discharge in Bratislava is	2025 m^3/s	

The debatable, one sided benefits come in the form:

- **flood protection** between Bratislava and Sap, especially the **Hungarian territory** (compare floods and flood territory in 1954 and 1965)
- **electricity production** (10 - 12 % of the whole consumption in the Slovakia)
- less consumption of brown coal, less exhales
- **improvement in shipping** (certainty of dip during the whole year, time saving, saving of energy, improvement of entrance into Bratislava harbor, exclusion of fords and moving sandbanks)
- improvement in **agriculture**, increase of ground water level, decrease of irrigation needed, less impacts upon ground water
- improvement in **forestry**, higher ground water levels, more typical for floodplain
- new **recreation** possibilities
- more water for irrigation
- continuous **supply of the Mosoni Danube**
- improved **supply of the Maly Danube**
- **water for the river branches**, inundation and the valuable floodplain biotopes, Slovak territory
- stopping the erosion at Bratislava
- decrease of problems of sedimentation downstream Sap
- **saving the 40 km long stretch of floodplain** in comparison with other hydropower stations on the Danube
- no village was abolished
- indirectly due to increased revenues

In report [B] the EC Working Group concluded: "**In the past, the measures taken for the navigation constrained the possibilities for the development of the Danube and the**

floodplain area. With the past endikements, especially during the last century the original zonation in vegetation towards higher grounds and associated forests was largely 'diked' out of the system. **Assuming that the navigation will no longer use the main river over a length of 40 km, a unique situation has arisen.** Initiated by technical measures, the river and the **floodplain area can develop more naturally."**

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In the winter of 1993, the Slovak investor company VVsp (Vodohospodarska Vystavba s.p.) started to build an artificial water-input system for the remaining parts of the valuable floodplain system in Slovakia which was about to totally dry up. Since the May of 1993, an input structure in the power canal near the village of Dobrohost has been leading ca. 30 m^3/sec of Gabcikovo reservoir water into a large, sealed canal. This provides a constant filling of the interconnected side-arms which are dissected by newly erected or enlarged lateral dikes (creating 7 "cassettes").

A water-input system for the floodplain system in Slovakia and similar system on Hungarian side had been planned much earlier than in winter 1993. WWF probably does not know that **the water input system for Hungarian floodplain with capacity of up to 200 m^3/s is already ready** and it is a part of the ready made Dunakiliti weir. At nearly the same river kilometer, the water input system from power canal with maximal capacity of 243 m^3/s (to supply the Slovak floodplain) has been build at the same time (together with the construction of power canal), it means much earlier than mentioned in WWF article. Both water-inputs are parts of construction plans. WWF can be sure, that the input system is as large as necessary for yielding this discharge and canal is sealed only near the intake structure. Remember the report [G], p. 27 **"According to the experience from supplying discharge to the Slovakian branches after May 1993, 70 m^3/s was apparently sufficient to clean the river bottom from mud at so many places that a very significant infiltration to the ground water system started."** And WWF is speaking about sealed canal. Discharge into the river branches on the Slovak side is not constant but permanent with variable similar nature discharge and water level fluctuation. Discharge and lateral dikes make it possible to inundate the area, if needed. Similar work has been done on the Hungarian territory, except the fulfilling the river branches with water via the ready made water intake structure or prepared other intake places upwards Dunakiliti weir.

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Due to the ongoing river diversion and the drying up of its entire side-arm system, Hungary started at the end of July 1993 a similar input of water (10 m^3/sec coming from the Cunovo weir) into its side-arm system.

It is surely not a similar input of water. Water is taken from the **Mosoni Danube which is now supplied with permanent discharge** in average more than 20 m^3/s through the Mosoni water-input structure constructed for this purpose at the Cunovo weir. Ready made input structure in Dunakiliti weir and openings on the Danube upstream Dunakiliti are not used, it means that half of the Mosoni Danube water is now used instead of water from the Danube.

Situation in side-arm system in pre-dam conditions can be described as in report [E], p. 23 "...much lower velocity and periods and places with stagnant water. In dryer years a negative trend has been observed...".

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In April 1993, WWF published excerpts from the first Slovak groundwater monitoring data (26 October to 31 December 1992) indicating some organic pollution in several groundwater observation wells near the storage lake ((7). While this first monitoring is too premature giving sound information about possible changes in the aquifer, WWF's concerned, scientific interpretation contradicted the official, very positive interpretation by Slovak authorities. After this, no more comprehensive information on groundwater monitoring was published or available, not even to the extent needed for the EC experts (see chapter Comments A).

About this accusation we will discuss later. At this point it is necessary to stress that the **Slovak side had prepared for the EC experts all required data.**

On the first formal meeting on 8 - 9 September 1993 in Bratislava, there was present a database specialist, the head of the Center of Monitoring at the Slovak Hydrometeorological Institute and he was ready to grant any data. On this meeting the EC experts had asked "**The Slovak and Hungarian experts to collect data and to prepare the agreed data analysis for the respective territories.**" The Slovak side prepared all agreed and required data and except this it confirmed the willingness immediately to grant any data which are in the monitoring database and also the data concerning the putting the hydropower plant into operation.

The situation during the work of Working Group we would like to explain by quotations from the Data Report [E] and from the negotiations on 27 October - 2 November 1993 (Minutes in [E], p. 1) "**the Hungarian Data Report was delayed by a week and did not contain all the data and analyses agreed upon.**".

In the report on temporary water management regime (report [G], p. 68 - 69) there is 5 times said that "**The three EC experts and the Slovakian expert recommend that data** on:
- surface water levels
- surface water quality
- ground water levels
- ground water quality
- flora and fauna

from the national monitoring networks should be exchanged. The Hungarian expert in **theory agrees to exchange all relevant environmental data.** Further agreement is necessary, however, on the detailed elaboration of this after the political decision has been made on which TWMR should be implemented." This confirms that the Hungarian side consciously did not grant the data to the EC experts. We suppose that the WWF had compared the data granted by the Hungary and Slovakia.

We would like to confirm that the Slovak side has been willing to grant all data from the National Center of Monitoring to the EC experts. Evaluation of these data in special reports is carried out regularly.

Except this, the EC experts had to disposal special measurements prepared in framework of program PHARE and they had direct access to these data.

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New Important Facts

River bed erosion

Slovak sources often state that over the last two to three decades the growing river bed erosion resulted in decreasing levels of surface and groundwater downstream of Bratislava, causing a serious deterioration of the wetlands and of the drinking water supply. However, the various origins of these effects were never really quantified. A Slovak study from June 1991 reveals that the reason for this impact was neither the river regulation measures for navigation (excavating 3.5 mil. m^3 of gravel over 40 years) nor the catching of river sediments by the Austrian and Bavarian hydrodams located upstream (the regular bedload is 3-400,000 m^3/year). The really outstanding interference was the huge gravel excavation near Bratislava: in the period of 1976 to 1989, ca. 50 mil. m^3 were exploited from the river bed. Following a WWF estimation, this caused ca. two thirds of the deformation and erosion processes monitored both up- and downstream. This can be observed up to Hainburg (Austria) and in the floodplains near Gabcikovo. It also threatened the stability of the bridges in Bratislava and lowered the groundwater table reducing the productivity of several important drinking water wells near Bratislava.

This leads to the conclusion that the recent overexploitation of the gravel resources near Bratislava supported the "urgent need" (as claimed by Slovak river engineers) to finish the Gabcikovo project. The excavated gravel was used for large-scale industrial constructions in Bratislava and for the building of the Gabcikovo scheme. Without this activity, the river bed erosion would be a small problem today.

The EC experts in [B] clearly expressed that **"The main channel has been significantly lowered due to erosion by a combination of several man-made factors:**

- **dam construction in Austria in the last decades resulting in a sediment (bed-load) deficit;**
- **excavation of gravel downstream of Bratislava;**
- **natural erosion due to the very high velocities in the straightened and narrowed navigation channel;**
- **prevention of bank erosion due to fortification of river banks."**

Slovak study from June 1991 [1] shows that from 1976 to 1989 48.3 mil. m^3 and not circa 50 mil. m^3 were exploited from the river bed. This excavation happened not near Bratislava, but between Bratislava and Sturovo, exactly from the rkm 1709.024 downstream from Sturovo up to rkm 1880.00 at Bratislava. This excavation happened on the stretch of length 171.0 km. In the section from the place of the damming the Danube near Cunovo downstream up to Sap, the excavation from 1976 to 1989 was 3.5 mil. m^3 of gravel, or exactly from rkm 1861.74 (near Ostrovne Lucky) downstream up to rkm 1806.95 (near Medvedov) the excavated volume was 3.74 mil. m^3 of gravel. All these data are included in the report submitted by Slovak side [H]. Since 1984 the gravel excavation upstream from Samorin up to Devin had been stopped, except the excavation because of navigation (excavation of fords). Average volume of excavated bedload material before 1960 was from 530000 to 730000 m^3 per year.

At the beginning of this century, the riparian states thought to establish safe navigation conditions at low water level. Series of measures were taken to attempt to achieve this aim:

- **Closing of river branches** so as to direct the flow into one main straightened channel
- **Fortification of river banks** with stone and concrete works to stop lateral erosion
- **Dredging of gravel on the river bottom** to prepare navigation route - kinete
- **Placing regulation dikes** (or groynes) to concentrate the flow into the navigation channel
- **Dredging of moving sand banks and fords.**

Several new ford sections appeared in the Bratislava region with low navigation depths and extremely narrow shipping channels - kinete, e.g. at rkm 1868, 1864, 1862 - 1860. In addition, navigation depths in Bratislava's port decreased rapidly. The port, originally designed for navigation depth of 2.5 m was for most of the time without access for larger vessels. This was an irremediable problem because further excavation would progressively undermine the docks' entrance thresholds and walls.

We would like to inform the WWF about a few articles published in PERSPEKTIVEN [6 - 9], (see Appendix).

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Drinking water supply

Numerous informed sources confirmed that, since the summer of 1993, the water works (drinking water wells) at Samorin reduced their production to two thirds, those at Kalinkovo stopped altogether. Official sources explain this by claiming a surplus of drinking water production in other wells upstream, being positively affected by the lifted groundwater due to the Gabcikovo storage lake.

However, other water experts expected before the filling of the lake, that these wells would be the first to be potentially affected by a changed groundwater quality due to infiltration of more polluted Danube water or by enhanced leakage of old waste deposits in the area (including from the refinery Slovnaft).

Simple look at the map and in the field will ensure the WWF experts that Slovnaft is far away from the Samorin and Kalinkovo well fields and that between well fields and reservoir with flowing water (not a lake) there is no old or new waste disposal in the area. Look at the ground water level equipotential map (Fig. 1.23) will disclose the experts that the situation around the Slovnaft is after putting Gabcikovo hydropower station into operation much better than in pre-dam conditions. Kalinkovo well field was created in 1972 as a compensation for the Bratislava's second waterworks. The wells are now situated close to the reservoir and are therefore monitored very carefully. Water is still used for water supply but after reduction of water consumption in reduced form. At present the pumping quantity is continuously 200 l/s.

Samorin well field was enlarged by four wells as a reserve in the case that wells in Kalinkovo would not fulfilled the qualitative standards. Development of pumped water quality in Kalinkovo is still without signs of deterioration. However, the water experts expected that Kalinkovo could be affected firstly. Therefore monitoring and special measures have been performed, including special ground water survey in framework of PHARE project.

WWF is not aware of the fact that there exist natural processes of ground water quality development. One among various criteria is the ground water velocity and time used to fulfill the hydrogeochemical processes. Based on this knowledge, the location of wells is chosen. This is in opposite to situating of water supply wells at Budapest.

WWF is of the opinion that ground water quality will be changed "due to infiltration of more polluted Danube water". What does it mean? Is the Danube water now more polluted than in pre-dam conditions? Does WWF think that after damming the Danube, the Danube water has started to infiltrate into aquifer? The Danube water quality was in the past, especially in 1970's, much worse.

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Economic benefits of self-purification processes
The Finance Institute of the Technical University in Vienna recently concluded a cost-benefit analysis comparing a Danube national park with several variants of hydropower plants downstream of Vienna. The extraordinarily better economic benefits of the national park alternative are based, among others, on the work of water organisms which, in an intact floodplain, significantly contribute to the cleaning of organic water pollution and, thus, to the improvement of water quality on the surface and in the aquifer. Under the alternative of hydrodams, i.e. also in the case of the Gabcikovo scheme, this work has to be done by sewage treatment plants and water purification schemes for the drinking water supply, both very expensive installations. The Austrian Finance Institute calculated that in Austria investments of ca. ATS 640 million (ca. ECU 47 mil.) and operational costs of ca. ATS 60 million per year would be needed as a substitute to the "free work" of floodplain organisms.

This significant economic value has been largely ignored in the evaluation of the EC Working Group Reports (especially in their Scenarios) when comparing the former river situation with the present one, where the water is diverted from the floodplain into the storage lake with its many negative attributes (sedimentation, colmation, infiltration of less purified or even more polluted water into the aquifer and towards the near-by drinking water wells).

WWF is not aware of advantages and disadvantages of different forms of energy production. If Slovakia wished to replace hydropower production through its coal burning plants it would not only be forced to exploit one of its few non-renewable resources but increases the ear pollution by Sulphur and Arsenic, soil pollution, ground water pollution and such production will produce ash-disposal areas. Is this really the scientific wish of WWF?

The Finance Institute obviously is not acquainted with the EC expert report where the inundation of the Hungarian and Slovak side is described. The intact floodplain significantly contributing the cleaning of organic water pollution (in the past mainly from Schwechat refinery) existed earlier. Percentage of discharge through the Danube and through its branches before their cutting off and closing is shown in the Table 1.3. The first number in the table is percentage of the discharge in the main stream of the Danube, the number in brackets is percentage of the discharge through the river branches. It can be seen that e.g. from rkm 1833.0 to 1816.0, in the area of Gabcikovo, the discharge in the river branches was before the closing the river branches (in 1955 - 1961) approximately 20 % of the discharge of the Danube in Bratislava, also at low discharges. Flow in almost all river branches existed (before 1992) in the pre-dam conditions at discharge 3500 - 4500 m^3/s, altogether in 17 days per year. Flow in some river arms existed for 78 days per year at discharge 2500 - 3500 m^3/s. **The main difference between the "intact floodplain" conditions in the late 1950's and pre-dam conditions is that in the far past the main river branches were supplied with water all the time, while in pre-dam conditions only few weeks in a year. Except this, the Danube water was much more polluted that time.**

The EC experts have confirmed the bad qualitative conditions in river branches [B] **"The water quality of the side branches differs from that of the main Danube channel. Due to the much lower velocities and periods and places with stagnant water."** We draw attention to the Internationale Arbeitsgemeinschaft der Wasserwerke im Rheineinzugsgebiet, 13. Arbeitstagung, 8 - 11. Oktober 1991, Scheveningen, "Trinkwasserschutzgebiete dürfen nicht überflutet werden" presented by Prof. Dr. D. Maier.

WWF is probably not aware of these facts. Therefore the economic benefits of self-purification processes described by the Finance Institute are for area downstream Bratislava turned upside-down. **In the reality, the water in the branch system on both sides in pre-dam conditions was of worse quality than in the main Danube channel and had negative impact on ground water quality.** As an example there could be the ground water quality at the locality Dobrohost. Similar examples are now being evident from Austria where the worsening of ground water quality is caused by creation of polders in floodplains (e.g. Altenwörth). WWF has not considered the fact that there are differences in geological and hydrogeological conditions and between Gabcikovo scheme and the other hydrodams on the Danube.

In its natural state, the Rhine, as the Danube did not have a stable river-bed and the bed changed after each flood. This created a major problem for navigation. The narrowing of the river-bed increased the flow gradient on the Rhine and triggered erosion actively. The bed became deeper, bringing about the gradual isolation and disappearance of most river branches. Project developed by Slovakia and Hungary was able to benefit from the negative experience. One of the objectives of the G - N Project is to reverse the trend in the Danube branches and side areas to dry up and to prevent the disappearance of inundation.

It is necessary to stress that the water was not diverted from the floodplain into the storage lake. Downstream from Bratislava the floodplain is maintained and prevented from drying up, some parts are re-forested. **The inundation area downstream Cunovo was completely saved and on the Slovak side supplied with water. Water was diverted into floodplain.** Sedimentation, colmation and infiltration are kept under control and quality of ground water is maintained. The reservoir area is not larger than it would be in the river variant. **Hydropower stations are not producing pollution in opposite to other types of power stations.**

Therefore it is not the true what is written in the WWF Statement that ***the loss of self-purification capacity due to the diversion of the Danube, together with the lack of***

sufficient sewage treatment schemes has led to a decrease of Danube water quality downstream of Bratislava and to the increased need for respective, expensive investments.

Quotation from the publication "State of the Hungarian Environment" [30] is: "**Bank-filtered groundwater is the main source of supply for the communities situated along the Danube river.** Indeed, Budapest alone withdraws some 312 million cubic meters of bank-filtered water every year for municipal use.

The groundwater is highly polluted under a major part of the island (Csepel Island) for each of the four components considered - nitrate, organic carbon, iron, and manganese.

The water quality in northern and southern well fields has been compared. The percentage of consistently poor quality well water was only 8.7 for the northern fields, but soared to nearly 47 percent in the southern well fields.

The following considerations should be kept in mind:

- The trend towards poorer quality groundwater is an unbroken one;
- It is interesting to note that the annual mean values in the Danube for the same components reflect a deteriorating trend over the same period;
- The rate of deterioration, expressed in percent/year, was lower in the Danube than in the water wells for all components; and
- In addition to the deteriorating quality of Danube water and the partially anaerobic conditions in the bottom sediment, the background pollution in this region is also growing and contributing to poorer quality well water.

This continuing crisis is due fundamentally to the untreated wastewater discharge into the Danube from sewer outlets in Budapest. And the situation is not expected to improve for at least 5 - 10 years."

The list of constructed sewage treatment schemes in the framework of Gabcikovo - Nagymaros project is following:

place	price in Slovak crowns (million)
Gabcikovo	3.0
Petrzalka	344.0
Samorin	68.0
Samorin - Agricultural Cooperative	6.0
Malinovo - I.	6.0
Malinovo - II.	42.0
Rovinka - Hamuliakovo	23.0
Kyselica - Rohovce	47.0
Baka	9.0
Gabcikovo - II.	11.0
Vojka	9.0
Bodiky	19.0

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Legal situation in Slovakia

In February 1993, WWF published an internal document from the Slovak environment ministry stating that the needed permissions for the completion of the Gabcikovo storage lake dikes, for the use of Danube water, for the diversion of the Danube and for the operation of the Gabcikovo scheme could not be granted by the responsible Slovak authorities to the operator VVsp.

Following WWF's present information, these permissions were granted by the responsible district authority Bratislava Vidiek only on 17 May 1993, i.e. ***for more than 6 months the Danube was diverted and the Gabcikovo scheme was operating without the respective, needed Slovak permissions.***

The reason for the delayed permission process is the fact that, already on 25 June 1991, the ***Slovak environment commission (= ministry) SKZP being the central authority for water economy prescribed a specific, binding "Statement"*** *(called the "19 Conditions" under § 14 of the Slovak Water Act no. 138/1973 Zb)* ***as a prerequisite to permit the use of water and to operate Gabcikovo.*** *This statement says that the suggested technical solution for Gabcikovo (i.e. the "Variant C") is only possible by the fulfillment of these specifically determined Conditions.*

Especially, ***the conditions no. 11*** *(demanding the inundation of the Slovak floodplains under natural conditions from the old river bed)* ***and no. 18*** *(demanding 1,300 - 1,500 m³/sec of water during the vegetation period in the Old Danube)* ***are not fulfilled by the investor company.***

On 17 April 1993, a specific permission for the manipulation of Danube water was granted, *apparently replacing the Condition no. 18 for an interim period because the technical situation at the Cunovo weir did not allow a higher discharge at this time. The Slovak state attorney wrote in a letter on 19 August 1993 that, "on 17 May 1993, the investor received the permissions for accumulation and damming of surface waters at the Danube on 17 May 1993. With this decision, the 'Preliminary Manipulation Order for the operation of the Gabcikovo powerplant by the preliminary solution on the territory of the Slovak Republic' was approved."*

However, as the investor was unable to technically provide more water for the Old Danube, this specific order was granted by the authority under the conditions that ***a minimum flow of 600 m³/sec be guaranteed in the Old Danube,*** *that a proposal for a new water manipulation order be presented by the investor by 1 October 1993 and that* ***this order expire on the 15 November of 1993.*** *In fact, the monitoring data in the EC Reports show that only 300 - 400 m³/sec were flowing in the Danube throughout the year, i.e.* ***the order was not fulfilled. Today, this interim manipulation order has again expired and has not yet been renewed.***

To provide the reader with the full information about conditions for putting the Gabcikovo into operation by provisional solution (Variant C) we present the CONDITIONS prescribed by the Slovak Environmental Commission:

1. To demonstrate by documentation the procedure of self-purifying processes and their capacity in the course of infiltration of the surface water into the river-bank region.
2. To demonstrate by documentation the pollution of soil and of underground-water horizons in the dead-branches system of the upper part of Zitny ostrov. To specify more

accurately the character and the content of pollutants and the propagation into the ground water at present conditions and at a higher hydraulic gradient.

3. To assess and demonstrate by documentation the influence of the temporary solution of the Gabcikovo Project on the regime of underground water, from the point of view of municipal water supply.
4. To make a prognosis of the evolution of the quality of underground-water used for municipal water supply and to propose a technology of treatment, corresponding to the results. To match the time-schedule of the treatment measures with the schedule of finishing the Gabcikovo Project, taking in consideration also the results of the PHARE Project, coordinated by Prof. Mucha.
5. The change in the form of the reservoir may change the conditions of infiltration of surface water into the region of municipal water wells, especially of the source Dobrohost. To demonstrate by a research on an adequate model, the impact of the temporary solution on the capacity of these sources.
6. The flow and sedimentation conditions of the diminished reservoir will be changed. To demonstrate by a research on a mathematical model the impact of the temporary solution on the allocation of sediments and on the infiltration conditions. To estimate by the model also the possibility of reduction of the surface of the reservoir in the vicinity of the municipal water source Samorin.
7. Due to higher hydraulic gradients, especially on the right side of the reservoir, quicker sealing of the bottom by sediments may be expected. The intensity of this process would be a function of water-levels in the reservoir and in the Danube. To propose measures reducing the sealing process of the reservoir and of the unsealed power-canal.
8. To assess the influence of the old river-bed (the possible drainage effect) on the regime of the ground-water levels on both sides of the Danube, after the situation of the weir 11 km upstream of Dunakiliti.
9. To propose a solution for improving navigation conditions downstream of Palkovicovo, taking account of changed conditions of solids flow and increased erosion of the river-bed and reconsidering also the solution of Mr. Bartolcic of March 1991.
10. To secure storage of sediments dredged from the reservoir, outside the protected region of Zitny ostrov, in a form of controlled dumps fulfilling the given conditions of protection of quality of surface and ground waters.
11. To secure communication between the dead-branch system and the Danube in both ways and to enable the flow through the branches from Dobrohost to Palkovicovo. Periodical inundation with river-water, in correspondence with the natural regime of flows (mainly in May - June, secondarily in August - September) should last 5 to 7 days, but not longer than 14 days.
12. To include into the design: permanent structures, which together with mobile equipment would serve for elimination of pollution of the water by oil products.
13. To secure the supply of water into the Mosoni Danube according to conditions agreed-on by Czecho-Slovakia and Hungary in 1948, on the base of the Paris Peace Treaty.
14. As the construction will be realized in the inundation area of the Danube, to schedule the works into a period of lower flows, but nevertheless, to propose measures for foregoing or reduction of damages, for the case of higher flows of the Danube.
15. In connection with the reduced surface of the reservoir, to assess the possibility of passing floods and ice and to secure flood-protection of the adjacent region in the course of construction and of operation.
16. To secure monitoring of water-levels and flows in all decisive places of the Project, to gain an oversight about the hydraulic regime of the whole influenced region.
17. In the frame of the design of General Flood-Protection Measures, to include (in cooperating with the competent authorities) also the small protected regions - the two

proposed natural reservation areas "Istragon" and "Island of the Sea-Eagle", the protected natural formations "Kings Meadow" and protected "summer-oaks" at the forester's lodge.

18. **To secure the natural physiologic processes of the actual flora of the old bed of the Danube during the vegetation period (mainly from March to September), it is necessary to secure a flow of about 1300 to 1500 cumecs. Further it is inevitable, to secure such a flow in the old river-bed, which would enable the underground water level to touch the soil horizon and which would prevent the drainage effect of the empty river-bed.** To **evaluate, whether the proposed minimal flow of 600 cumecs would fulfill these** conditions. To secure the fulfillment of the above-mentioned conditions also during the construction-period. With regard to the lack of data about the depth of the top-soil cover (above the sterile gravel) and with the aim of finding the optimal water-level, to elaborate a prognosis of the water-level regime in the old river-bed at a flow of 1300 to 1500 cumecs and the corresponding underground water level.
19. To prove the necessary security of the flood-protection measures in the region of the right lateral canal (the Bodiky region) at a 1000-years flow of the Danube.

Most of conditions have been already fulfilled and some of them (conditions No. 9, 11, 17) are under fulfilling. In the WWF report there are mentioned the conditions No. 11 and 18. Flow through the branch system from Dobrohost to Palkovicovo is ensured by the outlet structure at the power canal at Dobrohost. Periodical inundation of the area is ensured by the discharge regulation at the outlet structure where maximal discharge into river branch system of 234 m^3/s is possible. Fish passages are under construction in the whole inundation and between the river branches and the river Danube. Interconnection between the Danube and the river branches is possible via lowering in river banks during the flood situation in the Danube. Improvement of communication between the branch system and the Danube in both ways is projected using underwater weirs and artificial fords which should rise the water level in that way that such communication is possible. Hungarian side has opened the river bank upstream of Dunakiliti at three places. Approved construction of underwater weir of height of approximately 2 m will supply this branch system with water and will ensure both ways communication between the Danube and river branches upstream of Dunakiliti.

Condition No. 18 is aimed to secure such a flow in the old river bed which would enable the ground water level to touch the soil horizon and which would prevent the drainage effect of the river. The necessary water level in the river is estimated for discharge of 1300 - 1500 m^3/s. This ground water level was not only reached but exceeded by supplying the river branch system with the high enough quantity of water (in average 40 m^3/s) by discharge in the old river Danube less than 400 m^3/s. Underwater weirs and artificial fords would additionally improve the situation and would interconnect the Danube with the branch system (see Chapter 2).

From the conditions it is clear that the effort of the government is to optimize the whole system as much as possible with the special emphasis to the floodplain area.

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Comments on the Results of the EC Mission September - December 1993

The political interests of both Hungary and Slovakia strongly affected the selected volume and data of the submitted reports. This led to the exclusion of available data/studies and of competent scientists to which the EC experts should have been given access.

As for the Hungarian side is concerned, it did not grant the data and analyses agreed upon (see page 74).

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The first result of the review reveals that the largely missing or one-sided information does not actually justify the many general conclusions of the two EC reports.

EC experts have had surely much more information and especially experience than the authors of this WWF report (see Chapter 2).

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Based on the year's experience gained from this section of the Danube, other rivers and similar engineering projects, it must be stated that the river diversion and the operation of Gabcikovo <u>inevitably</u> will result in detrimental alterations for the hydrology/biogeochemistry (ground- and surface waters), for the geomorphological processes (sedimentation/erosion) and for the floodplain ecology (diversity of biocenoses and especially adapted species) during the next years in the wetland and adjacent areas. Even though many impacts are not yet visible to the public, they can already be monitored by experts.

The project Gabcikovo - Nagymaros was based on long-term experience in Slovakia, Slovak scientists and on designer's work on the Rhine, the Danube and other rivers. It is necessary to stress that as early as in 1963, a concerted effort was made to examine the so-called territorial/technical consequences of the project, that is the effect of the Gabcikovo - Nagymaros system on the ecosystems of the surrounding area. It was decided that a territorial plan should be drawn up, the aim of which was to resolve the possibility of negative environmental impacts. On the Slovak side, the work was entrusted to Urbion in Bratislava, while on the Hungarian side it was carried out by VATI in Budapest. The study "Biological project of the territory affected by the construction of the Gabcikovo - Nagymaros project", the so-called "Bioproject" was completed in 1976 by Urbion with the participation of the Slovak Academy of Sciences. In 1986 the "Bioproject" was updated.

According to bioproject 1986 update and subsequent re-examinations it was considered in May 1989 that the Dunakiliti weir should channel 350 m^3/s into the Danube on continual basis with the weekly increased flow up to 1300 m^3/s each week, in order to prevent the deposition of fine sediments in the river-bed. Following modifications were also foreseen:

- construction of 7 - 8 underwater weirs
- constructions of weirs in side areas to maintain the proper water level with openings for fish to pass without difficulty
- construction of lowered sections in the banks of the Danube so that when the flow of 1300 m^3/s was put into the Danube, this could flow into the side areas allowing interconnection between the Danube and the arms
- fish-pass in Dunakiliti.

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The monitoring data, as used for and presented in the EC Reports, only partly refer to the most sensible indicators. The experts' conclusions largely underestimate the importance of monitored impacts. By consequence, the experts' recommendations are based on insufficient knowledge, and miss basic facts and ecological needs crucial for the existence of the floodplain ecosystem and the preservation of the groundwater.

This statement is too general without real background in description. **The main indicators of impact** of putting the Gabcikovo hydropower station into operation **are surely surface and ground water levels and flow parameters**. Knowledge of the EC experts (see Chapter 2) and related experts are surely deeper than the WWF independent scientists. It seems that the opposite of the WWF assertion is true. The WWF does not recognize the real basic ecological differences between floodplain and polder, between ground water quality and ground water pollution. It does not recognize the processes of "self-purification" by ground water recharge and riverbed infiltration, differences between poplars and willows, etc.

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... any further "independent" scientific study or analysis should involve the local, competent but independent experts. ... the political pressure on science (which exists in the case of Gabcikovo) will never allow a really objective result. It is very much in the interest of scientists that their work be separated from political interests and interpretation.

One of "further independent scientific study or analysis" written by the "local competent but independent experts" is: FUTURE of DANUBE, Ecological findings, predictions and proposals based on data from the Slovak part of territory affected by construction of the Gabcikovo - Nagymaros River Barrage System, prepared by Holcik et al. [11], (see Appendix).

At this place we would like to confirm, that the mentioned study is really very well done scientific study, relying on the monitored data from the Slovak territory. This report we will comment later.

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A. Evaluation of the Monitoring

Surface and groundwater quality/quantity

The following findings are based on the two EC Mission Reports (4, 5), the Slovak data reports on "Surface and Groundwater Quality" (6) as well as on the first monitoring report on water quality during the filling of the Gabcikovo dam (26 Oct. - 31 Dec. 1992) (7) which WWF could receive in its complete form; thus, this report (7) can serve as a important reference for comparison with the other data provided.

*The given Slovak information (6) loses credibility in interpreting the changes in the aquifer. The analysis is a general torso of results which is **non-representative** of the changes in the groundwater.*

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∗ Table 2 indicates observation points ("10" and "RU") on the right banks of the river which are not identical to the selected observation wells for the reservoir's impacts, given in Table 4 (Rusovce-Ostrovne lucky "D1-D6");

In the part 2/2 of the "Surface Water and Ground Water Quality" [H], (see Appendix), there is a map of all ground water quality monitoring objects and a map of extended monitoring of water quality. As examples there are given 60 figures chosen as typical water sources used for water supply. These are of course not identical with wells D1 - D6, which are included in extended ground water monitoring list of objects. The wells S4, 10 and RU have been chosen, because these wells are typical water supply wells. These wells can show the real ground water quality and impact of Gabcikovo upon the ground water quality used for water supply. In the Table 3 of the report [H], there is an example of basic statistics, using supporting software included in database. Explanation to the results is given in the Tables 3.1, 3.2. Wells D1 - D6 are included in the list of objects of extended ground water monitoring. These wells are observation wells with the untight top and they are not protected against the impact from the surface. These wells are used for observation of all parameters described in mentioned report, but they are not representative for microbiological pollution, organic pollution and microelements pollution. EC experts have had access to all data and parameters listed in the report. Hungary has given neither data nor a list of monitored wells, only statement [J] that "Since the diversion of the Danube no significant change of water quality could be ascertained in surface and subsurface water."

WWF is not aware of a fact that some parameters (e.g. microbiological parameters, organic pollutants as air pollution, pesticides, herbicides, organic solvents, etc.) should not be analyzed from short-term pumped water wells and from not protected open observation wells.

WWF's declaration is based on clear misinterpretation of existing data. If WWF had made a professional and scientifically based analysis they would have reached the opposite conclusion.

Water pumped from the drinking water wells are of course very thoroughly analyzed. No toxic chemicals have ever been found in this groundwater. Analyses carried out so far have shown no changes in ground water quality since the start of Gabcikovo more than one year ago.

The observation wells are monitored on a routine basis. Data from this observation network have for many years shown the accidental occurrence of some of these chemicals. The reasons for this difference between data from the clean drinking water wells and the polluted observation wells are that some observation wells are located in areas with known old pollution, e.g. near refinery, and furthermore that some of the water samples and wells have become polluted from the surface and due to improper sampling technique and other manipulation in the well - water level measuring, etc.

The data from the observation wells, referred to by WWF show the same level of concentration as has been recorded in these wells for many years or some accidental occurrence due to pollution from surface. Furthermore, most of the observations used by WWF were made only one day after the start of operation of Gabcikovo - which also clearly

Table 3.1: Extended monitoring - example of basic statistics

Object	Parameter	N	arit. mean	median	min	max	min-max	st. dev.	V*100
Analysed period: 25.10.92-28.6.93 (SKOV, 1993)									
S4	Object Name: S-4, exploited well of WS Kalinkovo Localization: x=1290959,65, y=566105,91, z=129,8, screen=40-80 m								
	TDS_{105}	10	350,6	398,5	218	393,8	175,8	63,8	18,2
	O_2	15	0,47	0,8	0,2	0,4	0,2	0,241	50,9
	COD_{Mn}	18	0,76	0,8	0,6	0,9	0,3	0,121	15,9
	Fe	18	0,012	0,02	0	0,02	0,02	0,01	79,8
	Mn	18	0,1	0,1	0,1	0,1	0	0	0
	NO_3	18	10,14	10,3	7,3	11,5	4,2	1,16	11,4
	SO_4^{2-}	10	42,35	42,2	41,4	42,6	1,2	0,56	1,3
	Cl^-	10	18,98	18,5	17,5	20,4	2,9	0,86	4,5
	PO_4^{3-}	9	0,028	0,05	0	0,05	0,05	0,025	89,4
	fluoranthene	12	0,027	0,04	0	0,04	0,04	0,019	70,7
	benzo(a)pyrene	12	0,027	0,04	0	0,04	0,04	0,019	70,7
	lindan	11	0,025	0,04	0	0,04	0,04	0,019	75,6
	pentachlorophenol	11	0,395	0,05	0,05	0,05	0	0,457	115,6
	PCB	11	0,001	0,001	0	0,001	0,001	0	75,6
	DDT	11	0,013	0,02	0	0,02	0,02	0,1	75,6

Important notice:

The statistical analysis was performed using accompanied software supporting the database (SKOV Bratislava). As it is obvious from the results, organic contaminants should have a very high concentrations.

After investigation of method of calculations it was found out, that the values < X (*"concentration bellow detection limit of equipment"*) were included in the calculations in the form =X *"concentration equal to detection limit"*. Next table shows the real concentrations of organic contaminants measured in the well S-4. **There was no contamination detected concerning these parameters** during analysed period.

This example demonstrates the importance of method how the data are pre-processed for statistics. Using "standard methods" we can instead of characterisation of contaminants calculate the statistics of detection limits of equipment.

Table 3.2: Extended monitoring - real measurements

Object	Parameter (ug/l)	fluoranthene	benzo(a) pyrene	lindan	pentachlorophenol	PCB	DDT
Period of monitoring: 25.10.92-28.6.93							
S4	Object Name:S-4, exploited well of WS Kalinkovo Localization: x=1290959.65, y=566105.91, z=129.8, screen=40-80 m						
	limit [CSN]	*0,04*	*0,01*	*3*	*10*	*0,05*	*1*
	Sample: 1	0	0	0	< 1	0	0
	2	0	0	0	< 1	0	0
	3	-	-	-	-	-	-
	4	0	0	0	< 1	0	0
	5	-	-	-	-	-	-
	6	0	0	0	< 1	0	0
	7	-	-	-	-	-	-
	8	< 0.04	< 0.04	< 0.04	< 0.05	<0.001	<0.02
	9	-	-	-	-	-	-
	10	< 0.04	< 0.04	< 0.04	< 0.05	<0.001	<0.02
	11	< 0.04	< 0.04	< 0.04	< 0.05	<0.001	<0.02
	12	< 0.04	< 0.04	< 0.04	< 0.05	<0.001	<0.02
	13	< 0.04	< 0.04	-	-	-	-
	14	< 0.04	< 0.04	< 0.04	< 0.05	<0.001	<0.02
	15	-	-	-	-	-	-
	16	< 0.04	< 0.04	< 0.04	< 0.05	<0.001	<0.02
	17	-	-	-	-	-	-
	18	< 0.04	< 0.04	< 0.04	< 0.05	<0.001	<0.02

document that these chemicals are a result of past activities and cannot possibly have any link to the Gabcikovo hydropower project, especially in the deep horizons.

Altogether, there is so far no sign of changes in ground water quality after the start of the Gabcikovo, except in the Ostrovne Lucky area just south of the reservoir, where improvements have occurred. Nevertheless, the situation is of course subject to continuous monitoring and thorough analysis.

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- *The data shown in the graphical analysis do not correspond to the data structure and frequency of the monitoring in the indicated period and in the respective tables (e.g. while the sampling frequency is once every 2 weeks, the attached respective graphs show much less sampled data).*

The data in Figs. 1 - 60 of the above mentioned report are taken directly from the municipal waterworks. Waterworks have their own structure and frequency of the data monitoring. Extended ground water monitoring data are in the database. EC experts had access to these data.

♣♣♣♣♣

- *The only given example (well S4 Kalinkovo) does not fulfill the demand of a solid documentation of the changes in chemistry and of the element concentration in the observed aquifer on both sides of the Danube. Looking at the monitoring of groundwater quality changes in the first stage of the reservoir filling (Oct. to Dec. 1992), this object was non-representative from the standpoint of specific organic elements. The presented Table 3 does not show the non-polar extractable matter which is part of every chemical analysis and which could indicate with high evidence the degree of organic pollution of the entire area and of all objects.*

WWF should know what it is spoken about. In any analytical laboratory it is well known that non-polar extractable matters are products used in chemistry, agriculture and some of them are air pollutants, others are sprayed over the surface. In the monitored components, the non-polar extractable matter is included as NEL (see Appendix) and stored in database. In the example of basic statistics (see Appendix) there are included some specific non-polar extractable chemicals (PCB, benzo(a)pyrene, lindan, etc.). Some of them could indicate with high evidence also natural sources, e.g. Algae. This cannot be distinguished only by NEL group analysis.

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Table 10 shows the given technical parameters of observation objects having several horizontal levels. It is questionable why the object S4 Kalinkovo was given as model because

S4 has only one, very large horizon (depth of 40 - 80 m), while most other wells have small horizons of only a few meters depth, being much more precise for the indication of changes.

It is stated that the well S4 is one of the continuously exploited wells from the Kalinkovo municipal woterworks. This a model well for real water supply, well closed in a well housing. Production wells have usually a long screen (horizon), piezometers and observation wells have usually short screen and are not protected against pollution from surface and air.

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Data on hazardous organic pollutants and heavy metals are not presented in the supplied documents in spite of their analysis. According to the first monitoring report (7), elevated concentrations of dichlorethen, dichlorbenzen, pentachlorfenol, benzopyren, hexachlorbenzen and lindan were recorded in the surface and groundwater.

In further discussion we would like to inform WWF about some properties of the mentioned chemicals:

Dichlorethen

1,1-dichloroethene (1,1-dichloroethylene) - limit (CSN): 300 ng/l.
Uses: adhesives; component of synthetic fibers.
Pollution of air. In rural Washington, Dec. 74 - Feb. 75, ground level concentration: < 5 ppt.
Waste water treatment: half life for evaporation from 1 ppm aqueous solution at 25 °C, still air, average depth of 6.5 cm: 27.2 min.

1,2-dichloroethene (1,2-dichloroethylene)
Uses: solvent for fats; additive to dye and lacquer solutions; constituent of parfumes, thermoplastics.
Waste water treatment: half life for evaporation from 1 ppm aqueous solution at 25 °C, still air, average depth of 6.5 cm: 19.4 - 24.0 min.

Dichlorbenzen

1,2-dichlorobenzene - limit (CSN): 300 ng/l.
Uses: solvent; dye; fumigant and insecticide; metal polishes.
Water quality:
- in river Maas (The Netherlands): average in 1973: 0.13 μg/l.
- in Zürich lake: 16 - 26 ppt.
- in tap water (Zürich): 4 ppt.

Waste water treatment: degradation by bacteria Pseudomonas.

Pentachlorfenol

Pentachlorophenol (PCP; penta) - limit (CSN): 10 μg/l.
Source: organic chemical industry, pesticide, agricultural runoff.
Uses: insecticides, algicides, herbicides, fungicides, preservation of wood and wood products.
Biodegrability: decomposition rate in soil suspension > 72 days for complete disappearance by bacteria Pseudomonas.

Benzopyren

Benzo(a)pyrene - limit (CSN): 0.01 µg/l.

Source: coal tar processing, petroleum refining; coal, coke, kerosene processing, heat sources;

natural sources - synthesized by various bacteria, e.g. Escherichia coli,

- by algae Chlorella vulgaris,

man caused: combustion of tobacco, fuels, present in gasoline, used motor oil, tar.

Pollution: Emission from typical European gasoline engine, combustion of fuel oil, natural gas, domestic heating Budapest (1966) 74 ng/m^3 of air.

Degradation: microbial biodegradation to CO_2, transformation by soil micro-organisms.

Brussels sand aquifer water: < 0.4 ng/l

Danube water in Ulm Germany: 0.6 ng/l

tap water Germany (1968): 0.5 - 4.0 ng/l

Treatment: chlorinating: 0.3 mg/l of chlorine by 1 ppb - 92 % reduction in 2 hours

ozonization

mechanical and biological purification.

Hexachlorbenzen

Hexachlorobenzene - limit (CSN): 10 ng/l.

Source: organic chemical industry.

Uses: wood preservation, fungicide, seed treatment, impregnation of paper, herbicide, pesticide.

Degradation: by bacteria Pseudomonas.

Lindan

Lindane (gama - hexachlorocyclohexane) - limit (CSN): 3 µg/l.

Use: medicinal mfg. (scabicide); insecticide mfg.

Biodegradation: anaerobe bacteria up to 90 % degraded in 4 days, transformed to chlorine-free metabolites.

75 - 100 % disappearance from soils: 3 - 10 years.

We would like to stress that the hydropower plant is producing electricity and surely it is not producing all the products of organic chemical industry and emissions from cars, houses, combustion plants, agrochemicals, etc. which all can enter the water in observation wells and the samples during sampling the wells.

The Gabcikovo hydropower station and the whole system is not producing these chemicals and is not polluting surface, soil, water, air, etc. with these pollutants. Why there is not a word against production and use of these pollutants in any of the WWF reports? (see "PRESS" in Appendix). Why WWF is not involved in improvement of water quality of water supply in Budapest for 2 million people (see page 79)?

*****

Data on selected sampling points and selected water quality parameters are presented in ref. 6. It is not explained why these points and these parameters have been chosen and why only example of statistical evaluation is presented. The important criterion for the impact assessment are the selected sampling points, for those are the most sensitive to the changes in water quality. The selected parameters also have the largest temporal variations and the *most significant impacts on environmental health.* ***This has to be documented before the conclusions about "insignificant impact on water quality" can be made.***

The whole database containing thousands of data was to disposal to the experts. There was given a list of localities and observation points, list of analyzed chemicals and an example how the data could be elaborated on the spot, without delay. Except this, the reports prepared at the Centre of Monitoring were to disposal in Bratislava. **Impact of Gabcikovo on ground water quality in Slovakia after one year of operation is INSIGNIFICANT.**

*****

According to drinking water standards (in Slovakia CSN 75 7111 approved: 1989, CSFR) important physical and chemical indicators such as heavy metals (Cd, Pb, Hg, Cu, Zn), other trace inorganic elements (Ba, Be, Cr, Ni, Se, Ag, V) and many organic indicators (dichlorbenzen, dichlorethen, pentachlorfenol, hexachlorbenzen, lindan, PCB etc.) are important. Such pollutants can be dangerous even at very low concentrations, especially if they act in combination. Their effect on health is still not fully understood. Some of them tend to accumulate in sediments and later, under changing conditions of the water regime and the water quality, they can be released and migrate to groundwater reservoirs. This phenomenon is called an "environmental time bomb" because of its retardation and accumulation effect.

This is a very general statement. This is well known from various heavy polluted rivers. Special reports and survey have been elaborated. Review of all reports and a new evaluation of sediments is given in [24] prepared in framework of PHARE program (see Chapter 1.6).

*****

Unfortunately, any data and any discussion which would enable the evaluation of this environmental hazard could not be found in the documents. *The data in (7), and previous* ***data known about organic pollution of bottom sediments, indicate that a potential danger is real.*** *However, the data are not complete enough to make any definite conclusions. From the biogeochemical point of view,* ***the data on pollution*** *of heavy metals, other trace inorganic elements and organic pollutants of bottom sediments, alluvium sediments, surface water and groundwater* ***have to be presented <u>in full</u> before any scientific conclusion can be made as regards to the impacts of Gabcikovo dam on the water quality.***

The data are complete enough to conclude that **alluvium gravel and sediments are not polluted** and surely less polluted than in other European rivers. Exception is hydraulically protected area of Slovnaft's refinery. The data in (7) - organic pollution - e.g. benzo(a)pyrene, lindan, etc., were found in deep horizons in observation wells.

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The properties of sediments can vary considerably. It would be very helpful to know distribution coefficients of organic compounds between water and the sediments as well as experimental data on the ability of the sediments to yield the pollutants to groundwater.

The distribution coefficients are known, experimental data exist [24].

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* *It is not evident why the data are not available for independent evaluation. If it is proved by interlaboratory validity tests that the data are correct, it should be possible for a small team of independent hydrochemical, hygiene and medical experts to evaluate the impact of the Gabcikovo dam on water quality and on consumers of the water.*

Data have been available and they are available for any kind of independent evaluation. Interlaboratory tests have been done, international experts have taken part at sampling, analyzing and evaluating processes. EU experts knew about it very well (see page 74).

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* ***A review of the originally monitored data together with a control sampling and analysis should be made by an independent expert team and not by parties involved in this difficult dispute.***

The party, most involved politically in this dispute, is WWF. Review on control sampling has been done.

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* *Unless the Working Group, which produced this report, had other data available, we do not think that the data are adequate to justify their conclusions.*

In opposite to WWF, the Working Group has had all necessary data and all existing data to disposal. Except this, the experts know the territory very well. According to our opinion and opinion of the experts, the monitoring system and data are adequate to justify the conclusions.

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Flora and Fauna (incl. Forestry)

The Report sections and conclusions dealing with this topic reflect the poor data base which was provided by Slovakia and Hungary for evaluation. Even though a more profound *scientific data base exists, the best available knowledge, data and experts were not involved in the evaluation.*

There exists a huge database for flora and fauna and WWF knows very well about it. The database consists of following items (for more information see Appendix):

Soil

Monitoring is carried out at 20 monitoring areas twice a year and at 10 monitoring areas once in 2 years.

Forestry

Monitoring of forestry is carried out at 24 monitoring areas.

Biota - Flora and Fauna

Flora and fauna are monitored at 13 monitoring areas.

*****

The Hungarian report is insufficient to give any sound statement or conclusion. Large losses in fish biomass and the visible, critical state of the floodplain forests are a remarkable indication of the changed situation. However, these and other indicators are not properly documented and interpreted.

The situation just after damming the Danube is described in the EC expert report [B]. Yes, the loss of fish biomass was documented. Critical state of the floodplain forests was documented too.

WWF should read e.g. in report [B] "The operation of Variant C has influenced the Danube seriously". ....."This causes a huge immediate damage to all water organisms especially those living in the side branches, e.g. fish and bentic organisms (mainly the mussels)", etc.

Similarly, the situation is described in [H].

*****

The Slovak report and the reference list do not contain the very important Slovak monitoring studies or species databases which were produced in the Slovak floodplains over the last years (especially by the Institute for Ecosozology at the Slovak Academy of Sciences). However, certain details in this report are obviously taken from this monitoring.

The Slovak report rely upon the mentioned database and older studies. The work of the Institute is well known. Summarizing report [11] (see title page in Appendix) was written in 1992 for the Hungarian organization Ister, involved in the politics around the Danube. Indeed, why the Hungary has not used this report during EU experts' work?

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The authors overestimate the detrimental impacts of the decreased water levels in the last decades ("disappearing of the whole nature biocenoses") and are far too optimistic regarding ecological benefits for the forests through the simulation of floods.

This phrase about overestimation of impact of water is in contradiction to the real high ground water level and dynamic character of water regime in real floodplain which ecosystem needs. This is well accepted scientific knowledge. Floodplain without high enough ground water level and without some flooding of some part of inundation is not a floodplain of 'Au' type but simple 'polder' with stagnant water or without water, with all ecological consequences. Floodplain even requires disturbances to maintain their resilience. We would like to stress that more than 90 % of all forests between Bratislava and Györ were changed to lignoculture of cultivated poplars which have created transformation of the whole previously original vegetation which is now influenced by synantrope and neophyte weeds. Forests are no longer natural but compensated substituted economical forests aimed to produce fast growing woods. Natural forests on the Slovak side have been degenerated by drying up because the ground water level decreased. This is simple a fact visible for example downwards from Bratislava.

WWF should at least read the well known studies of mentioned Institute or at least few quotations in following text (pages 103 - 109).

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The study lacks a more thorough, critical evaluation of the newly constructed lateral dikes (cf. chapter B) in Slovak floodplains and of several important indicator groups other than forests (e.g. birds, beetles, mammals and molluscs).

In the Slovak floodplain, there have not been only recently constructed lateral dikes. Lateral dikes have been re-constructed from previously used lateral structures (see Chapter 2.2.2, page 54 and [29]) with the goal to ensure the proper water level for average discharge of 40 m^3/s, to ensure water level and discharge fluctuation and to ensure interconnection with the Danube using e.g. underwater weirs. Some improvements as fish passages (not fish ladders) are still under construction.

Indicator groups other than forests are included in Slovak report [H] - FLORA, FAUNA AND FORESTRY - English version, Chapter III.

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WWF learned that a special ichthyological prognoses study on the impacts of Gabcikovo was ordered and submitted in the summer of 1993 to the relevant Slovak authorities. However, it did not become part of the Slovak or the EC reports.

Because of supplying the Danube with average discharge of 400 m^3/s over a length of 40 km with high enough velocities this prognoses are doubtful and dubious. Except this, the old river branches are supplied with running water. A large part of measures is not ready yet, especially the interconnection between the Danube and river branches should be realized. This is delayed because of decisions of the Hungarian Parliament.

The goal of the EU report was an "Assessment of Impacts" based on measured data and not to discuss old prognoses. Mentioned prognoses are studied to undertake such steps and measures that the unfavorable prognoses will not happen or will be minimized. The next goal of the EU experts was to discuss and recommend appropriate measures. In [G] it is written "In order to provide reliable and undisputed data on the most important effects of the current water discharge and the remedial measures already undertaken as well as to make **recommendations for appropriate** measures the Republic of Hungary and the Republic of Slovakia will establish a Group of Monitoring and Water Management Experts."

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The Slovak report is incorrect in stating that the decrease of surface and groundwater levels were only caused by river bed regulation and the construction of upstream hydrodams. The huge impacts originating from Slovak and Hungarian gravel excavation are ignored.

In the Slovak report [H] there is exactly written: "Long-term hydrological development of the region in the past was influenced by:
- **river regulations, straightening of bed, closing and raising unnaturally the entrance thresholds of previous meanders and river branches** (this was the first impact dated back in previous centuries),
- **exploitation of sand and gravel** (this started in this century),
- **construction of river dams upstream altered the bed-load balance,** etc. (this is recent and present situation).

The result is the higher flow velocity in the Danube, diminishing of the bed-load transport via Bratislava and increasing the river bed erosion. Investigation showed the substantial deepening of the river bed and the trend to further erosion of the river bottom. This caused a long-term lowering of the level in the Danube which resulted also in long-term lowering of ground water levels."

In the EC Data report [E] there is written: "The main channel has been significantly lowered due to erosion caused by a combination of several man made factors:
- **dam construction in Austria** in the last decades resulting in a sediment (in particular bed load) deficit;
- **excavation of gravel;**
- **bed erosion due to the very high velocities** in the straightened and narrowed navigation channel; and
- **prevention of bank erosion** due to fortification of river banks.

WWF is in contradiction to all EC, Slovak and Hungarian reports. Why? Why the independent nonpolitical WWF is informing the whole world with false and decisive information? What is WWF aiming at?

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There is no comparison with other intact floodplain ecosystems (e.g. the Danube upstream of Bratislava) or with floodplains damaged in the past by other hydroschemes (the Danube upstream of Vienna, the Rhine downstream of Basel, the Rhone etc.) from which the state of the floodplain ecosystem prior and after the Danube diversion could be better compared and estimated (cf. page 65: Hügin 1981). Then it would have been possible to give a better prognosis than the authors did.

There is really no comparison with the floodplain ecosystems upstream of Bratislava, because between them there exists granite thresholds interconnecting the Alps and the Carpathians. There it is no comparison with other hydropower stations on the Danube because only Gabcikovo is saving floodplain over a length of 40 km and is not channeled river with uniform cross-section (except lateral power canal). Only in Gabcikovo the floodplain on the Danube river branch system is supplied with running water and is not creating polders with stagnant or nearly stagnant water behind levees. Also diversity is increased and not decreased in comparison with pre-dam conditions. Cascades and discharges in the Rhine (15 m^3/s) are not comparable with discharge (400 m^3/s in average) and underwater weirs or artificial fords. References to Dister (1988), Hügin (1981) and Seibert (1975) are given in the Slovak report [H], pp. 62 - 64.

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It is not clear how 'a considerable part of biotopes' will 'gradually turn by successive way to 'original state" (at the end of the 50's), if only some forest plantations, an increased water level and a watering of the side-arm system will be provided for the floodplain area.

The crucial importance of the open connection with the floodplain side-arm system is largely ignored. There are no comments on the changed nutrient input and exchange when discussing the artificial water input from the canal in comparison to the natural situation at the end of the '50s.

WWF should read at least condition no. 11 prescribed by the Slovak Environmental Commission. In the Slovak separated report [C] there is stated:
The Danube has been changed during the centuries by embankments, river straightening and regulation to allow for shipping (Fig. 1.4). Man has largely changed the boundary conditions, e.g. by closing the river branches and dikes across the branches. Water management has therefore to reckon with the natural dynamics and may even be forced to copy and support natural processes. The biodiversity which was monotonized in the past is to be recover to reach the variety in abiotic - especially water and moisture regime conditions.

In the chapter "Possible Remedial Measures" there is written:

- **to re-open the fortifications and thresholds on the river branches** (Fig. 1.4) **intakes** and **to re-open the river branch system**
- **to make some shallow underwater weirs in the Danube to ensure the flow into the river branches**
- **to use the Dunakiliti weir for the water level and ground water level optimization**
- etc.

We would like to add some ideas. Since the beginning of 1950's, extensive research to inventory of biological diversity of the territory along the Danube river has been carried out. Results indicated, that natural floodplain forest of the Danube was replaced by cultural forests (plantages) of introduced cultivars of poplar (Populus euramericana, cv. Róbusta, cv. I-214, and others), with special forest management. Introduction and invasion of several aliens (e.g. species of the genera Solidago, Aster and Impatiens) have changed the character of the forestry. Other changes in wildlife and autochtonous flora were caused by water management and structures, preventing fast flooding, preventing the flow of water in river branches, changes of water quality (oxygen conditions) in river branches, etc. (Fig. 1.5).

As a result of ground water decrease in the area summer oak and narrow leaves ash die out. Instead of original wet hard wood species came black, gray and white poplar, willows and alders. In the 20th century, the soft and transient inundation forest changed into cultivated poplars and Salix alba. This problem is most evident under Bratislava, where until now ca 500 ha of forests have already dried (Fig. 1.13).

Since 1985 the research activity has been concerned upon the definition of the biological diversity in the territory. Conclusions of these studies and other related projects resulted in formulations of requirements, for minimizing the negative effects of the construction and operation of the hydraulic structure on the living organisms, biocenosis and ecosystems in the influenced area. Based on these results, some adjustments in the design of the structure were elaborated. General ecological requirements prescribed by the Slovak Environmental Commission (Ministry of Environment of Slovak Republic) are based on these studies (e.g. the so-called "Bioproject").

The WWF is probably not aware of the following single facts:

- Without inundating the floodplain and without continuously flowing water in the riverside areas and branches, there is no nutrient input
- Nutrient input consists of components in solution and of suspended forms. There is no reduction of content of components in solution in water from the canal. Nutrients in suspended form are bound on the smallest suspended particles. Only the largest suspended particles are settled in reservoir (60 %). The general reduction of suspended nutrients is therefore between 20 - 40 %, but amount of water and the general sum of nutrients is much larger than by pre-dam conditions.

In Hungarian Data report there is written that in the old Danube measured downstream from the damming the Danube in Rajka and Dunaremete, virtually the same sediment concentration levels have been found after the damming as compared to the pre-dam conditions.

Except this, the Slovak side is interested in re-opening the connection between the Danube and floodplain and using underwater weirs and fords to ensure both the way interconnection and flooding the inundation.

During the flood the sediment concentration will be similar as in the pre-dam conditions, therefore the floodplain will be supplied with nutrient input similar as in 1950s.

*****

The estimation, that the needed floods can be simulated from the Dobrohost intake structure of the Gabcikovo canal and that this can recreate the hydropedological situation of this territory at the end of the fifties, ignores all available data and experience about such artificial measures from the Rhine and Upper Danube; it is far too optimistic (cf. chapter B).

There are differences between the Danube in the Gabcikovo reach and the river Rhine. The differences are as follows:

- in the upper Danube there is the floodplain changed by hydropower structures from the typical 'Au' (through flowing) into 'Polder' type (stagnant water). Therefore Gabcikovo is not comparable with mentioned upper Danube's measures. From the qualitative and ecological point of view, there are two completely different types of floodplain. The differences are:

	Au	Polder
Water	flowing v > 0.1 m/s	standing v < 0.1 m/s
Oxygen	oxygen rich	without oxygen
River arms bed	permeable	impermeable -colmated
River bed	sand, fine sand	fine sand with organic matter
Flooding	1 - 3 times per year with flowing water	no real flooding and if, then no flowing water
Ground water	oxygen conditions	reduction conditions
Amonium	no	yes
Iron	no	yes
Mangan	no	yes
Organic matter	little	much
Evaporation/infiltration	infiltration > evaporation	infiltration < evaporation
GWL fluctuation	yes	no

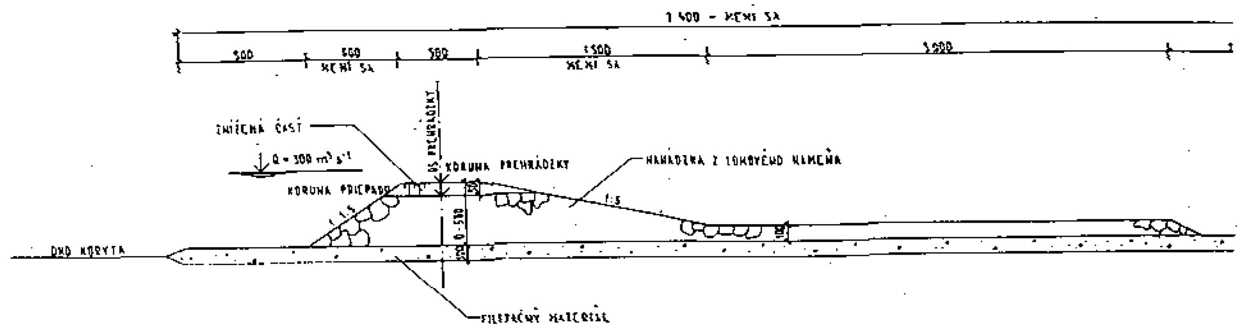
- in upper Rhine discharge in old river is much smaller than at Gabcikovo (only 15 - 30 m^3/s). Except this, in the Rhine there are realized instead of underwater weirs (Fig. 3.1) the transverse barrages (Fig. 3.2).

*****

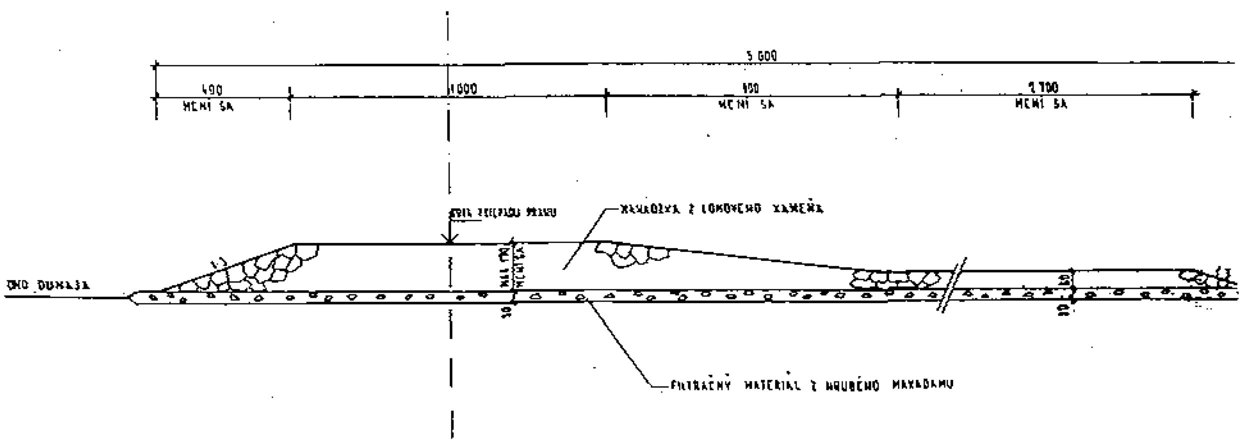
The given example used to "prove " the restoration of soil moisture due to the Gabcikovo scheme, while comparing the mean losses of leaves in August 1992 and 1993, is actually unfair:

- *August 1992 was a very dry period, as even the Slovak authors stress.*

Underwater weir - longitudinal cross-section



Artificial ford - longitudinal cross-section



Transversal cross-section of artificial ford in rkm 1836.6

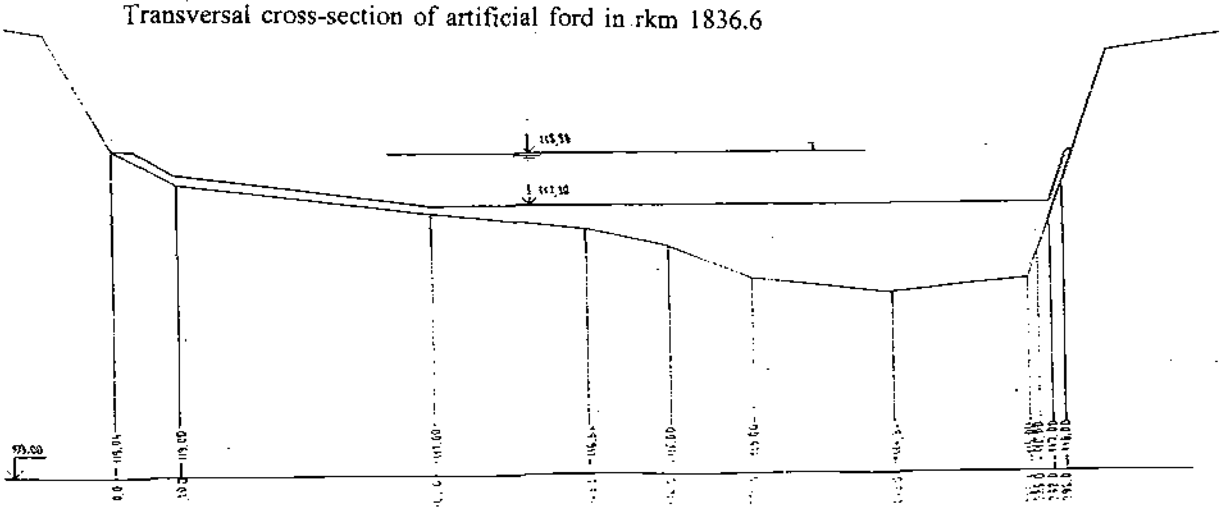


Fig. 3.1: Underwater weir and artificial ford

figure omitted

Fig. 3.2: Transverse barrage on the Rhine

* *In other locations (rather than the quoted Cunovo/Rusovce area) especially along the Danube up- and downstream from Dobrohost, the groundwater level was not raised, but lowered by up to 2 meters due to the river diversion: there, not positive but damaging effects in the floodplain forests can be found in 1993, as compared to 1992.*

It is well known that the years 1992 and also 1993 were dry. Differences between these two years could be seen from precipitation (in mm per month) and this could be compared with long-term monthly averages in the period 1951 - 1980 (A) and 1981 - 1990 (B).

Locality SAMORIN:

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1992	24	10	62	17	16	93	32	0	44	57	65	59
1993	29	23	11	20	25	48	64	49	42	65	67	66
A	37	33	34	42	51	71	69	54	34	39	51	40
B	43	43	30	23	52	52	39	56	50	33	43	49

Locality DUNAJSKA STREDA:

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1992	17	5	51	22	20	121	78	2	36	56	46	80
1993	27	18	15	8	15	33	59	36	39	96	68	80
A	29	31	31	42	48	63	68	55	36	40	53	38
B	34	38	32	27	51	48	34	69	41	35	42	39

We would like to remind to the WWF that **for willows and similar woods which are growing on accessible ground water level do not exist dry years or periods.** Metabolism of such plants does not depend on precipitation.

Slovak Data report is based on data from Slovak territory. We have to confirm that downstream from Cunovo (it means from Dobrohost to Sap at the Slovak floodplain area) **ground water was really raised and not lowered as it was stated in the WWF Statement** (see Chapter 1.4.2). So at the Slovak territory there is a positive and not damaging effect. The increase of ground water level in this area can be influenced by water levels in seepage canals, in the Danube and in river branches. Bottom permeability can be influenced by discharge in river branches. Therefore the intake structure is constructed to yield the amount of up to 243 m^3/s.

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Another example is the strange comparison of Aranea species diversity of the very wet, morphologically dynamic Danube inland delta with the xerothermal, stable Jur peat-bog: spiders are no indicators for floodplains because they prefer constant habitat conditions; second, the peat-bog (Carici elongatae - Alnetum) is not a floodplain ecosystem.

The same applies for the example of butterflies. For floodplain biotopes, such a comparison would be much more appropriate using e.g. beetles (Carabidae, Staphylinidae).

In the Slovak report the Jur peat-bog is mentioned only as example for comparison of intensity of research and number of data to disposal.

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The report does not address the problems of the important Istragov side-arm area (upstream of Palkovicovo) which is, as yet, not supplied by artificial water input (a new canal is planned from Gabcikovo power plant!) and has therefore been drying out, since the Danube was diverted in fall 1992.

Istragov area is going to be supplied with water. Interconnection with output canal is under construction.

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... to reconnect the side-arms with the main river even though this is partly recognized as absolutely crucial for the survival of the biocenoses, especially the regeneration and migration of the fish fauna.

This is the Slovak proposal and some of fish passages are under projection and construction. Small underwater weirs or artificial fords are necessary to make this interconnection real. See e.g. the ready made openings upstream Dunakiliti on the Hungarian territory. But this is only possible because the inundation in the area of hydropower structure is intact, what is not the case upstream of Bratislava.

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... the monitoring data could have given many more results than the EC Report has referred to. It is not clear why its summary assessment of impacts ignores the visible damages in fish fauna, forests and habitats. The early general conclusion that the forestry

has been positively influenced in Slovakia must at least be doubted, especially when looking at the slow reaction of forests to changed environmental conditions.

In the report [B] all visible damages are described e.g. on page 25. "In addition, the operation of Variant C has influenced the Danube seriously. There is a reduction of the discharge for a reach of about 40 km downstream the dam to an extreme low level, which is considerably lower than the ever recorded minimum. In connection with this flow velocities and water depths decreased to unnatural values and most side branches (about 100 km) dried out."

"This causes a huge immediate damage to all water organisms especially those living in the side branches, e.g. fish and benthic organisms (mainly the mussels). The remaining shallow waters fail as spawning grounds. If the situation as described above will continue until the beginning of the vegetation period most of the fauna and flora depending on floodplain ecosystem conditions will be heavily damaged and may have resulted in the loss of essential portions of populations and thus in reduction of genetic diversity and thus adaptability. This especially concerns the four areas that are already protected or are proposed to be protected as nature reserves."

The general conclusion that Slovak forestry has been influenced positively issues from visiting the area and from the fact of increase of ground water level over the whole area, where previously in pre-dam conditions a long-term decrease of ground water levels was recognized. Slow reaction of forest is by slow general lowering of ground water level. By sudden increase of ground water level, there is sudden re-vitalization of forest and bush (Fig. 3.3).

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The suggested monitoring program will help to provide a clearer picture if it will be financed and really executed. This, however, is anything but certain in both countries.

Monitoring program is running. Some suggestions written by EC experts to improve existing monitoring have been accepted and are going to be paid not by EC as promised but by Slovakia. Generally, **Slovak monitoring is described by EU as "adequate".**

At the end of the chapter Flora and Fauna (including Forestry) we would like to inform the WWF about the work of **"Institute of Zoology and Ecosozology, Slovak Academy of Sciences"**. This is the proper title of the institute mentioned in this chapter. The most important report prepared by this institute is the report prepared for The East European Environmental Research Institute in Budapest which is directed by Janos Vargha, who is the laureate of alternative Nobel award for biology. The report is entitled **"FUTURE of DANUBE. Ecological findings, predictions and proposals based on data from the Slovak part of territory affected by construction of the Gabcikovo - Nagymaros River Barrage System"**, edited and written by Juraj Holcik with contributors [11] (see title page in Appendix). **This is the most important report evaluating the Gabcikovo - Nagymaros project area from the ecological point of view, including special evaluation of flora and fauna (including forestry).** Following text is only a short sample of direct quotation.

figure omitted

figure omitted

Fig. 3.3: Revitalization of forest

"The present number of fish occurring here amounts to 52 native and 13 introduced species. The impact of man, such as hydraulic engineering measures and overfishing eliminated such species as *Huso huso, Acipenser stellatus, A.nudiventris,* and also the migrating race of *A.gueldenstaedti* from this stretch of Danube. **Deepening of the Danube bottom during past three decades and the subsequent change of the floodplain hydrology are the main reasons of the decline of some, particularly phytophilic species** (*Cyprinus carpio, Abramis sapa, Carassius carassius, Scardinius erythrophthalmus, Tinca tinca*) **and some of them are facing the danger of extinction** (e.g. the native wild carp). **The last evaluation of the conservancy status of the fishes in Slovakia** (Holcik 1989), [19] **shows that most threatened fish species is just from the Danube river."**

"Since the mid of 1970's when the Danube river was heavily polluted by waste waters from petrochemical works (Holcik et al. 1981), [20], **the situation significantly improved. The purification stations in Vienna, Schwechat and in part also in Bratislava were put in operation and also the Slovnaft petrochemical work in Bratislava is now protected by the hydraulic blanket. Due to this the fish species which were not recorded in the Slovak - Hungarian section of Danube for about 20 years, started to appear again.** The fish killings were not recorded in this stretch of the river and the **fish caught directly in the main channel have lost their pronounced phenol taste and other odor and now are palatable.** Concerning the **nutrient** content it seems, that its amount shows the **decreasing trend during past years."**

"The following types of forest growths are to be found in the Danube floodplain:

a) soft floodplain woods (assoc. *Saliceto - Populetum*), with home species predominating - willows (*Salix alba, S.fragilis*), in a lesser measure poplars (*Populus nigra, P.alba*) and alders (Alnus glutinosa, A.incana). A characteristic feature is the high GW (up to 1.5 m) and repeated floodings, or at least overflow of the surface. The most valuable are spatially restricted swamp growths of old, purely vegetatively renovated willows;
b) mixed floodplain woods (assoc. *Fraxineto - Populetum*). They represent the most productive forests, well supplied with GW during the vegetation period and are regularly flooded and enriched with sediments. In the original growths, poplars predominate (*Populus nigra, P.alba, P.canescens*), ash trees (*Fraxinus excelsior, F.oxycarpa*), racemose birdcherry (*Padus racemosa*), elms (*Ulmus leavis, U.carpinifolia*), but there are also alders (*Alnus incana, A.glutinosa*) as also willows. At present, the species composition is strongly altered through land use oriented to a monoculture of improved Euro - American cultivars in which strains "I-214" and Robusta" predominate. Such growths are strongly homogenized as to structure and species, with consequences for the functioning and stability of the ecosystems strongly invaded by weeds of the expansive species goldenrod (*Solidago gigantea*) the starwort (*Aster* sp.). As to trees, the species the box-elder (*Acer negundo*) spreads expansively. In parts of the present growths of the mixed forests in the floodplain we may note a shift of certain characteristics towards more xerophilic types, which is locally evident in desiccation of popular monocultures;
c) hard floodplain woods (assoc. *Ulmeto - Quercetum*). The ground water in the original forests lies deeper, below 2 - 3 m but during the vegetation period it can rise up to the root system. Dominant timbers are *Quercus robur, Fraxinus excelsior* and *F.oxycarpa, Ulmus laevis* and *U.carpinifolia*, with admixtures of *Populus alba* and *P.nigra*. The species composition of the growths is somewhat adversely altered by the share of nonoriginal, economically exploited timber species (*Robinia pseudacacia, Juglans nigra, Ailanthus glandulosa, Acer pseudoplatanus*), as also by a change in the prevailing site conditions. These are for

the most part affected by a drop in the water table down to the gravel floor (in places to a depth of 8 - 9 m) as a result of deepening the Danube bed and interventions into the regime of GW. This becomes manifest in growth cessation, transparency of tree tops, drying up of trees and in places in a complete destruction of forest;

d) forest-steppe associations of the Danube brambles growth (Assoc. *Crataegeum danubiale*). They represent restricted associations midway between forest and nonforest phytocoenoses. They occur at sites where the gravel subsoil outcrops to the surface relief and vegetation is dependent on precipitation. They are noted for a loose connection of trees and bushes passing into forest-steppe and open spaces. The dominant species are *Quercus robur, Fraxinus* sp., *Ulmus* sp., *Crataegeus monogyna* and others."

"**The forests in the floodplain were dramatically altered during past 50 years or so. Only remnants of original both soft and hardwood forest growths now exist within the limits of the inland delta of this stretch of the Danube.** The total area of forests now amounts to 14000 ha, of which **90 % are represented by introduced poplar plantations composed of highly productive North American cultivars. Except of small parts of forests between Gabcikovo and Palkovicovo, their majority is negatively affected by the water level decline of the Danube river caused by its bed erosion. In the mid of 1970's when the Danube bed in Bratislava decreased by 1.2 m (due to dredging) the subsequent ground water drop resulted to drying of 400 ha of forests within one year.**"

"Communities of beetles (Carabidae and Staphylinidae) in the inland delta consist predominantly of the strongly or moderately hygrophilous species."

"The majority of carabids and staphylinids inhabiting the inland delta of the Danube is strongly endangered in regard to their stenotopy, high need for moisture and specialization on the wetland or river-bank habitats."

"Intervention into soil fertility resides in the assumed change of the GW by the RBS Gabcikovo on the greater part of the affected territory. **At the present time, the favorable water regime of soils is conditioned by the level of underground water 0.5 - 2.5 m below the surface** on an area of some 70 thousand ha of agricultural soil, **primarily in the central and eastern part of Zitny ostrov**, representing about 70 % of the total original area of the relevant territory. Some 7 thous. ha are humid areas, the rest (the western sector - or the Upper Zitny ostrov) has water deep below the terrain. **On areas with a favorable water regime, plants moisture needs are covered up to 15 - 65 % with underground water.** Works by Fulajtar and Jambor (1983), [21] imply that **underground water in this area increases wheat crops by 23 - 60 %, maize for grain by 12 - 36 % and sugar beet by 4 - 41 %. In the Upper Zitny ostrov, underground water lies deep below the terrain with gravel and sandy soils and is inaccessible for plants. Moreover, the ongoing long-term decline of the water table (since 1960) as a result of erosive processes in the Danube river bed near Bratislava absolutely rules out any utilization of underground water by plants in this part of Zitny ostrov before the construction of the river barrage system.**"

"**The original project of the Gabcikovo - Nagymaros River Barrage System (GNRBS) was repeatedly modified during the course of construction primarily due to pressure on the part of ecologists.** The changes concerned principally the quantities of water to be let into the old channel of the Danube and into the left-bank floodplain. Several projects were elaborated which attempted to ensure a higher level in the old channel and in the present floodplain between r.km 1811 and 1842, demanded by ecologists, with the aid of dikes or rocky weirs (in the old river bed), or dams and cascades with a controllable level (during inundation), with a minimum diversion of water from the reservoir, or the diversion canal."

"Later the project was altered so as to permit water to be fed through the diversion canal from the reservoir into the arms of the floodplain. In the first case, the present-day arms systems would for the most part disappear immediately the main channel would be dammed, due to the drop in the water table."

"The project was supplemented only during the course of construction with a facility for taking off water directly from the diversion canal above the village Dobrohost, with a maximum capacity of 234 m^3s^{-1} . With the aid of this facility, the present inland delta is to be supplied with a steady flow (20.0 - 30.0 m^3s^{-1}) a periodically increased, or a flood flow (max. 234 m^3s^{-1}). The inundation territory is to be divided by low transverse dikes into seven sectors with a cascade-like graded, controllable height of level (Szolgay et al., 1985), [22]. In subsequent projects, elaborated at the Hydraulic Research Institute in Bratislava, **the water supply regime of the floodplain was revised and made more precise with proposals for ensuring connection of both ends of the arms with the old channel**, which was not foreseen in the original project."

"The principal criterion for preserving the existing communities of aquatic organisms settling the arms systems is to ensure a mutual dynamic interaction of waters in the old channel and the arms systems."

"Conditions in the inland delta similar to those prevailing prior to the start of construction work on the HPS Gabcikovo, although artificially created, could probably be obtained by the realization of the so-called feedback regime, but solely on condition the dynamic interaction between the main channel and the waters of the inland delta is successfully simulated, with the preservation of the natural seasonal fluctuations and speed of flow at the original."

"The original project of GNRBS planned to feed the abandoned (old) channel in the sector of r.km 1842 - 1811 solely with seepage waters from the reservoir (about 50 m^3s^{-1}) and after the seepage had decreased, by letting 50 m^3s^{-1} from the reservoir through the Hrusov - Dunakiliti weir. Later, proposals were accepted for increasing the volume in the old channel from the reservoir (to 350 m^3s^{-1}) and several projects were elaborated that would ensure the level corresponding to the flow up to 1300 m^3s^{-1}, letting out 350 m^3s^{-1} of water through the weir (weirs, dikes, or raised bottom thresholds at sites of present-day fords)."

"Preservation of communication between the old channel and the arms systems is considered to be the cardinal condition for maintaining the existence of ichthyocoenoses and thereby also of fishery. In addition to the preservation of communications as such, of importance is also a regular **natural pulsation of the water level**. From the ichthyological and fishery aspect, the arms systems represent the most valuable part of the area of the inland delta touched by the construction works. In the interest of preserving the softwood repeated, short-term floods are foreseen."

"A more detailed **prognosis** is possible for two insect families already studied, viz. Carabidae and Staphylinidae:

1) an extinction of the majority of the hygrophilous species or an extreme decline in their abundance;

2) a disappearance of the more tolerant mesohygrophilous species, or these will be very rare due to the lower density of the drying forests and due to their preference of the shadowed sites;
3) the communities will be strongly penetrated by the eurytopic or field species from the surroundings of the remnants of the existing floodplain forests;
4) populations of the majority of the species occurring in the remnants of the floodplain forests will be male dominated and will not be able to exist autonomously;
5) the ecological structure of such communities will be extremely heterogeneous, the probability of their spontaneous regeneration will be very low.

Completion of the river barrage system on the Danube and its running will have the following impact on the inland delta:

- **An altered water regime and thereby also a gradual disappearance of the inland delta of the Danube;**
- **Disappearance of wetlands and moist grasslands;**
- **Perishing, and thereby also the consequent felling of the last remnants of ancient trees with hollows."**

"As a result of the permanent constructions in the river barrage system, forestry has lost 3000 ha of forests and another **2500 ha will dry out within 2 - 3 years after the system is put into operation.** As essential forest reconstruction will have to be carried out on an area of some 3600 ha, with a transition to hardwood trees. **The loss of the forest's recreational function is estimated at about 4200 ha."**

"Construction of the RBS on the Danube according to the original scheme, with a minimum discharge in the old channel, would mean considerable changes in the water table on an area of some 38 thous. ha of agricultural land. These assumed changes in the water table, calculated according to Halek (1979) would have the following adverse impact on agricultural production:

- **decrease in crops by 25 thous. tons in terms of cereals (minimum variant)**
- **loss of soil humus through mineralization, minimally by 10.5 million tons**
- **release of nitrates in humus mineralization in a minimum quantity of 1.5 million tons nitrogen."**

"The construction of further large-scale irrigation systems assumed a partial elimination of the decrease in crops."

"The new designs for an improved completion of the river barrage system on the Danube from the aspect of its impact on GW (Mucha et al. 1992), [23] presume a control of its level in soil and this not merely by means of drainage canals, but also through a control of flow between the diversion (upstream) canal to the hydroelectric power station near Gabcikovo and the Danube's natural bed. According to the authors of the project, also the retention reservoir near Hrusov is expected to be used to this end. It is also planned to ensure an optimum fluctuation of the water table in the Danube's littoral zone in order to avoid a deterioration of its quality (nitrates content). **The purposed procedures might help significantly to raise the water table in the Upper Zitny ostrov and thus to improve the water regime of soils for ensuring humidity for agricultural plants.** This solution strikingly lowers the danger of lower crops in consequence of the drop of the water table according to the original project. In addition, it removes the danger of humus mineralization and accumulation of an excessive quantity of nitrates in the soil. Its realization does away with the need to solve the deficit of humidity for agricultural produce through the construction

of new irrigation systems. Moreover, it permits to lower the intensity of irrigation in Upper Zitny ostrov."

"As the function of the inland delta depends on the mechanism of action of the hydrological regime, the function of the entire ecosystem may be ensured by adhering to the following conditions:

1) **to preserve or renew a permanent connection between the main channel and the arms systems,**
2) **to ensure a permanent dynamic flow in the old river bed,**
3) **to ensure continuous flow not only in the old river bed, but likewise in the arms systems,**
4) **to ensure such a seasonal fluctuation of water levels in the old river bed and arms systems as corresponds to the natural rhythm of the level regime during the course of the year and permits a periodical flooding of the inundation territory.** Seasonality, extent and duration of flooding must be anchored in the manipulation regulations."

"**In the past,** to ensure navigation, a series of measures were adopted at the expense of the arms system i.e. **a uniform river bed was thus created,** its **levees were raised,** whereby the **side arms were impoverished.** Were it not for the favorable properties of the arms systems in reducing the flood wave and taking off large discharge, they would evidently have been completely done away with by now. This, of course, resulted in numerous undesirable consequences, the most conspicuous of which are (as regards the substitution of discharge by swelling) **a gradual earthing and a threatening disappearance of several arms.** The contemporary hydrotechnic structures permit navigation in the diverted sector with considerably lower claims to discharge flow. Nonetheless, despite this, the trend to impoverish the flow through the inland delta is going on, this time in the name of energy claims, and the physiotactically dubious conception of compensating the discharge with swelling is also envisaged for the main channel of the Danube. ... the present-day (inundated) landscape has been modeled and is kept alive by a 2000 m^3s^{-1} discharge. In an area where a considerable part of the energy is planned to be fed into the mains, hence, to take off the system without compensation, we must plan **compensatory inputs** into the landscape. In designing practice, this means to propose adjustments to the river bed so that it would have a **satisfactory level while preserving a** CV **(flow velocity) over 0.5 $m.s^{-1}$** (preferably around 1 $m.s^{-1}$) and **that the arms system would naturally fill also with a substantially lower Q** (i.e. about 1000 m^3s^{-1})."

"At places where water from the arms will enter the old river bed, it would be enough to construct rocky chutes on one side only, permitting migration from the old river bed into the arms, but in places where a two-way flow will be involved, these chutes should be on either side. On dams where water is to flow from the river bed to the arms, chutes should be built from the side of the arms."

Please, compare this text with the EC Data report and visit the Danube delta between Bratislava and Sap. Please, compare the prediction and the reality written in EC report. The struggle is to eliminate all negative impacts and to optimize the whole system as much as possible. A lot of this has already happened. Water management regime is already elaborated as written above [F].

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B. Comments on the Recommendations for a Temporary Water Management Regime

The ecologically more acceptable range between 40 % and 95 % of water for the Old Danube as an interim solution, which in fact is realistic from the technical point of view, was not discussed at all.

This includes the EC experts not noticing the original Slovak legal prerequisites for the operation of Gabcikovo (the "19 Conditions" demanding 65 - 75 % of water in the Old Danube) as well as the 66 % compromise solution which was suggested in February 1993 by EC Commission and accepted by the Hungarian side. ***Such a scenario would certainly reduce the ecological problems and would still leave a large amount of water for Slovak energy production.***

The suggested minimum discharge of 400 m^3/sec is well below the historical minimum of the river in this region. This will promote the extraordinary drainage effect of the river, affecting the floodplains and the adjacent lands. A minimum discharge of 600 m^3/sec is close to the historic minima and technically feasible at the Cunovo bypass weir.

10 % of discharge (2025 m^3/s = average Danube discharge) means:
- 200 m^3/s in average
- value of 14.3 % of Gabcikovo production
- 300 million kWh per year of electric power
- at least 400 million Slovak crowns per year
- saving of 0.4 million tons per year of coal
- corresponds to 0.125 million tons per year of ashes if burning coal
- saving of 0.45 million tons per year of oxygen

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Underwater weirs
As one "remedial measure", the new construction of two underwater weirs is recommended. The Slovak engineer's plan to build the same kind of such weirs as on the Southern Upper Rhine (e.g. near Strasbourg). ***From the many years of experience about these weirs on the Upper Rhine and the many scientific data produced on their impacts it can be stated that this measure will be inappropriate, inefficient and ecologically detrimental for the Danube and it will rather worsen the situation:*** *it will dissect the river continuum into a chain of ponds and result in higher erosion downstream from each weir (cascade effect); upstream from the weir it will create standing water, higher eutrophication and sedimentation processes (colmation) reducing the river water quality, i.e. a complete change of the former bedload regime. The design of the planned underwater weirs creates such great velocities that fish will not migrate; elsewhere, artificial fish ladders proved to be useless investments.*

On top of this, ***underwater weirs proved to have no decisive, positive impact on the groundwater.*** *The water levels will be adjusting only to the downstream water level of each weir. Even with a narrow sequence of many weirs, these drawbacks could only partly be* *reduced. In addition, the important exchange between surface and groundwater will be reduced after some time due to upstream colmation. On the Upper Rhine e.g. in the Weisweil weir section, less than 20 % of the "inundated" area maintained ecological conditions similar to floodplains, but over 80 % of the former, typical ecosystem is lost today (Henrichfreise 1993).*

The goal of underwater weir is:

* **to rise the water level** so that water can flow into **river branch** situated upstream
* **to rise water level** and at the same time to rise the **ground water level**
* **to slow down erosion** and successively to rise a river bottom to a new stage.

The construction of under water weirs is very shallow, similar to natural fords or moving sandbanks (see Fig. 3.1). Weirs are build up from natural stones and gravel used for river bank fortification and dikes (groynes). Underwater weirs are shaped along the weir and river is narrower upstream of the weir. This is the main difference in comparison with the Upper Rhine, well known the river steps on river branches (Fig. 3.2).

Discharge is large enough to ensure needed velocities. To speak about a chain of ponds is simple sign of not understanding situation. Also there exist no cascade effects, no standing water, no higher eutrophication, no colmation. An example in a smaller scale can be seen in Slovak river branch system, in the main river arm. Velocities are there high enough to clean the river arm bottom, to reduce colmation, to break euthrophication, to force infiltration.

An example is the velocity in the Danube at the Old Bridge in Bratislava, where the water level is now raised 2 m at low discharge (800 m^3/s). There is flowing water, it is not a lake.

On top of this, colmation has its criteria of origin and degree. According to WWF many years' experience, a lot of river bank filtration well fields should be colmated. Why the wells for example in Budapest and in Komarno are still yielding water? Answer is, because of the velocity of flow and its changes. Velocities in the Danube and also in the river branches on Slovak side are high enough, to keep colmation in some extent. Velocity in the Danube, also upstream of planned underwater weirs, will be larger than at Budapest or Komarno.

The water levels will be not adjusted only to the downstream water level of each weir. It is simple neglecting of all natural laws and WWF itself can not believe this. After putting the Gabcikovo into operation because of not dredging the fords, which are natural underwater weirs the ground water after previous decrease is slowly rising. This is documented also in the Hungarian report.

Generally speaking, Gabcikovo system of structures is not comparable with e.g. Weisweil weir. This is clear for every not prejudiced visitor.

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Lateral dikes in the floodplain

Even though in 1991 the Slovak environment ministry expressively(!) criticized such measures as very detrimental and demanded a solution ensuring a water input in the side-arms from the Danube and a removal of the disclosures between the river and the side-

arms (no. 11 of the "19 Conditions" from 25 June 1991), the Gabcikovo engineers started to build this scheme in winter 1992/93 destroying parts of the side-arm system, reinforcing the disclosures with the Danube and starting a permanent inundation of the wetland in May 1993. Condition no. 11 stated already in 1991 that 'the construction of lateral dikes in the inundation area and the creation of cassettes will damage the thru-flowing of the side-arms and result in an unnatural water regime of surface and groundwater, which with their oxygen regime and nutrient contents will not correspond to the needs of floodplain forests. It would provoke a non-desired long-term inundation of the forests causing its complete or significant change.'

This view is strongly supported by the WWF scientists: these dikes will transform the previous continuum of the floodplain into a chain of practically independent ponds which perhaps give the impression of an intact wetland at first sight and in very short term. It may even be true that the new water levels following the new artificial water input from the Dobrohost intake structure lifted the water level to a higher level than under recent predam conditions. However, the single-point inflow of water, its stable, significantly reduced volume and its changed water quality (the water comes from the storage lake having lost most of its suspended matter including nutrients crucial for the floodplain ecosystem) in fact result in detrimental effects.

The water level just upstream from each lateral dike is lifted too high and remains stable over many months. This is damaging for natural floodplain biocenoses. Further upstream from each lateral dike, the water damming has no more impact: the dammed water remains horizontal, while the floodplain morphology is inclined.

No independent ponds (except two new material pits between Vojka and Bodiky), no stable and stagnant water, no horizontal water level, no loss of nutrient. This was explained earlier. We can only recommend to WWF to visit and to work in the area.

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This measure induces a real threat to the affected floodplain forests. Contrary to the propaganda of the Slovak investor company in 1993, the artificial water input has not "saved the Danube inland delta". Moreover, the negative scientific prognosis is already reality, as it was revealed during recent studies by French scientists from the Lyon university who investigated the lower part of this Slovak floodplain section in 1992 and 1993: they found clear signs of physiological problems for willows which in large numbers soon will die or have already died (especially large trees).

Yes, there are known physiological problems of large old willows in pre-dam conditions, which has the French scientist recognized. Ground water level has increased since May 1993 in the whole Slovak floodplain. It means, that he studied the previous pre-dam long-term development in 1992 and 1993.

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In addition, the lateral dikes proved to impede the migration of fish and other water organisms because they created high barriers which no Danube fish can cross. In 1992, there were four small lateral dikes in the side-arms near the village Baka; in fall 1993, the number of even larger barriers increased to ten. The French studies documented a drastic loss of fish biomass as compared to the 1992 situation: apparently almost all large fish have gone, only a few species dominate (e.g. bleaks = Alburnus a.) while the original diverse fish cenoses are largely altered today. The detailed analysis will be available in January 1994.

Slovak Cartography published a map [27] where all older lateral dikes are shown. All 10 dikes are in the map. Lateral dikes were re-constructed, regulation weirs at some places were added.

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*Finally, the construction of these new lateral dikes together with the permanent, controlled filling of the channels provided unlimited access for many more visitors (recreation!) and for the often illegal construction of weekend houses all over the floodplain: **the wetland, which until recently hosted many threatened, but sensible species is today dramatically endangered by the threat of turning into a big recreation area for thousands of people.***

The whole area from Bratislava to Sap is 50 km long and has two sides. Enough space for organized tourism and protected area. 90 % of the area is cultivated (forest plantation). Some areas are already protected and closed for tourism.

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It can be concluded that, after the weirs and dikes were largely tested on the Upper Rhine in the 1960s and 1970s, they will have no satisfying effect on ecology, groundwater or forestry at the Danube.

This is true in the Upper Rhine.

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*Unfortunatelly, the most important recommendation of the EC Report suggesting a **"deposition of gravel"** downstream of the Cunovo weir is not discussed any further.*

Deposition of gravel is included in the reports [A, B, I, G (p. 64)].

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C. Technical Limits of the Present and Future Discharge into the Old Danube
Temporary Water Management are largely dependent on the technical situation of the Gabcikovo scheme, especially the Cunovo diversion weir, with its various openings.

Cunovo weir, shiplocks and power station are under construction now and will be ready in 1996. This will extend the discharge capacity at Cunovo to that as in Dunakiliti weir, which is completed, but is used only during the large floods.

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*A relatively small problem arose with the **ferry service** in the Gabcikovo canal providing a second connection to the three isolated villages.*

The road connecting the three villages with Bratislava is under construction. This will be the third connection.

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*... **navigation** was closed several times, especially on 29 days between 20 October and 30 November 1992.*

The 29 days of closing the navigation was during putting the Gabcikovo into operation and a large winter flood. This is common situation on all waterworks and during the flood situations.

Titbit for the WWF was the new stopping of navigation in March and April 1994. Besides, for such cases, operation of shiplock in Dunakiliti was foreseen.

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*The **Cunovo bypass weir** was originally designed for auxiliary purposes with a hydraulic capacity of 1,460 m^3/sec (4 gates). However, after a few hours of operation, it proved to have a faulty design for the strong erosion activities at its downstream parts (9). Therefore, the weir's discharge is limited in all cases to 600 m^3/sec, otherwise it could be destroyed by erosion.*

Cunovo bypass weir is temporary structure now with limited discharge via spillway of 600 m^3/s. Definite weir, shiplocks and hydropower station is under construction with large enough capacity.

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Two tainter gates (each 24 m long and 25 t heavy) were washed 2 km downstream onto Hungarian territory.

Tainter gates are heavy but hollow. Archimedes law is still valid.

*****

This explains why one of the remedial measures of the EC Working Group recommends the "construction of an underwater weir at RKM 1845.5 for improving the operational reliability of water supply from the inundation weir (less maintenance of the spillway). ... Without this there is a large risk that the inundation weir spillway will be under repair most of the time".

WWF is aware of the fact that the proposed underwater weir in rkm 1845.5 ensures the filling the branches system in Hungary with water and ensures at the same time the crucial needed interconnection of Hungarian river branches with the Danube at least on two or three places (Fig 3.4). If the underwater weir is 1 - 2 m high, an increase in the water level will not reach the inundation weir. The Hungarian and Slovak administration agreed with the Hungarian proposal of realization of a similar underwater weir in rkm 1843 which can put into use also the ready made inlet structure of the Hungarian branch system in Dunakiliti. EC Working Group made political compromise and advanced the proposed place of the underwater weir upstream, **so that Dunakiliti inlet structure for supplying Hungarian inundation can not be used.** This was decision to satisfy the wish of the Hungarian Parliament.

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*The **sedimentation** processes in the Cunovo storage lake were always stressed by the Slovak side as an important limit for a higher discharge of water into the Old Danube because a reduced discharge in the storage lake will enhance the undesired settling of suspended load. The new EC Report (4) confirms that "all bed load and 60 % of the suspended bed load have settled in the reservoir" and that the damming at Cunovo has highly significantly disturbed the sedimentation/erosion balance in the Danube. It must be stated:*

1. ***The Slovak side now admits for the first time that this problem in the storage lake already exists.** Even the building of artificial islands in the storage lake cannot stop this process. Mostlikely, detrimental biochemical processes inducing a threat for the groundwater quality have started and thus will probably threaten the drinking water nearby.*

The Slovak side from the very beginning have been aware of the sedimentation in the reservoir. This sedimentation of the bed load is small in the reach from Bratislava to Rusovce (ca 150000 m^3/year) and has positive effect. Later, gravel and sand will be dredged and added downstream Cunovo weir. Guiding structures in the reservoir (which is now not a storage lake) are not constructed to stop these processes, but to distribute them over the area

figure omitted

Fig. 3.4: Openings in the river embankments for supplying the Hungarian floodplain with water

so that at some places is **alternating sedimentation and erosion.** This guiding structures are functioning only if the water is flowing with high enough velocity. Under such conditions at these places "mostlikely" detrimental processes will not start and mostlikely detrimental processes will not exist in reservoir. Reservoir is not a polder as it is, the case at the sides of the hydropower structures upstream Bratislava.

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1. *Beside finer bed sediments, there will be a clear deficit of transportable matter compared to the river's transport capacity in the Danube downstream from the reservoir. This will* ***inevitably result in erosion processes downstream from both the Cunovo and the Gabcikovo weirs****, similar to such effects on other dams elsewhere.*

WWF is not aware of changed transport capacity in the Danube downstream Cunovo weir. There is not direct similarity with other dams "elsewhere". In the opposite, because of destruction of river bank fortification, meandering of river, interconnection with river branches, underwater weirs and fortified fords and if necessary adding sediments at Bratislava, this all will make this effect no important.

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D. Comments on the Social Situation of Local People

The unreliable ferry service (it runs mostly once an hour due to limited fuel; its limited capacity often leads to long waiting times; it often has to stop during fog, wind and ice) causes unacceptable travel times.

In contrast, the new road will mainly serve those who (now develop an interest in) spend their week-end or recreation time in this area. Together with the new, permanent access to the entire wetland over the lateral dikes, the permanently filled-in waterways, the hundreds of often illegally built week-end houses along the side-arms and the newly planned recreation areas at the gravel pits, ***a total transformation/alienation of the wetland and of the traditional villages with their social structure is now being implemented from the outside:*** *This process is technocratically oriented, ignoring traditional local interests and ecological sensibilities.* ***It is urgent that this will be stopped, and where possible, reversed.***

There will be three access possibilities to the three villages and those are: directly from Bratislava, via Gabcikovo power station and the mentioned ferry boat. There was always permanent access to the entire floodplain between villages and the Danube. Only in the latest 20 years the river branches have not been permanently filled-in with water. We ask WWF to give a list of "hundreds of illegally built week-end houses" in this floodplain. Gravel pits are situated out of a floodplain forest. Lateral dikes are old roads used by forestry.

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Recommendations by WWF and Independent Scientists

A. Recommendations with Respect to the EC Reports

*..., **WWF** suggests producing as soon as possible*

* ***a water quality study** including*
    * *control sampling and analysis on the changes in surface and groundwater quality,*
    * *changes of the underground currents and*
    * *potential impacts on the drinking water reservoir;*
* ***a river engineering study** investigating*
    * *the present state of the Cunovo scheme,*
    * *the technical possibilities and costs for the improvement of the discharge into the Old Danube and*
    * *the new variant to reduce the undesired sedimentation processes in the storage lake up- and downstream from the Cunovo weir through the construction of a small navigation route.*

***Each study should be worked out by an independent expert team also involving local, competent experts,** providing that they can work independently from the government and the Gabcikovo operator.*

Until now there have been various independent studies. One such a study is under realization in framework of EU PHARE program. The program is not only study but an optimization of all aquatic elements:

- surface water
- ground water
- agriculture and forestry
- environment in connection with water

The main goal of this program is to define and solve problems and to make and realize suggestions. Some results are already available (see pages 103 - 109). Parallel studies are in framework of monitoring at various institutions, universities and the Slovak Academy of Sciences.

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B. Alternative Recommendations for the Future Water Regimes

However, it is clearly a question of the European political interest how quickly the needed political negotiations will produce results and how much time will be allowed to pass by for the realisation of the urgently needed and hopefully agreed steps.

What is the real WWF political interest in this case story? Is WWF really politically independent? Is the Gabcikovo project technical problem or political one?

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The scientists involved are convinced that this "gentle solution" can be achieved faster, cheaper and politically easier, than the "technical solution" the EC Mission's Working Group was able to agree on.

Every new solution has to respect the following priority objectives:

1. The reestablishment of the hydrological dynamics both

in the old river bed,
in the side-arm system and
in the floodplains.

... the water level fluctuations ... have to run in such a way as they were at least under pre-dam conditions, and at best before the serious gravel excavations started (i.e. 1960s). This automatically entails the needed natural input of nutrients into the floodplain.

The Gabcikovo project and the Slovak proposals of water regime fulfill these requirements.

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2. The restoration of the groundwater table dynamics

This is possible only under a non-restricted connection between the surface water and the aquifer.

This requirement is fulfilled by existing state. Proper water management regime has been proposed.

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

This will allow the migration of organisms and diaspores.

The Hungarian and Slovak project of re-establishment of connection has been stopped by political means by the Hungarian Parliament.

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4. The enhancement of the morphodynamics

Erosion and sedimentation are prerequisites for the habitat and biological dynamics of floodplains. They should be promoted to the largest extent possible.

It has happened on the Slovak floodplain.

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5. The restoration of self-purification processes
They have to be supported to the maximum extent in the entire floodplain and river area.

Restoration has already re-started at Rusovce, between Bratislava and Kalinkovo, in the Mosoni Danube, in the Slovak inundation. "Self-pollution" processes have been stopped in the Slovak floodplain.

*****

C. Short-term Solution
Based on the technically possible

- *discharge minimum of 600 m^3/sec and*
- *discharge maximum of at least 940 m^3/sec (more up to 1,500 m^3/sec depending on the technical possibilities of the Cunovo weirs and with respect to the Slovak legal order stated in the "19 Conditions" from June 1991).*

Higher average discharge will create eutrophication problems with following water quality changes and secondarily it will create pollution of air, soil, etc. (page 110).

WWF suggests as an urgent measure for the next two years, which are needed for the preparation of the long-term solution, instead of underwater weirs **the accumulation of sediment bodies in the old river bed in the form of gravel banks and islands.**

Better possibility is to let the Danube, at least partially, to meander over the floodplain. To accumulate sediments, it means to excavate and transport sediments to a proper place and then to put them somewhere into water. This process in the large scale is not very ecologically friendly.

*****

Even though this interim solution cannot balance the drawbacks of underwater weirs concerning the groundwater levels,

- *it largely prevents upstream colmation and*
- *eutrophication,*
- *it preserves the river continuum and*
- *allows free migration of fish and other organisms in the river bed.*
- *In addition, it is no alien construction (like an artificial underwater weir) in the river bed, and uses authochtonous material from the river bed itself and from the banks This measure does not disturb or change the typical environment for the river biocenoses.*
- *These sediment bodies allow an easy transition towards the needed long-term solution which is suggested in D.*

Underwater weir is similar to natural ford. At the same time it is the bottom fortification to some extent. Underwater weirs are not the river steps.

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These sediment bodies can easily be built up within a short-term of a few weeks ***using the existing local gravel and sand deposits in the old river bed.***

Exactly, from this material will be built the underwater weirs or if WWF wishes - artificial fords.

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D. Long-term Solution

Starting from the above-mentioned facts that

- *the previous, natural water level dynamics, with all their positive effects for the floodplains and the groundwater, have to be restored,*
- *the discharge in the Old Danube realistically will remain below the former discharge,*
- *at least the Slovak legal standards (as stated in the "19 Conditions" from June 1991 following § 14 of the Slovak Water Law) will be fulfilled, but in their meaning of a dynamic discharge (cf. description in B) of 65 to 75 % of water,*
- *an acceptable compromise will be found, orienting on the EC proposal from February 1993 (average discharge of 66 %) which was already accepted by Hungary,*

the compensation of the discharge deficit (25 - 35 %) can only be achieved by
lifting and constricting the present river bed
which is entailed by a reduction of the existing discharge area.

The lifting and constricting of the river bed can be achieved by the deposition of gravel and small sized boulders in the old river bed. Similar to the short-term solution, this measure includes the forming of islands and gravel banks. It is expected that a stretch of ca. 20 - 30 km downstream of Cunovo has to be filled up with a volume of one to two meters. For this purpose, an amount of ca. 5 - 10 million m^3 *gravel and boulders will be needed.*

As a second WWF recommendation it is suggested that
the storage lake up- and downstream of Cunovo be reduced by new dikes to a navigation route.

The objective is to reduce the sedimentation and undesired biochemical processes in surface and groundwater of this artificial lake (which has no efficient sealing to the underground like the power canal) to the minimum extent. This will reduce the potential water pollution threatening the nearby and downstream drinking water wells. The area in-between the new dikes parallel to the navigation route and the present lake dikes should be turned into restoration areas. If done in the appropriate way, these man-made biotopes can develop over the years into secondary wetland biotopes.

It is evident that the entire planning and realisation of this solution has to be examined thoroughly and in detail by an ***independent, international water engineering institute*** *together* ***with an ecological institute experienced in river management.***

In contrast to other proposals, this "gentle" solution offers a ***comprehensive approach*** *to the river area.* ***It will help to limit and partly even reverse the detrimental changes induced*** *by the Gabcikovo scheme. It will not only bring a long-term preservation of this floodplain*

ecosystem of European importance but it guarantees an improvement of the presently critical groundwater situation. It is a solution for the Danube and the base for an ecologically-oriented, economic development of the border region which is to serve the livelihood of people living on both sides of the river.

Decision making for the long-term solution will be based on thoroughly study of monitored data and on evaluation of long-term development in the area. The solution will be tuned to the best conditions and this with co-operation with the best environmental institutions.

4. EPILOGUE

Environmental impact of construction of hydropower system lies in construction of weir, function of which is impoundment of water, construction of hydropower station and construction of water supply for turbines. Water supply for turbines is constructed by canalizing a river (making a river into a canal by straightening, building the high embankments along the river), or by building the water supply canal aside from river bringing water to turbines. In the first case, hydropower station is built up directly at the river. This is typical for Nagymaros. Part of the floodplain is covered with impounded water and a part is changed into "polders" (depression with stagnant water behind the embankments). Original floodplain is lost. In the second case, the hydropower station is at some distance from the river. This is typical for Gabcikovo. The floodplain is saved, but the water regime is changed and should be therefore optimized by appropriate measures.

In the past, measures taken for the navigation constrained the possibilities for the development of the Danube and the floodplain area. The ecological changes in the area are subject to a long-term trend of river bed and water levels decreasing caused by a variety of reasons, above all the large river regulation works, which implied deliberate and unnatural cutting off and bundling of river branches into one main, straightened and heavily fortified channel for navigation. Assuming the navigation will no longer use the main river, a unique situation has arisen. Supported by technical measures, the river and the floodplain can develop more naturally.

The **main impact** of a construction of hydropower system **lies in the changes in water and ground water regime.** These changes are the **primary changes.** They are **measurable immediately** or in short time after putting system into operation. Ecological changes (except large losses in fish biomass immediately after diverting larger part of water) and especially the changes of several important ecological indicators, e.g. forest, birds, beetles, mammals, fish, mollusks, are **secondary changes** and are usually measurable **after a longer period,** but at the earliest in the next vegetation period. **It was the aim of the EU experts to estimate the primary changes, changes in water and ground water regime, because the first measures and remedy measures are of hydrological type.** To evaluate and propose such measures, there are needed the characterization of **long-term pre-dam condition trends** and **short-term changes during, before and after damming the Danube. It is therefore only obvious that mainly water regime measurements were taken into consideration in the EU expert's report.**

Gabcikovo - Nagymaros system of barrages, locks, dikes, canals, etc. represents an **extremely complex system.** To understand this system, it is necessary to create a **plausible and consistent framework for thinking about the problem and a tool to organize and analyze the available information in specific project-oriented context.** Except this, it is necessary to have a **deep interdisciplinary knowledge.** A simple example for an "independent" reader can be the problem of occurrence of benzopyrene in an observation well (page 90). An independent scientist should not only know that benzopyrene is an hazardous organic pollutant and he should not only compare analyzed concentration with some standards, but should know something about the possible pollution sources of chemicals, about its degradation, transformation, treatment, etc. But this is only one part. He should know about ground water flow, recharge of aquifer, processes in the aquifer and this all according to the local geological, hydrological, etc. conditions. Except this, the independent scientist should know something about construction of production water wells and observation wells and especially of concrete wells if some anomalies are measured. In our example organic pollutants have been detected in a deep observation well (Rusovce - Ostrovne Lucky D3/3) in a depth of 71 m, only one day after fulfilling of reservoir with water, in the upper part of the reservoir by Rusovce where there was not flooded area and the Danube is flowing in its previous river bed. Water level was raised, that time not unnaturaly high, to the level 128.5 m asl which is approximately level at previous average discharge in summer period. The real scientist should ask a few questions:

- What is the origin of pollution?
- What is polluted, ground water, well or sample by sampling?
- Is it possible that this kind of pollution can travel from river into the well in such short time?
- What can be the reason for this occurrence?

The answer will be: scientifically and theoretically it is not possible that e.g. lindan could occur in the ground water in this observation well. Occurrence of such substances in the mentioned well is probably from the air and dust, because this wells are observation wells constructed for measurements of ground water levels and not for microbiology and special chemicals. Wells are not pumped continuously and are not isolated from air pollution and dust. Pump the wells properly and try again. This was also done and no pollution was measured. We have discussed all these topics with the WWF independent scientist on the Conference in Papiernicky, one of the authors of the WWF Statement. Is he really independent and is he really scientist? Is WWF really interested in scientific dispute or in political one?

Comprehensive statement, as the WWF Statement seems at the first sight to be, **however should also look at the positive impacts,** i.e. environmental improvements that are possible directly (e.g. hydropower replacing fossil fuel), (see page 110) or indirectly (due to increased revenues) as a consequence of a new development project, e.g. supplying floodplain with water, new road, tourism, etc. Further such statement should be comparative, not an absolute assessment.

Recommendations by WWF and independent scientists are trivial. Surface and ground water flow and quality including sedimentation processes are already studied in the Slovakia very carefully e.g. in the EU PHARE project, and measured and studied by various other organizations in framework of Centre of Monitoring. Independent experts are included, control sampling and analyses are carried out.

The **re-establishment of the hydrological dynamics** in old river bed, river branches, floodplain and ground water have been proposed [I, F]. For WWF scientists it is known that such real proposals have been elaborated. For example, discharge in river branches on each side should be 1/50 of discharge in Bratislava, which ensures natural discharge and water levels fluctuation (up to 2 m) and the whole variety of flow velocities. Except this, in special occasional flooding of floodplain is foreseen. Similar water management is proposed for the Danube including more water in vegetation period, fluctuation of discharges and water levels, according to previous studies. The means for ground water fluctuation are the Danube, seepage canals, inundation area, reservoir. By superposition of these means, necessary ground water fluctuation estimated by previous studies could be reached. There is no fear that connection between the surface and ground water would be lost (see experience from the Slovak floodplain, page 64).

There was not non-inhibited connection between the river and the floodplain in pre-dam conditions. Proposals and approved projects for such connection exist. Some of them in floodplain are under construction. Co-operation of Hungarian side would be welcome and would yield into much better conditions than there were the pre-dam conditions. Erosion and sedimentation is promoted from Devin down to Rusovce, from Cunovo to Sap and in reservoir from Cunovo to Samorin.

Self-purification processes are restored in the Mosoni Danube, in the Danube at Petrzalka and Rusovce, from Bratislava to Kalinkovo and in the floodplain area. This will be improved in addition after connecting the Danube with river branches.

Slovak side will ensure the necessary discharge into the Mosoni and Maly Danube, into the Danube and will optimize step by step the whole structure, based on evaluation of monitoring.

Meandering of old Danube, new islands, new banks, fords, erosion of river bank fortification, etc. are realities. This process will continue. Some underwater weirs are needed to start the process of river flow via floodplain and eventual to start new partial meandering in floodplain.

Underwater weirs are not colmating because velocities in all cases and at all places will be higher than 0.3 m/s. There will be in all cases turbulent flow, no thermal stratification and no eutrophication in the Danube. Underwater weirs are similar to natural fords and preserve the river continuum well. They do not prohibit migration of fish and other organisms. Underwater weir will be created by large stones and gravel using authochtonous material from river bank fortification and river banks.

Lifting and constricting the present river bed already started. Some gravel will be added after construction of Cunovo shiplocks or after putting Dunakiliti into operation. To construct new dikes in reservoir downstream of Cunovo is not realistic because the needed amount of gravel. It will in addition create polder situation and from the point of view of ecology, such proposal is not sound. There is not fear at present conditions that some undesired biogeochemical processes could start in reservoir. Sedimentation is regulated in the reservoir area. Reservoir is not a lake.

In general, the WWF Statement is based on very simplified way of thinking. The WWF has all materials and data as the EC experts and in addition some more data from Hungary and probably some special reports from Slovakia. The result is slandering of EC experts, slandering of Slovak and Hungarian institutions, scientists, experts and designers.

WWF sentences are very emotive, but in very general level. In the whole Statement there is no exact number, scientific demonstration of facts, no discussion. Perhaps, the text give the impression of the whole wisdom and sound judgment.

Typical sentences are:

WWF has been actively engaged in the Gabcikovo case since 1986.

Until now we have not seen any real scientific study on so much discussed topics.

The goal of this WWF paper is:

- *to give an independent, scientifically based review on the present situation in the Danube region affected by Gabcikovo*
- *to critically comment on the Report of the EC Mission*
- *to give recommendations for the future management of the river*

WWF Statement is neither independent, nor scientific review. It can be seen e.g. from the "PRESS" (see Appendix) or from the letter of one of the authors: "Der WWF und die anderen NGO Kämpfen seit mehreren Jahren gegen die Wasserbau-Lobby und besitzen unfangreiches Datenmaterial."

But neverthless, for WWF is typical:

- to put themselves into position of independent scientific organization
- to criticize EU experts and other experts outside of WWF
- to give "clever" advice
- to distribute appeals and organize press-conference

... along the Danube up- and downstream from Dobrohost, the groundwater level was not raised, but lowered by up to 2 meters due to river diversion ...

Well, we have simple no words. This is complete negation of all measurements. Simple advice of ground water level increase up- and downstream Dobrohost is at following places:

- Strkovec - lake
- Zlate piesky - lake
- Biskupicke rameno - river branch
- cottage settlement at Hamuliakovo
- gravel pits - lakes between Vojka and Bodiky
- lakes and not interconnected depressions in the floodplain on the Slovak territory
- all observation wells in the Slovak part of inundation
- domestic wells in the upper part of Zitny ostrov area

On 28 April 1993 WWF spread an appeal (see "PRESS" in Appendix) for "Urgent Action by European Ministers to Avert Further Disaster at Gabcikovo". There it is written:
"The only way to prevent a disaster is to immediately restore at least 80 % of water to the original riverbed, said Mr. Alexander Zinke, a WWF biogeographer who visited Gabcikovo a few days ago."

Such arguments as WWF is using (after visiting Gabcikovo) simply put the whole Gabcikovo - Nagymaros cause on the plane of pity and injured feelings, and are a direct admission of bancruptery as regards real scientific arguments and principles in WWF. We would advise to all who want to make an independent examination of the environmental effects of Gabcikovo project to visit the place, to speak with people, designers and other specialists in all related topics and to study all opinions.

REFERENCES IN THE WWF STATEMENT

(1) WWF (1989): Stellungnahme des WWF zum Staustufenprojekt Gabcikovo - Nagymaros. I.A. Ungar. Inst. f. Intl. Angelegenheiten. Rastatt.

(2) WWF (1992): Energy for Slovakia - Options of an environment - oriented policy. Ed.: Austrian Ecology Institute, Vienna.

(3) WWF (1992): Construction and operation of Variant C of the Gabcikovo - Nagymaros project under international law. Legal study by Dr. G. Berrisch, Brussels.

(4) EC Mission Data Report (2 November 1993) on Assessment of Impacts of the Gabcikovo Project and Recommendations for the Strengthening of the Monitoring System. Budapest.

(5) EC Mission Report (1 December 1993) on Temporary Water Management Regime. Bratislava.

(6) Surface and Groundwater Quality (October 1993): Parts 1/2 and 2/2 by RH Union, Bratislava.

(7) Extended Monitoring of Water Quality during the Filling of the Gabcikovo Dam (period 26 October - 31 December 1992): Slovak Hydrometeorological Institute SHMU, Bratislava.

(8) EC Mission Report (November 1992): Working Group of independent experts on Variant C of the Gabcikovo - Nagymaros project.

(9) EC Mission Report (May 1993): Field inspection at the Gabcikovo construction site.

EC REPORTS

[A] Commission of the European Communities, Czech and Slovak Federative Republic, Republic of Hungary. Fact Finding Mission on Variant C of the Gabcikovo - Nagymaros Project, Mission Report, Bratislava, October 31, 1992.

[B] Commission of the European Communities, Czech and Slovak Federative Republic, Republic of Hungary. Working Group of Independent Experts on Variant C of the Gabcikovo -Nagymaros Project, Working Group Report, Budapest, November 23, 1992.

[C] Commission of the European Communities. Working Group of Independent Experts on the Gabcikovo - Nagymaros dam. Part of Working Group Report elaborated by Univ. Prof. Igor Mucha on behalf of Czech and Slovak Federative Republic, Final version, Bratislava, November 20, 1992.

[D] Commission of the European Communities. Field Inspection at the Gabcikovo Construction Site. Mission Report, Bratislava, May 24, 1993.

[E] Commission of the European Communities, Republic of Hungary, Slovak Republic. Working Group of Monitoring and Water Management Experts for Gabcikovo System of Locks. DATA REPORT - Assessment of Impacts of Gabcikovo Project and Recommendations for Strengthening of Monitoring System, Budapest, November 2, 1993.

[F] Commission of the European Communities, Republic of Hungary, Slovak Republic. Working Group of Monitoring and Water Management Experts for Gabcikovo System of Locks. REPORT ON TEMPORARY WATER MANAGEMENT REGIME, INDEPENDENT SCENARIO. Appendix D of the report [G] in separate volume, elaborated by Univ. Prof. Igor Mucha on behalf of Slovak Republic, Bratislava, November 28, 1993.

[G] Commission of the European Communities, Republic of Hungary, Slovak Republic. Working Group of Monitoring and Water Management Experts for Gabcikovo System of Locks. REPORT ON TEMPORARY WATER MANAGEMENT REGIME, Bratislava, December 1, 1993.

[H] Comenius University, Faculty of Natural Sciences, Ground Water Division. CONTRIBUTIONS TO DATA REPORT. Bratislava, October 15, 1993. List of included data reports:
SURFACE AND GROUND WATER REGIME IN THE SLOVAK PART OF THE DANUBE ALLUVIUM
1. General Description
1.1. Surface and Ground Water Regime in the Slovak Part of the Alluvium
1.2. Discharge Data
1.3. Surface Water Level Data
1.4. Ground Water Level Data - part 1
1.4. Ground Water Level Data - part 2
2. Surface Water and Ground Water Quality - part 1
2.1. Tab. 1: Surface Water
Surface Water and Ground Water Quality - part 2
2.2. Tab. 2: Water Sources
2.3. Tab. 3: Extended monitoring
SEDIMENT TRANSPORT AND SEDIMENTATION/EROSION
FLORA, FAUNA AND FORESTRY
IRRIGATION WATER AND AGRICULTURE
ELECTRICITY PRODUCTION AND NAVIGATION

[I] Slovak Republic. Temporary Regime of Water Management and Remedial Measures (Gabcikovo - Nagymaros Project), Bratislava, January 18, 1993.

[J] Group of Monitoring and Water Management Experts for the Gabcikovo System of Locks. Data Report of Hungarian Party, prepared by G. Vida et al., Budapest, October 21, 1993.

REFERENCES

[1] Stancikova, A., Bacik, M., 1991: Analyza doterajsieho morfologickeho vyvoja stareho koryta Dunaja a prognoza zmien pri dlhodobej prevadzke VD Gabcikovo. VUVH, Bratislava.

[2] Czech and Slovak Federative Republic, 1990: Surface Water and Ground Water Model of Danubian Lowland between Bratislava and Komarno: Ecological Model of Water Resources and Management. Invitation of Proposals. Bratislava.

[3] Commission of the European Communities, Czech and Slovak Federative Republic, 1991: Danubian Lowland - Ground Water Model, No.: PHARE/90/062/030/001/EC/WAT/1, Tender Dossier of Study Contract. Bratislava.

[4] Treaty between the Hungarian People's Republic and the Czechoslovak Socialist Republic Concerning the Construction and Operation of the Gabcikovo - Nagymaros System of Locks. United Nations - Treaty Series, Vol. 1109. I-17134. came into force on 30 June 1978.

[5] Dister, E., Roux, A. L., Paces, T., Bernhart, H. H., Zinke, A., 1994: A New Solution for the Danube. WWF Statement on the EC Mission Reports of the "Working Group of Monitoring and Management Experts" and on the Overall Situation of the Gabcikovo Hydrodam Project. Vienna/Rastatt, 31 January 1994.

[6] Kresser, W., 1988: Die Eintiefung der Donau Unterhalb von Wien. PERSPEKTIVEN, Heft 9/10, pp. 41 - 43.

[7] Prazan, H., 1988: Staustufe Wien - Freudenau. Geschiebetransport und Sohleintiefung der Donau. PERSPEKTIVEN, Heft 9/10, pp. 44 - 45.

[8] Zottl, H., 1988: Staustufe Wien - Freudenau. Sohlstabilität im Raum Wien bis Bad Deutsch Altenburg. PERSPEKTIVEN, Heft 9/10, pp. 46 - 51.

[9] PERSPEKTIVEN, 1991: Die Donau als Lebensraum. Heft 1A/1991.

[10] Mucha, V., et al., 1966: Limnológia československého úseku Dunaja. SAV, Bratislava.

[11] Holcik, et al., 1992: Future of Danube. Ecological findings, predictions and proposals based on data from the Slovak part of territory affected by construction of the Gabcikovo - Nagymaros River Barrage System. Report prepared for ISTER. Institute for Zoology and Ecosozology of Slovak Academy of Sciences, Bratislava.

[12] Duba, D., 1968: Hydrologia podzemnych vôd. SAV Bratislava, s. 349.

[13] Fink, J., 1966: Die Paläogeographie der Donau. In Limnologie der Donau, (Hrsg. R. Liepold), Liefg.2. Stuttgart, pp. 1 - 50.

[14] Franko, O., Remsik, A., Fendek, M., Bodis, D., 1984: Geotermalna energia centralnej depresie podunajskej panvy - prognozne zasoby. Ciastkova zaverecna sprava GUDS, Bratislava.

[15] Janacek, J., 1967: Vyskum tektoniky juznej casti Podunajskej niziny s ohladom na vystavbu vodneho diela Dunaj. Zaverecna sprava, GUDS.

[16] Pospisil, P., 1991: Vyhodnotenie efektivnosti cistenia studni a urcenie novych odbernych mnozstiev - Pecensky les. Manuskript, Bratislava, Archiv VaK.

[17] Pospisil, P., Kucera, K., 1992: Vplyv erozie koryta Dunaja na zdroje podzemnej vody v pririecnej zone. Vodohospodarsky casopis, 40, c. 5, ss. 459 - 467.

[18] Vaskovsky, I., et al., 1982: Vysvetlivky ku geologickej mape juhovychodnej casti Podunajskej niziny 1:50000. GUDS Bratislava, s. 115.

[19] Holcik, J., 1989: Navrh cerveneho zoznamu ohrozenych kruhoustnych a ryb Slovenska. Pamiatky a priroda 20, 6:26 - 28.

[20] Holcik, J., Bastl, I., Ertl, M., Vranovsky, M., 1981: Hydrogiology and Ichthyology of the Czechoslovak Danube in relation to predicted changes after the construction of the Gabcikovo - Nagymaros river barrage system. Prace Lab. Rybar. Hydrobiol, 3:19 - 158.

[21] Fulajtar, E., Jambor, P., 1983: Prognoza vplyvu sustavy vodnych diel na Dunaji a dolnom Vahu na pôdne pomery v prilahlej oblasti. Geograficky casopis, 35:292 - 312.

[22] Szolgay, J., Lindtner, J., Harton, W., 1985: Uprava ramennej sustavy v lavostrannom inundovanom uzemi a stareho koryta Dunaja v useku 1842 az 1811. VUVH, Bratislava. Final Report. Unpublished.

[23] Mucha, I., (ed.), 1992: Optimalizacia dokoncenia vodneho diela Gabcikovo na uzemi CSFR z hladiska vplyvov na podzemnu vodu. Prirodovedecka fakulta UK, Bratislava. Final Report. Unpublished.

[24] Rodak, D., et al., 1993: Kvalita sedimentov dunajskych naplavov z hladiska obsahu a migracie kontaminujucich latok v podzemnych vodach. PFUK, Konzultacna skupina "Podzemna voda", Bratislava.

[25] Mucha, I., et al., 1992: Mechanizmus samocistiacich procesov pri brehovej infiltracii a kvalita podzemnej vody vodnych zdrojov. PFUK, Konzultacna skupina "Podzemna voda", Bratislava.

[26] Liepolt, R., 1965 - 1967: Limnologie der Donau. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

[27] Subova, A., Mucha, I., Klauco, S., 1993: Zitny ostrov - prehodnotenie vyuzitelnych zasob podzemnych vod. C. 16/92-HG, Vodne zdroje, a.s., Bratislava.

[28] Klauco, S., Pospiechova, O., Vyskocil, P., 1994: Rozsirene sledovanie kvality vody pocas napustania a prévadzky SVDG. Suhrnne hodnotenie vysledkov za obdobie 25. oktobra 1992 - 31. decembra 1993. SHMU, Bratislava.

[29] Vodacka a rybarska mapa, 1987, Bratislava.

[30] Hungarian Academy of Sciences, Ministry for Environment and Water Management, Hungarian Central Statistical Office, 1990: State of the Hungarian Environment. Budapest.

Annex 3

EXCERPTS FROM THE GABČÍKOVO-NAGYMAROS PROJECT:
IMPACTS ON NATURE AND ON THE BALANCE OF NATURE POSITION TAKEN BY JOACHIM LÖSING,
UNIVERSITY OF ESSEN, GHS, A STUDY ELABORATED FOR WORLD WILDLIFE FUND (WWF)

Essen, November 1986

Contents

(TRANSLATED FROM GERMAN, SECTIONS 1, 2, 3, AND 4 OMITTED)

5. Ecological Impacts of the Project

Ample scientific estimates, analyses, and forecasts based on the observation of comparable projects, presented by Boroviczény et al. (1986a, b), E. Wendelberger (recently in 1982) and many other members of the Ecological Commission of the federal government of Austria, Groups "Donaugestaltung" and "Nationalpark", are available for the Upper Danube and apart from local details, they can be applied to the project area without further ado as political borders seldom coincide with natural borders. Even the experience gained in the different phases of hydraulic engineering construction on the Upper Rhine in the recent period of almost 150 years (Schäfer 1973, 1974; Hügin 1981; Dister recently in 1985; for other works see Literature) can be utilised for estimating the impacts of this project considering that in principle, there is little difference in hydrodynamics and flow morphology between the rivers. It would be foolhardy to leave these results out of consideration since any reproaches later incurred for the same mistake could not otherwise be disallowed. A quantification and weighting of the different impacts will be absolutely necessary only as far as the details are concerned.

Furthermore, the results of projects, in part larger ones, of quite a number are available showing that the same problems occur globally rather than on a national scale (cf. Ibrahim 1984, Stüben 1986).

Taking this actual experience as a starting point, let some expectable impacts be presented here, together with the authors' own observations.

Two barrages and the diversion of the Danube result in a change in all the factors acting in this system, which must be brought from the dynamic balance of their interactions prevailing so far to a new balance level with the factorial weightings shifted. The large number of the factors (cf. Dilger, 1986) makes a perfect quantitative forecast of the interlaced interdependencies and interactions impossible. However, a circumscription of the different factors and their impacts is possible.

Both reservoirs of a total surface of more than 120 km will influence the climate in the Small Hungarian Lowland and in the Visegrád pass. The temperature of waters with a large surface and flat bottom increases and decreases more rapidly than that of land surfaces covered with a dense vegetation like forests.

Also sinking groundwater levels result in climatic changes when the capillary current breaks away towards the surface. The shallow-rooted agricultural vegetation as well as the forests must therefore reduce their transpiration early in the year. The atmospheric humidity increasing the yield, which has favourably affected the agricultural production in the wetland so far, must decrease as a result and this leads to losses. A reduction by 1.5 - 2 % in the yield can thus be reckoned with, as a conservative estimate (Népszabadság, 1985). The conditions which must be provided for electricity generation affect the hydrological factors markedly. For peak load operation, the water of the Danube must be retained in the reservoir at Dunakiliti and then passed through the turbines of the Gabčíkovo power plant twice a day. The flow behaviour typical of the Danube, the water level fluctuations, the flow rate, the inundations and the water output will change considerably. As a result of the equalising effect of the retainment of water before both power plants, the differences in river discharge, water level and flow rate will decrease to an average level. Accordingly, the barrage system becomes an element of the earlier barrage system of the Austrian Danube, however, due to the dimensions of the reservoir, it increases the effect of the barrage system considerably.

Instead of periodical fluctuations, a system perfectly new to the Danube is brought about between the Gabčíkovo and Nagymaros power plants: two tidal waves of a height of up to 4.5 m produce a flood situation twice a day. The impact of this phenomenon on the riverbed can be studied within a short period, e.g., in case of the Greek rivers. Within only six years, the peak load power plant over Arta (West-Greece) with its daily tide at noon time has destroyed the famous old bridge across Arachthos, one of the oldest and largest historical bridges in Southeast-Europe, so that it is now dilapidated. Erosion predominated in the entire region downstream from the power plant.

Historical buildings are also affected along the Danube in the project area. According to a list of the National Museum of Budapest, 45 of the "especially valuable cultural resources" (category 1) alone are in danger (quoted from PROFIL, No. 3/1986).

In case of the Nagymaros power plant, an inverse process will take place. The tidal waves will be prevented from running along and the river discharges will be even more strongly equalised.

Smaller inundations do not reach the downstream region any more. Instead, the region of the furcation zone especially adapted to this will become a desert. Only water that can not be received by the outflow canal in excess of 5.000 m^3/s, a rare event, will be let into the old riverbed system by the Dunakiliti barrage. Hence, the contrast between drought and extreme inundations will be typical of the regime over this section. Normally, water in the Old Danube should flow at a rate of 50 (-100) m^3/s. Since this flow rate is not enough to supply all old branches with water, weirs to be constructed at regular intervals damming the remaining water are foreseen.

Figure (omitted)

Besides hydrological factors, sedimentological factors also are affected. The solid load of the Danube is retained by the reservoir at Dunakiliti. With the weirs opened from below, part of the solid matter can be discharged similar to the practice adopted in the case of the Austrian power plants. In this case, the highest drag force occurs at the bottom and thus a blockage before the power plant can be prevented. Whether the drag force is high enough to successively convey the total solid load reaching the reservoir is, in the case of a reservoir length of 20 km, questionable. The debris which arrives settles in a way similar to that in the case of, for example, a slope. Thus, it is sorted by grain size when settling, depending on the rate of flow. That means that debris of coarser grain size remains at the bottom even at the beginning of damming up, and it must therefore be regularly removed by dredging to prevent the water itself from blocking up its course. Finer grains of the debris together with the finest particles which have suspended so far settle in pocket-shaped pools on both sides of the section of higher flow rate. Hence, without permanent maintenance, the service life of the reservoir is rather limited. Somewhat different is the situation in the case of a damming up before the Nagymaros power plant. This power plant would be located more or less in the region of the old Danube valley and it is not operated in peak load mode but permanently depending on the water inflow. The decreasing ratio of the solid load will flow from the planned artificial cavities in the bottom under both power plants into natural cavities downstream, which again results again in problems farther away downstream due to a decrease of the slope and sedimentation.

Excavation of water conduits is also foreseen at Palkovičovo where the old Danube and the drain canal meet. They are designed on the one hand to offset the differences in water level between the canal and the riverbed, resulting from the utilization of a maximum height of fall for peak load operation and, on the other hand, to reduce the bank towards the old riverbed of the Danube to a length of 5 km (cf. Chapter 2). As has been mentioned, the increased slope in the old furcation zone must be stepped by means of barrages. Hence, no significant supplies could be expected from here.

Hydrological and sedimentological consequences cause limnological changes. Temperature fluctuations in stagnant backwater result in lamination which also changes the chemical parameters. In spite of rapid changes in the conditions of lamination and stability, the oxygen content which has been kept at a high level by turbulent current in the river decreases and especially if the water is moving in the epilimnion and the metalimnion. Farther away from the "channel line" in the lakes, both values must decrease below a critical limit on the ground to permit the settlement of zoobenthos on the fine sediments rich in nutrients.

Additionally, the communication of river waste with groundwater becomes difficult due to settled suspended matter on the one hand, and due to this reduced exchange, a lasting deterioration of the quality of groundwater can not be prevented even by extensive sealing measures in the backwater as well as in the canal on the other hand. Virologists, among them E. Lund (WHO) expect an endangerment of drinking water recovery from groundwater in the region between the Small Hungarian Lowland and Budapest as well as in the Vienna basin, especially by the sewage of Vienna. Twelve million persons in the three countries might be affected by this.

However, anaerobic conditions take place not only in the benthos of backwaters but also in the cavities of clastic rock of the bottom and in the Old Danube downstream from the Dunakiliti barrage. The rate of groundwater flow (cf. Chapter 3) will be too slow to be able to drain the contaminated groundwater (Erdélyi, 1983). This can be attributed not only the sealing techniques applied (narrow walls in dykes, concrete in the canal and bentonite under backwater) to the undesirable slow flow rate of water in the Old Danube (50-100 m^3/s according to Népszabadság, 1985 and/or 50 - 200 m^3/s according to Erdélyi, 1983). Since one can reckon with higher flow rates in the old riverbed on 14 days per year only, these amounts of water will not be enough to hold up the negative processes in the groundwater regime. It remains to be clarified whether the water supplied is real were surface water from the Danube: in a seepage canal running parallel to the retaining dykes, designed to receive the water seeping through the dyke.

In the case of a slow flow rate like this, the level of the accompanying groundwaters communicating with the river water still relatively freely here would decrease considerably and dynamic water level fluctuations are excluded. As a result, the pores in the bed of natural and artificial channels waters will no longer be regularly washed out and through siltation, the process resulting in reduced interaction between groundwater and surface water becomes increasingly significant.

Low groundwater levels, missing water level fluctuations and overflows as well as hydrological and sedimentological changes will not leave nature unaffected. Should all the abiotic factors shift uniformly in one direction with only their earlier character remaining unchanged, the biocoenoses could accommodate themselves to the changes without any major qualitative consequence. Should, for example, the mean water level decrease due to deepening of the bottom, the successions of vegetation could, in principle, follow the deepening by "sinking" the levels. Losses would be incurred by them only in quantity[1]. Their "socialisation" would remain unchanged. Instead, the abiotic factors shift in different directions with a different intensity each so that the entire system of their effects which has determined the ecosystem so far loses its dynamic balance

1 See the forecasts of HORĹNSZKY et al. (1979).

and assumes new basic structures. A distinction shall be made here between three, perfectly different, fields that is, between the backwaters, the Old Danube and the recent riverbed.

The Danube loses its character as a river in both reservoirs. Movements occur only to a reduced extent as has been said in the course of discussion of the hydrological factors. Only the water level would experience frequent fluctuations, caused by an alternation of incoming tidal waves and low water. Since in the reservoir at Dunakiliti, the impoundment level to be reached lies at about 6 m above the present mean water level, the majority of the present land surface will be flooded[2]. Islands possibly remaining, if their surface is too small for use for forestry, will offer land for a new succession of vegetation the inventory of species of which, however, must be adaptable to the extreme but slow fluctuations. Therefore, the number of species must be rather limited and include only a fraction of the original species. Below the impoundment level, the vegetation would include willowland elements while above the impoundment level, elements of dry hardwood forests, and even zonal oak-and-beech forests have a chance. Islands with dry slopes offer ideal conditions for alder forests (Thelypteri-Alnetum), which seldom occur in Szigetköz even today. Such forests best accommodate themselves to stagnant water conditions. However, missing (flowing) floods would result in a change in the inventory of species even in the case of these forests so that they would be similar to those lying outside the dyke. Higher elevations with a subsoil of coarse gravel offer favourable conditions for the development of "hotlands". The wetland vegetation and the vegetation of zonal forests is replaced here with Pannonian steppe elements.

Major surfaces of this formation will appear in the recent wetland as well as in the wetland of the Old Danube in Szigetköz. It might also appear in Csallóköz between the Danube-bend and Budapest. Utilization of these regions for agriculture and forestry is so to speak excluded. Shifting earth and sand due to soil erosion could be an additional problem, all the more because this phenomenon is unpredictable especially in forests since it occurs to a certain extent only after deforestation or destruction of trees at places where the pedological conditions are met. In other parts of the (subrecent) old wetland, the decreasing groundwater level will result in an accelerated replacement of the residues of hardwood forests with a zonal vegetation typical of lowlands. Other changes in vegetation take place in the recent wetland. In principle, all the associations between the initial states and the final state of the three successions (cf. Chapter 4) may fall out here that is, a gap will develop between the "low willowland" (Salicetum albae-fragilis caricetosum) and the dry subassociations of the hardwood forests since the level would change by a few decimetres only. It is only the alderland as a long-time state in the organogenic succession that experiences an extension over large surfaces similarly to "hotland".

The composition of species of all the other associations which may occur then only fragmentarily as a transition belt between both extremes must change on the basis of the predominant organogenic successions to such an extent that new associations will develop. An example for this fundamental change, taken from the southern part of the Upper Rhine, is given by Hügin (1981).

Figure (omitted)

2 Surface lost in Hungary: altogether 4.600 hectares under water, of this 400 hectares outside the dyke, 60 hectares orchard, 1.500 hectares forest (official data).

Catastrophic floods, as they occur infrequently, might have little influence on this development. The greater could be their damage to the animal world. Although the fauna (incapable of flying) would be almost entirely destroyed even under natural conditions in the case of such a catastrophe, a resettling of the populations on higher land surfaces is difficult and lengthy because of the small number and the isolation of refuges. Moreover, part of the species appearing there is no longer adaptable to the conditions prevailing in wetlands.

Still more severe conditions might be provided for the animal world in the recent bed of the Danube in the future. Due to a daily fluctuation of up to 4.5 m of the water level, a stocking of the bare ground free from vegetation at that time is impossible. A few fish species and birds might then constitute the vertebral fauna as a majority. The vegetation would similarly be defined by the daily "flux and reflux", the lower vegetation limit lies no longer just below the mean water level but it coincides with the (daily) mean tide level. With a view to reduce lateral erosion, the necessary dams will be located too close to the riverbed, leaving thus not much surface for settling. Also here, the extremes without transient will be reflected by the vegetable associations. If a vegetation can live here at all, willow-bushes and ... can best accommodate themselves to the conditions prevailing in this region at that time.

With all the impacts summed up, the measures to be taken with regard to the project result in considerable losses

a) in the dynamics of living and non-living nature

b) in the structural variety of biogeocoenoses,

c) in the variety of species and density of individuals

d) in continuous large-surface complexes

and what remains is isolation of populations due to the reduction in surface and the disruption of the biotope, changes in successions as well as water famine in both natural and cultivated land (with losses in yield) within a region rich in water. In one word, the wetland of the Danube would lose its character over a length of 220 km.

6. Recommendations

To evaluate all the aforementioned impacts on the project area but also on the entire region downstream, it is necessary that all factors (or at least the representative indicators) be quantified and weighted. However, on the basis of the data available, this is not possible *ad hoc*. This could be achieved only by a comprehensive environmental impact assessment by a team including designers and scientists from all fields involved, taking all aspects into consideration. However, such an assessment together with the fact-finding taken as a basis for it would have a sense only if it had preceded the commencement of the project instead of taking place in the phase of detail projects.

Given below are some special recommendations which follow directly from the above analyses:

The most severe impacts could be avoided if the Gabčíkovo power plant were never operated in peak load mode again and if the Old Danube received more water from the Dunakiliti barrage. In the first case, the backwater would be utilised by the power plant at a more or less uniform rate and neither damming up nor the Nagymaros power plant would be required any more because a daily "flux and reflux" would discontinue. The second recommendation means that the level fluctuations of the Danube upstream from Dunakiliti are transferred to the Old Danube in the form of a reduced, controlled discharge. This means at the same time that the wetlands of the region could keep their character on a lower morphological level. In this case, the minimum discharge should not lie below the lowest value of discharge of about 600 m^3/sec of the recent years. The rate of utilisation of the power plant would then be somewhat lower but this disadvantage could be easily offset by saving the resultant expenditures on agriculture, forestry, hydraulic engineering, drinking water recovery, import-export balance and on the balance of nature.

Figure (omitted)

Literature

Boroviczény, F., W. Lazowsky, H. Löffler, and F. Spitzenberger. (1986). (.J.) Kriterien für die Erhaltung des Ökosystems Au. Ecological Commission of the Federal Government, Group "Donaugestaltung", Group "Hydrodynamik und Flussmorphologie", p. 35.

Dilger, R. (1986): Der Staudamm ist kein Problem - aber der Stausee? - Bemerkungen zur ökologischen Basis von Umweltverträglichkeitsstudien bei Grosstaudammprojekten. Stüben, P.E. (1986). pp. 39-59 & Annex.

Dister, E. (1986): Geobotanische Untersuchungen in der hessischen Rheinaue als Grundlage für die Naturschutzarbeit. - Diss. Math. Nat. Fak. - Göttingen.

- - (1983): Zur Hochwassertoleranz von Auenwäldbaumen an lehmigen Standorten. - Verh. Ges. Ökol. 10, pp. 325-336.

- - (1985): Taschenpolder als Hochwasserschutzmassnahme am, Oberrhein. - GR 37(5), pp. 241-247.

Drescher, A. (1977): Die Auenwälder der March zwischen Zwendorf und Marchegg. - Diss. Form. - Nat. Fak. Wien.

Erdélyi, M. (1983): Natural resources and economic values of Győr Basin, NW Hungary. - Földrajzi Értesitô Vol. XXXII, 3-4, pp. 475-490.

Horánszky, A., Jakucs, P. and Simon, T.: Ecological problems of the Gabčíkovo-Nagymaros and Tisza II Barrage Systems. - MTA Dep. Biol. Publications, 22, pp. 407-415.

Hügin, G. (1981): Die Auenwälder des südlichen Oberrheintals - ihre Veränderung und Gefährdung durch den Rheinausbau. - Landschaft + Stadt 13 (2), pp. 78-91.

Fouad N., Ibrahim (1984): Der Hochstaudamm von Assuan - eine ökologische Katastrophe ? - GR 36 (5), pp. 236-242.

Kárpáti, I. and Pécsi, M. (1959): Correlations between the succession of natural groves and the flood-plain levels on the Great Hungarian Plain. - Acta Biologica Ac.Sci.Hung. 3, pp. 24-25.

- - and Toth, I. (1961-62): Die Auenwaldtypen Ungarns. -Acta Agronomica Ac.Sci.Hung. XI (3-4), pp. 421-450.

- - and Kĺrpĺtí, V. (1980): Die coenologischen Bedingungen und die Standortverhaltnisse der Auenwälder im Donaugebiet in Ungarn. - IV. Auenwald-Symposium in Strasbourg.

Kárpáti, I. (1982): Die Vegetation der Auen-Ökosysteme in Ungarn. - Published by Int. Arb.gem. Clusius-Forsch. (4), pp. 1-24.

Kevey, B. and Czimbek, GY. (1984): Beziehungen des Hains "Erster Mai" in Mosonmagyaróvár zu den natürlichen Pflanzendecke des Szigetköz. - Publications of Agrarwiss. Fak. Mosonmagyaróvár 16(6). pp. 235-255.

Lászlóffy, W. (1965): II. Die Hydrographie der Donau. - Stuttgart - (1), pp. 16-57.

Margl, H. (1972): Die Ökologie der Donauauen und ihre naturnahen Waldgesellschaften. - Naturgeschichte Wiens, Vol. 2. - Wien, München.

Népszabadság (Hung. Party newspaper) (1985): Über das Staustufensystem bei Bős:(Gabčíkovo) - Nagymaros. (24.08.85).

Niemeyer-Lüllwitz, A.and Zucchi (1985): Fliessgewasserkunde: Ökologie fliessender Gewässer under bes. Berücks. wasserbaulicher Eingriffe. - Frankfurt/M., Berlin, München, Salle, Aarau, Salzburg.

N.N. (O.J., about 1973): Einfluss der Staustufen Gabčíkovo-Nagymaros auf das europäische Wasserstrassensystem. - p. 32

Ricklefs, R.E., Naváh, Z., Turner, R.E. (1984): Conservation of ecological processes. - IUCN Commission on Ecology Papers, No. 8 & The Environmentalist, Vol. 4, (8), p. 16.

Rosenbladt, S. (1986): Ungarns verheerende Donau-Pläne. - Natur 9/86, pp. 36 - 45.

Schäfer, W.(1973, 1974): Staudämme - Entwicklungs"hilfe", Unweltzerstörung und Landraub. - Giessen, p. 262.

Wendelberger-Zeliška, E. (1952): Die Vegetation der Donau-Auen bei Wien und Wallsee. Landesbaudir. 11, Wels.

- - (1960): Die Auwaldtypen der Donau in Niederösterreich. - Zentralbl. ges. Forstwesen 72, pp. 65-92.

- - (1982): Grüne Wildnis am grossen Strom - Die Donauauen. - St. Pölten, Wien. p. 168.

Annex 4

EXCERPTS FROM POSITION TAKEN BY WWF (WORLD WILDLIFE FUND) WITH REGARD TO THE GABČÍKOVO BARRAGE PROJECT

COORDINATED BY
DR. E. DISTER AND DR. H. JUNGIUS

RASTATT, AUGUST 1989

Contents

(TRANSLATED FROM GERMAN, SECTIONS 1, 2, 4, AND 6 OMITTED)

Contents

3 Summary, Answers to the Different Questions

3.1 Is a resumption of the Gabčíkovo-Nagymaros Project justified on the basis of the ecological and technical data available at that time?

No. The documentation available to us suggests that considerable drinking water reserves may be endangered by the power plant construction. It is necessary to remember that drinking water reserves throughout Europe have been more and more destroyed anthropogenically (industry, transport, agriculture, waste treatment). It is therefore absolutely necessary that any of the still more or less intact groundwater reserves be preserved. Changes in the groundwater balance may affect the wetland ecosystem unfavourably even in the long run!

Concerning ichthyology and fishing as well as limnology, the answer to this question must be similarly "no" because on the basis of the available ecological and technical data, construction at Nagymaros must not be continued. Even if completed, the Gabčíkovo barrage must not be put into service unless the results of special studies of the effect of changes in operation (peak load mode) on the environment are available and the necessary measures to reduce the impacts to a minimum are taken.

Concerning recreation, the answer to this question must again be "no" as no comprehensive studies of the impacts of the Project on this type of utilisation are available at present at all.

3.2 Are additional studies necessary to give the grounds for allowing or refusing the resumption of Nagymaros or the implementation of the entire Project?

Experience obtained with the Danube and the Rhine so far show that, considering the conservation of the different resources (e.g. groundwater) and the natural ecosystems (river and wetland), no studies however costly can justify a hydroelectric power plant according to this conception.

For ichthyology and fishing, relatively few additional studies are required. It is only the abundance and the biomass of the fish population upstream from Nagymaros that have not been investigated sufficiently so far. Accordingly, no additional ichthyological investigations are necessary.

Just the very opposite is true for hydraulic engineering and utilisation for recreation. In these fields, no studies are available at all (utilisation for recreation) or, on the other hand, decisive calculations are missing, e.g. for the development of erosion downstream from the weirs at Dunakiliti and Nagymaros.

3.3 What are the impacts of the Project as designed at that time?

Many aspects of this question are discussed in detail in Chapter 2. Given below therefore is only a brief summary.

As a result of drainage of 95 % of water from the Danube into the canal, the ecosystem of the wetland will be destroyed along this river section.

Considerable ecological impacts on the river fauna and on wetland as a whole are expected. A significant reduction in the number of fish species is expected in the retained water at both places. The natural stock of fish will be limited to a few adaptable species only. Accordingly, concerning utilisation of the fish production, neither commercial nor sport fishing is expected to be successful in these waters. Downstream from Nagymaros, a reduction of 60-80 % in the rate of catch of fish is to be expected.

The surface of the most valuable part of the ecosystem (the furcation between Bratislava and Györ) will be reduced from 28.3 to 8.4 km^2

Qualitative and quantitative losses sustained by the groundwater accompanying the Danube can definitely be predicted. In the historical part of Hungary, the landscape will change unfavourably for ever. For the same reason (that is, to preserve the historically valuable that is, the original picture of Wachau), the plan to construct a power plant has been given up in Austria.

3.4 Should the total Project (Gabčíkovo-Nagymaros) be discontinued for ecological and technical reasons?

Yes! It is enough to study the documentation available to see what an enormous intrusion into the entire Danube section between Bratislava and Budapest this project means. Impacts on the most important groundwater reserves of Hungary and Slovakia are likely. Impacts on the wetland ecosystem have to be reckoned with. Therefore, the entire Project should be discontinued. The grounds for this are given below:

– In the 1960s when the first decisive steps were taken, no data on the ecology of this region were known in detail. Only rough analyses at the lowest possible costs were made, based on insufficient knowledge of the ecology in general and of the special ecological conditions in the region involved in particular. From among 3 concepts submitted, those including a drain canal had to result in the least impact from an economical point of view.

> – No specific requirements were imposed on the scientific institutions which had to investigate the impacts of these concepts on the ecology of the Danube and the adjacent regions. Entrusted with such investigations were no scientists before 1974 in Chechoslovakia and 1984/1985 in Hungary; however, it was too late at that time to change the basic concept.
>
> – Most of the impacts expected after completion of the Project are irreversible. This applies especially to the impacts affecting the fish fauna and the fish husbandry. However, the project will unfavourably affect forestry, agriculture, environmental protection and hygienic aspects as well.
>
> – All that we have come to know about the project makes us believe that both the Hungarian and the Czechoslovakian government approved of this concept on the basis of insufficient and, for the problem in question, inadequate information.

A moratorium of several years as in case of Hainburg would best be recommended.

4. Recommendations

A team of independent, reputed experts of the different fields involved should be entrusted with discussing the questions posed and carrying out detailed studies which become necessary on the basis of the discussion. This was the case in the decision process concerning the Hainburg barrage. Since these studies would take a time of minimum of 3 years,

- the construction should be discontinued for 3 years and
- impounding at Dunakiliti should not come about at all!

Should the Hungarian government decide to give up the Nagymaros Project on the basis of the considerable risks that can be recognised even today,

- modification of the operation of the Gabčikovo Power Plant in addition to
- restoration of the original conditions in Nagymaros will be inevitable, that means that
- peak load operation must be discontinued, and
- the water flow rate in the Danube must be increased by discharge dependent control (dynamic system).

A condition for operation of the Gabčikovo Power Plant is that the water quality problems arisen be reassuringly solved.

"Irresponsible endangerment of all this, a damage or destruction would not be simply a mistake, a misstep only but an irreparable felony also with respect to the future!" (Dosztanyi et al., 1987).

Annex 5

SILTING PROBLEM ARISING WITH THE REALIZATION OF THE GABČÍKOVO WATER SCHEME

M. Bačik and J. Kališ
Water Research Institute
Bratislava, October 1991.

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Oct. 21-26, 1991

SILTING PROBLEM ARISING WITH THE REALIZATION OF THE GABČIKOVO WATER SCHEME

by Jiři Kališ, Martin Bačik
Water Research Institute, Bratislava, ČSFR

1. INTRODUCTION

The Danube River enters the czecho-slovak territory at the Devin Gate (km 1880), where it reaches a middle course. Downstream from Bratislava the Danube enters the lowland where a number of branches have been created in the past. Due to large discharges they have permanently changed and a huge inland Danube Delta from Bratislava to Komarno was formed [5].

Since the 13-th century where embankment construction begun there in 19-th century continuous flood protection levees system along the course was created. The channel regulations realized in 19-th and 20-th century ensured both middle and small discharges. There at Czecho-Slovak - Hungarian border marked changes in the longitudinal bed slope exists (Fig. 1). At the river km 1880 up to 1820 the longitudinal slope is 0.35 to 0.4 ‰ . Then the slope decreases further to 0.2 ‰ at river km 1780. On next section of the course the longitudinal slope decreases to 0.086 ‰ [15].

Changes in longitudinal bed slope causes intensive sedimentation and this is why the Danube River flow is situated higher than the flood protection level territory. Morphological river channel instability is the reason of many problems, mainly as for the maintaining of the navigable depth. The Danube river is very important waterway and will assume its even greater importance after completion of Rhine - Main - Danube navigation channel in the year 1992. At the same time there on the common Czecho-Slovak - Hungarian section will be permanent obstruction to navigation which wouldn't satisfy the navigation conditions.

Providing the desirable conditions for navigation was one of the main reasons for the construction of Gabčíkovo - Nagymaros Project. The dam project system is intended for the more complex utilization of Danube 200 km long section between Bratislava and Budapest. The conception of mentioned Danube river utilization is generally known. The main purposes of the project are as follows:

- flood protection of the Danube area;
- creation of an international waterway with the navigation depth of 3.6 to 4.0 m;
- utilization of the hydro-energetic potential of the Danube river section;
- creation of the positive conditions for the infrastructural development of the region.

The Gabčíkovo - Nagymaros Project Scheme should consist of two parts: The Gabčíkovo Project and the Nagymaros Project. The main components of the Gabčíkovo Project comprise (Fig. 10):

- Hrušov-Dunakiliti Dam (a reservoir of 240 mil. m^3);
- derivation channel of the total lenght 25.2 km (headrace of 17.0 km);
- Gabčíkovo hydroelectric power plant (8 aggregates with total installed output of 720 MW) and two navigation locks (34 x 275 x x 4.5);

The Hrušov-Dunakiliti Dam is situated below Bratislava at Danube River km 1842. The derivation channel connects the reservoir with the Gabčíkovo hydroelectric power plant and navigation locks along the left bank of the river and at 1811 km inflows to the Danube channel. Further the project proposed the connection with the Nagymaros Water Scheme. In the year 1989 Hungarian Government decided to stop the construction of this part of the Gabčíkovo-Nagymaros Project.

In connection with the Gabčíkovo Project realization there was necessary to study some problems concerning the transport of sediments and the silting of Hrušov - Dunakiliti reservoir.

2. Problem of suspended load in Hrušov-Dunakiliti reservoir

The prognosis of silting were severaltime modified during the preparation phase of the project. In the past, the basic informations on the velocity distribution in the reservoir were obtained from the measurements on hydraulics and aerodynamics models.

Further the new method of the flow velocity distribution calculation has been applied based on shallow water equations and Leendertse's explicit-implicit algorithm [8]. Next to them new computation program utilized implicit ADI algorithm was used. By this way a new complex mathematical model was developed and enabled the implementation of the whole reservoir silting computation to PC computers [7].

By means of program PRUNA the distribution of mean velocities in verticals in the reservoir and the lag time by the help of PODO-33 program have been determined. Prognoses in acumulated water quality has utilized these data. The computation of reservoir silting required to devide the reservoir into the equidischarges zones as it was realized in the program PRUHY. For final computation of the reservoir silting program SILTING based on diffusion theory of suspended load [11], [12] has been used.

Until quite recently there ČSFR was no database on the quantity of transported suspended load in Danube river. Direct suspended load measurements were stopped at the beginning of the 60-ties. That is why the silting prognosis have utilized the measure results obtained in Austrian profile - Bad Deutsch Altenburg, which is located close to the Czecho-Slovak - Austrian border. The suspended load concentrations and their discharge in Bad Deutsch Altenburg profile during the average year are shown in Fig. 2. The next Fig. 3 represents dependences between water discharges and suspended load concentration. Data on Hrušov - Dunakiliti reservoir silting have been corrected for Morava tributary. As we didn't obtain the data on suspended load granulometry from our Austrian partners, we had to use older measurements data from Czecho-Slovak section of Danube, were updated in spring 1991.

The computations were done for six fractions (d < 0.005 mm; 0.005 - 0.01 mm; 0.01 - 0.02 mm; 0.02 - 0.05 mm; 0.05 - 0.1 mm; and 0.1 - 0.2 mm) and for discharges Q = 1 000; 2 000; 3 000; 4 000; 6 000 and 8 000 m^3s^{-1}, where the frequency curve of discharges was considered.

Our results showed that in average year about 79 % (2.27 mil. t) of total transported mass of 2.87 mil. t will settle in the reservoir. Considering the specific volume mass of settled sediments ρ_s = 1 250 - 1 300 kg m^{-3} then the volume of sediments will be 1.74 - 1.81 mil. m^3/year.

Data and results of computations are given in figures. Results obtained for the velocity distribution at Danube discharge of Q = 2 000 m^3s^{-1}, reservoir water level of 131.10 m above see level, Hrušov - Dunakiliti Dam discharge of Q = 350 m^3s^{-1}, and derivation channel discharge to the Gabčíkovo Hydro Power Plant of Q = 1 650 m^3s^{-1} are given in Fig. 4 and Fig. 5. Sediment distributions in the reservoir and mean grain size distribution during average year are illustrated in Fig. 6 and Fig. 7. The obtained model results provide the basic information for both operation and maintanance reservoir planning and accumulated water quality prognoses.

3. Problem of bed load in Hrušov-Dunakiliti reservoir

Sedimentation by the bed load transport in the reservoir of Hrušov - Dunakiliti isn't expected to cause serious problems as it was confirmed by the sedimentation prognoses based on one-dimensional mathematical model STACON [3]. This model is reliable enough for simulation of morphological processes. According to the model, sediments will silt only in the channel and their depth will not reach bank line level [4].

Our computations were based on bed load granulometry data.

The sediment transport was determined by Meyer Peter equation [9]. Its relatively good accuracy for the simulation of this Danube section was verified by our experts in the field measurements realized in the 50-ties [10]. Based on these results the values of coefficients A and B in Meyer Peter's equation have been adjusted. While the values of coefficients A and B in original Meyer Peter's equation were A = 0.047 and B = 0.25, respectively, these values for the Danube river section downstream from Bratislava are A = 0.041 and B = 0.28, respectively [14].

The reservoir sedimentation prognoses are set for the next 50 years. Of 24 hour discharges obtained from 1900 to 1986, 50 years of the highest sediment discharges were chosen. The whole hydrologic year was considered. Our prognoses were allways based on unreal hypothesis, that during 50 year reservoir operation there will be no dredging at all. Required timing and site of dredging were set. The results showed that the sediment settling will occur at the backwater end and at the upper part of reservoir, see Fig. 8.

4. CHANNEL BED STABILITY BELOW THE GABČÍKOVO HYDRO POWER STATION

The channel below the Gabčíkovo Hydro Power Station is 8.2 km long. The cross-sectional channel dimensions are greater than those of the Danube channel. They were proposed to reduce hydraulic losses and to maintain the channel stability. Grain size of the channel bed is much more smaller than that of gravels in Danube river channel.

In the evaluation of channel bed stability the results of granulometric analyses from 53 probes and the shear stress data under conditions of the unsteady flow caused by peak-operation of Gabčíkovo water power plant have been considered. Possibilities of stable bed armoring formation in the channel bed were considered.

Calculations of stable grain diameter were done according to Meyer Peter equation [9] and modified Ackers and White's method [1], [2]. Finally, the results of Meyer Peter equation were utilized because of their less favourable values. This fact is very important as far as the safety aspects of the project are concerned. The bed deformations in the individual profiles were calculated according to the equation:

$$\Delta z = K\, d_{stab} \frac{100 - p}{p}$$

where p - fraction of particles with the grain diameter greater than that of the stabile grain d_{stab} [%] and K - multiple of d_{stab} necessary for the stabile bed armoring formation. Considering possible deviation in real granulometry of probe analyses, in our calculations the value of K = 3.0 was utilized. We have found that the channel bed deformations are relatively small and wouldn't exceed some ten of cm [6]. The bed and banks stability of the outflow channel will not be endangered.

5. DEFORMATIONS DEVELOPMENT OF OLD DANUBE CHANNEL

Along the derivation channel from Hrušov Weir to Palkovičovo, there is approximately 31 km long river section, through which under normal operation only ecological discharge would flow. During flood events the old channel flow discharge will be reduced by derivation channel capacity of Q = 4 000 m^3s^{-1}, which is in Bratislava Q_{100} = 11 000 m^3s^{-1}. Further old Danube channel is supposed to provide the desirable conditions for ice releasing from Hrušov Weir and navigation, too. The original project also proposed the transport of bed load out of Hrušov reservoir. Our research results of Hrušov-Dunakiliti reservoir sedimentation, presented in Chapter 3 of our report, showed that all bed load sediments will settle at the reservoir head and at the end of backwater. There will be no transport to the dam profile.

The groundwater level regime both on Czecho-Slovak and Hungarian river side is influenced by water levels in old Danube channel. Their extreme decrease would lead to drying of large area, dying of lowland forest and there will be decrease in water resources capacity in the area near Danube channel.

The Gabčíkovo Project operation will considerably change discharge and water level regime of old Danube channel. At Hrušov reservoir inflows of $Q \leq 4\ 000\ m^3s^{-1}$ only ecological discharge is expected in old Danube channel. As for the magnitude of the ecological discharge until now there is no definite agreement about it. It is a subject of discussion between the experts in hydroenergy, water management and ecology. The discharges of $Q_{ec} = 50$ to $Q_{ec} = 1\ 350\ m^3s^{-1}$ are considered. As far as river morphology of this river section is concerned, it is important that there would be no bed load transport even at discharge of $Q_{ec} = 1\ 350\ m^3s^{-1}$. Begining of bed load transport is expected with higher discharges. The periodical occurance of these situations is supposed during flood events when the old Danube channel bed deformations will occur.

To study the influence of the channel bed deformations on surface- and groundwater level regime it was important to develop the prognoses of morphological development. The Danube channel bed deformations prognosis, like the reservoir sedimentation prognosis have been elaborated for the next 50 years [13]. One-dimensional mathematical model STACON [3] was applied. Calculations of bed load discharge were done according to Meyer-Peter equation.

The obtained results showed that the old Danube channel deformations will be relatively small (Fig. 9). Decrease in channel bed of 0.5 m would be expected in river section below Hrušov-Dunakliti Weir. On the next sections of the course the bed deformation will be of relatively equal level. The channel bed decreases, resp. bed silting only in some sites and for short sections will not exceed the value of $\pm$ 1 m. Only at the river section between 1814 - 1811.5 km there will occur intensive erosion at 1813.4 km and it will reach the depth near 3 m. This river section is characterized by expressive direction change of river Danube course (so called Bagomer bend). At present there are still problems during flood events on this river section.

6. Conclusions

As far as the construction of Gabčikovo Project is concerned following interesting problems of suspended load and bed load regime were studied, too :

- problems of old Danube channel longitudinal profile stability;
- problems of dredging in the tail of the derivation channel to guarantee navigation depth and simultaneously to increase head of water power plant, etc.

Unfortunately it is impossible to present them in more detail there.

Finally we want to thank the E.T.H. Zürich and conference organizers who supported our participation. Our special thanks to Dr. Martin Jäggi.

7. References

[1] ACKERS, P. - WHITE, W. R.: Sediment transport: New approach and analysis. Journal of the Hydraulics Division, Proceedings A.S.C.E., Vol. 99, No. HY11, 1973.

[2] ACKERS, P. - WHITE, W. R.: Bed material transport: A theory for total load and its verification. In: International Symposion on River Sedimentation, Paper B10. Beijing 1980.

[3] BAČÍK, M. - LAHODA, R.: Matematické modelovanie morfologického vývoja tokov (*Mathematical modelling of the alluvial channel morphology development*). Práce a štúdie č. 117. VÚVH Bratislava 1989.

[4] BAČÍK, M. - KÁLNOVÁ, V, - LUKÁČ, M. - TOPOĽSKÁ, J.: Prognóza zanášania zdrže Hrušov-Dunakiliti splaveninami (*Prognosis of the bed load sedimentation in the Hrušov-Dunakiliti reservoir*). Research Report B-PÚ-DOD-A56.04.02. VÚVH Bratislava 1991.

[5] GYALOKAY, M.: Ochrana Žitného ostrova pred veľkými vodami (*The flood protection of the Žitný ostrov*). Práce a štúdie č. 62. VÚVH Bratislava 1972.

[6] KALIŠ, J. - BAČÍK, M.: Matematické modelovanie pohybu dnových materiálov a vývoja deformácií profilu odpadového kanála vodného diela Gabčíkovo (*Mathematical modelling of the bed load transport and profile deformations of the channel bed below the Gabčíkovo water power station*). Research Report B-PÚ-DOD--537.00.02. VÚVH Bratislava 1984.

[7] KALIŠ, J. - KĽÚČOVSKÁ, J. - KVĚTON, R.: Prognóza zanášania zdrže Hrušov-Dunakiliti plaveninami (*Prognosis of the suspended load sedimentation in the Hrušov-Dunakiliti reservoir*). Research Report B-PÚ-DOD-A56.04.01. VÚVH Bratislava 1991.

[8] LEENDERTSE, J. J.: Aspect of a computational model for long--period water-wave propagation. Memorandum RM-5294-PR. The Rand Corporation. Santa Monica, California 1967.

[9] MEYER-PETER, E.: Quelqes problémes concernant le charriage des matières solides dans les rivières alpines et subalpines. La Houille Blanche, No. B, 1949.

[10] NÁTHER, B.: Priame meranie splavenín na Dunaji (*Field measurement of bed load on the Danube river*). Práce a štúdie č. 18 VÚVH Bratislava 1962.

[11] O'BRIEN, M. P.: Review of the theory of turbulent flow and its relation to sediment transportation. Transactions A.G.U., Vol. 14, 1933.

[12] ROUSE, H.: Modern conceptions of the mechanics of fluid turbulence Transactions A.S.C.E, Vol. 102, 1937.

[13] STANČÍKOVÁ, A. - BAČÍK, M.: Analýza doterajšieho morfologického vývoja starého koryta Dunaja a prognóza zmien pri dlhodobej prevádzke VD Gabčíkovo (*Analysis of previous morphology development in old Danube river channel and the prognosis of its deformations during long-term operation of the Gabčíkovo water scheme*). Research report B-PÚ-DOD-A56.09.01. VÚVH Bra-

tislava 1991.

[14] SZOLGAY, J.: Úprava česko-slovenského úseku Dunaja vzhľadom na hydrologický výskum splavenín a plavenín (*Regulation of the Czecho-Slovak Danube river section in relation to the hydrological research of suspended and bed load*). Práce a štúdie č. 21. VÚVH Bratislava 1962.

[15] SZOLGAY, J.: Riešenie rovnovážneho pozdĺžneho profilu Dunaja v spojení s exploatáciou štrkov (*Solution of the equilibrium longitudinal Danube river profile in relation to gravel dredging*). Veda a výskum praxi č. 33. VÚVH Bratislava 1971.

Address of the authors

Ing. Jiři Kališ, CSc.
Ing. Martin Bačik, CSc.
Water Research Institute
nabr. gen. L. Svobodu 5
812 49 Bartislava
CSFR

Fig. 1: LONGITUDINAL SLOPE OF THE DANUBE RIVER
IN SECTION BETWEEN MORAVA AND IPEL TRIBUTARIES

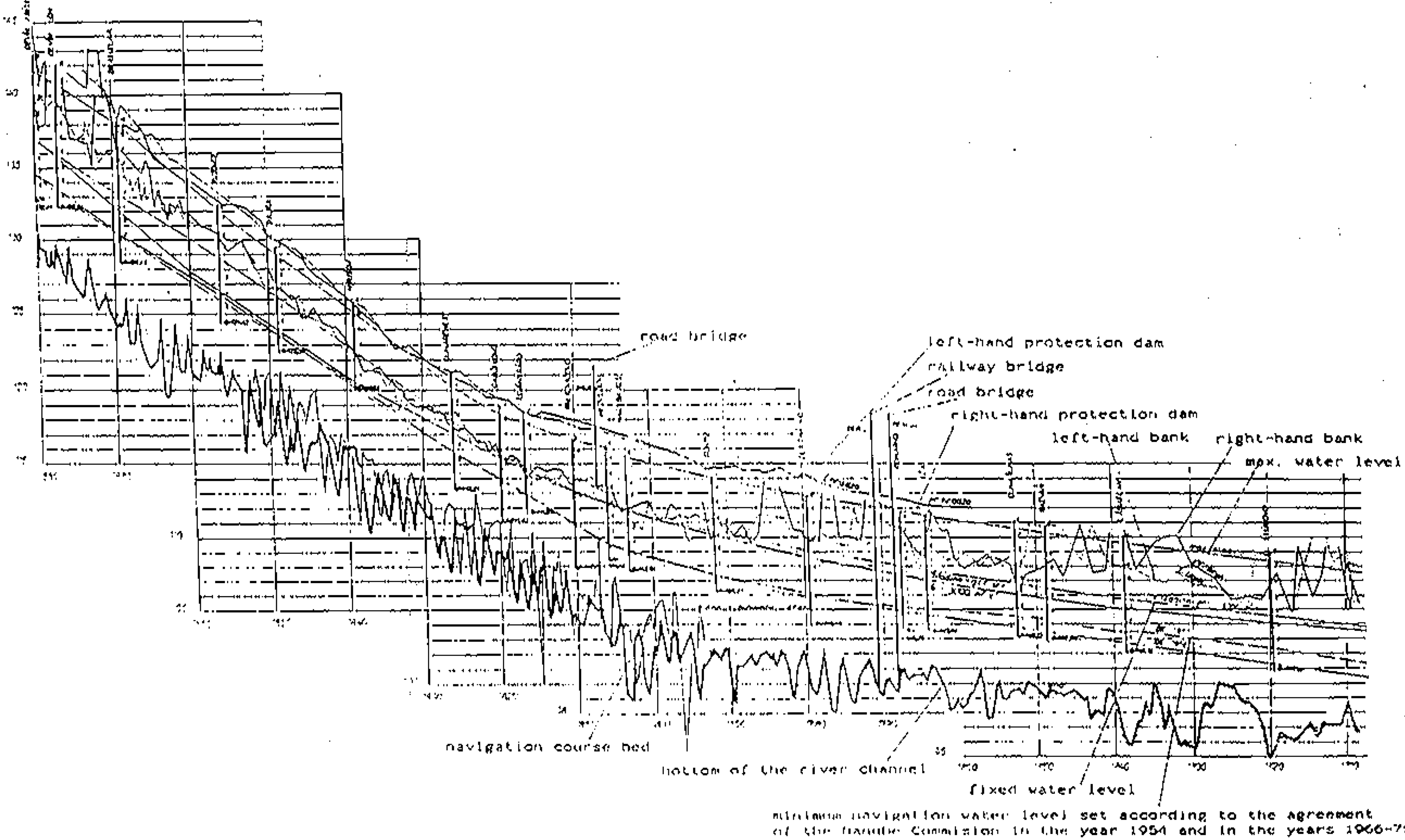


Fig.2 : Average month s concentrations cp [g/m3] and discharges Qp [kg/s] of suspended load at Bad Deutsch Altenburg during 1978-1987

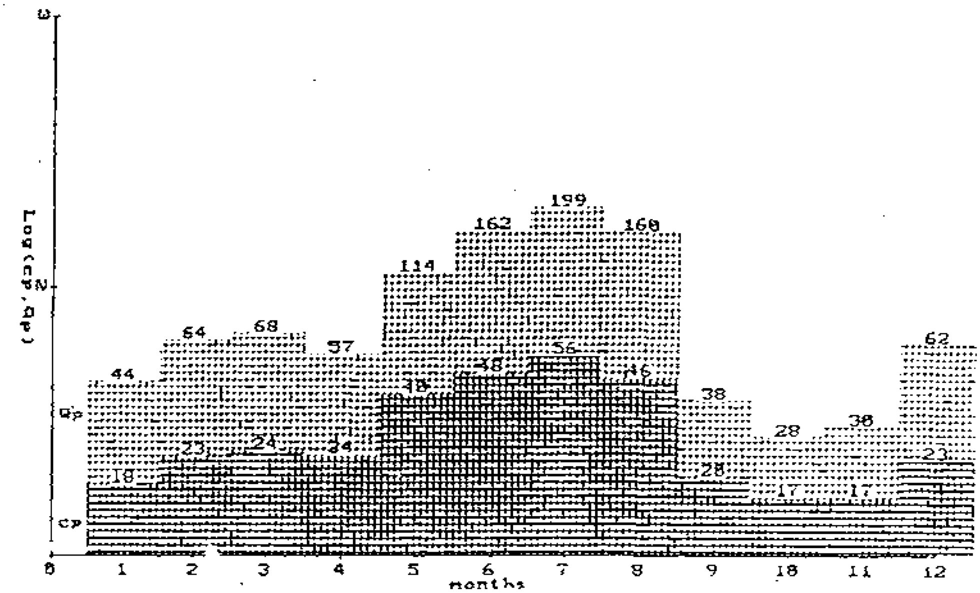


Fig. 3 : Approximation of the relation cp=a0.Q^a1 for the discharges from 700 to 6000 m3/s; considered for the mean values in classes of discharges a 100 m3/s; cp [g/m3]; Q [m3/s]

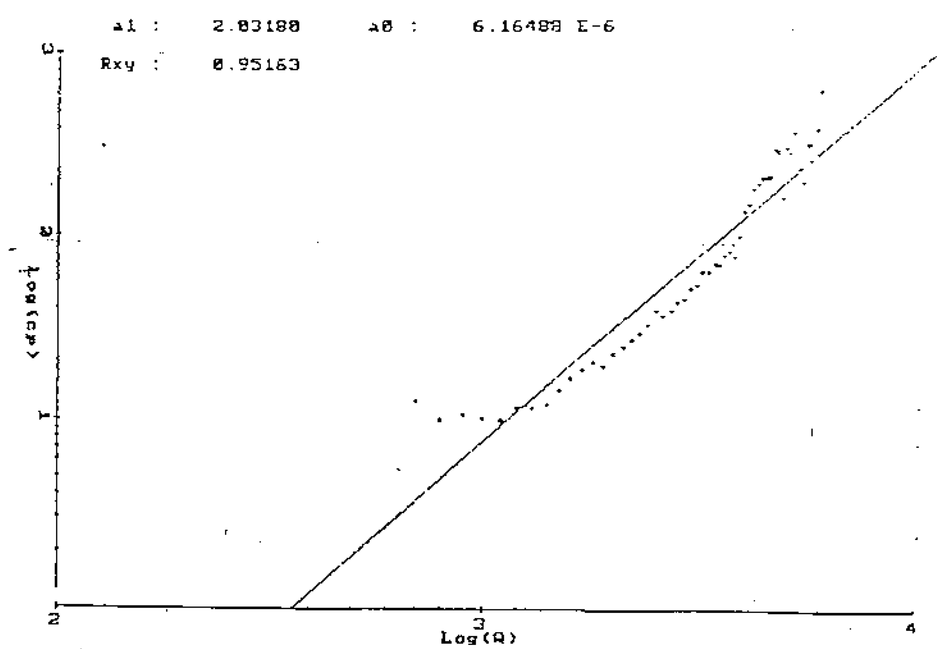


Fig.4: Velocity distribution (vectors) in Hrusov reservoir: Steady flow, Q = 2000 m3/s, Qd = 350 m3/s Qch = 1650 m3/s water level 131.1 m above sea level

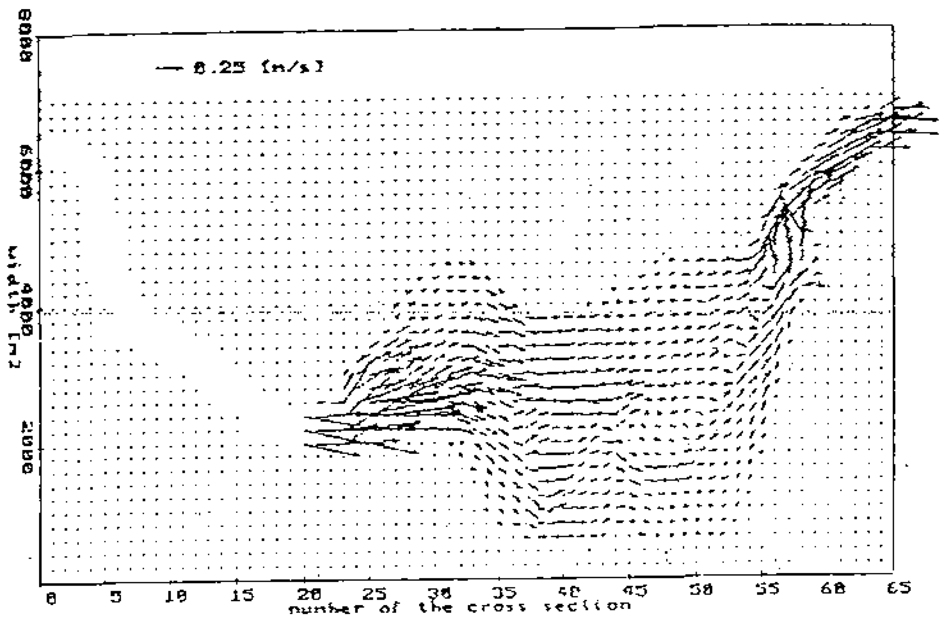


Fig.5: Velocity distribution (absolute values) in Hrušov reservoir: Steady flow, Q = 2000 m3/s, Qd = 350 m3/s, Qch = 1650 m3/s, water level 131.1 m above sea level

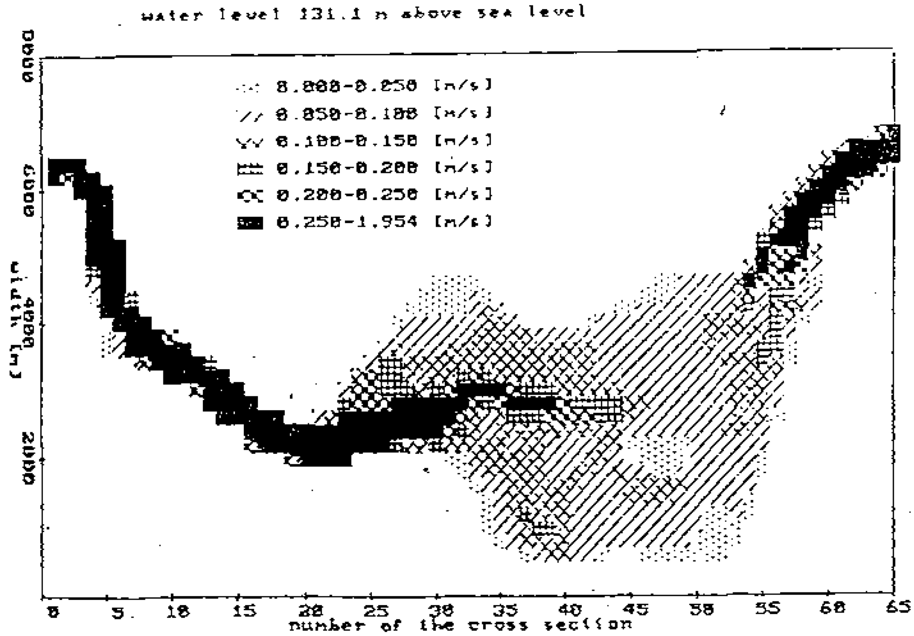


Fig.6: Settled sediments on m2 of the bottom through average year

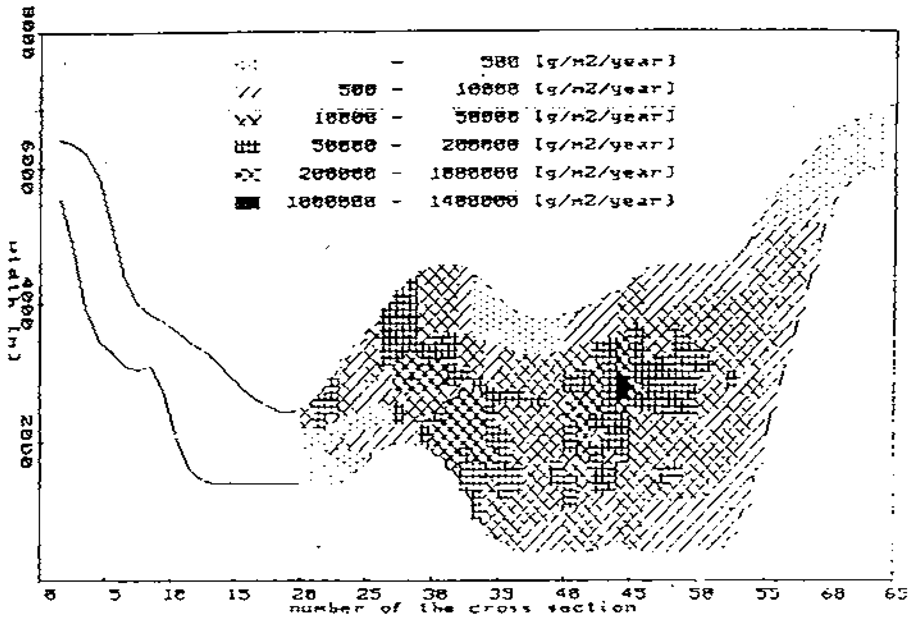


Fig.7: Distribution of the mean grain size of the settled sediments

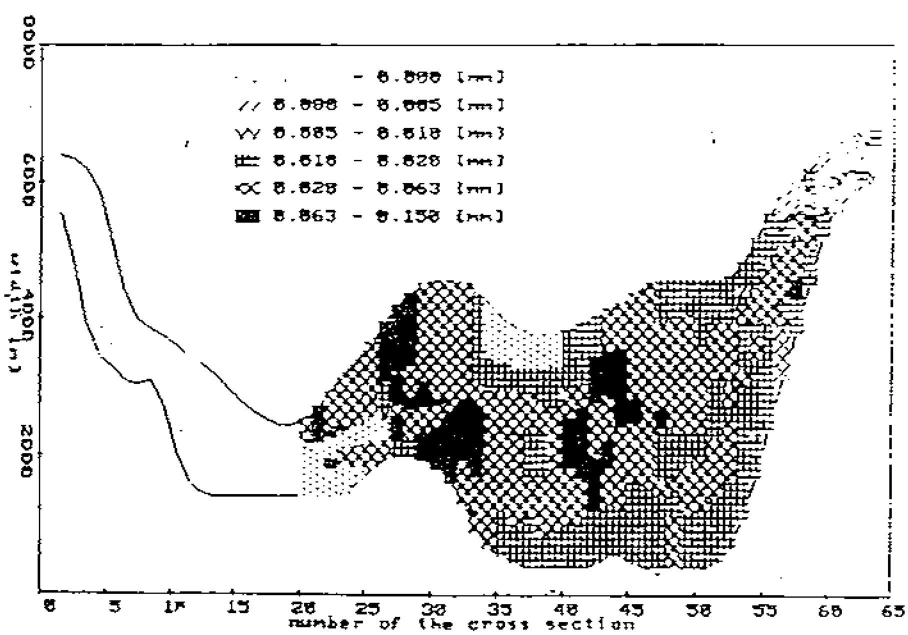


FIG. 8: SEDIMENTATION (PROGNOSIS) OF THE BED LOAD MATERIAL IN THE HRUSOV – DUNAKILITI RESERVOIR AND CHANGES OF WATER LEVELS DURING FLOOD DISCHARGE Q_{100}

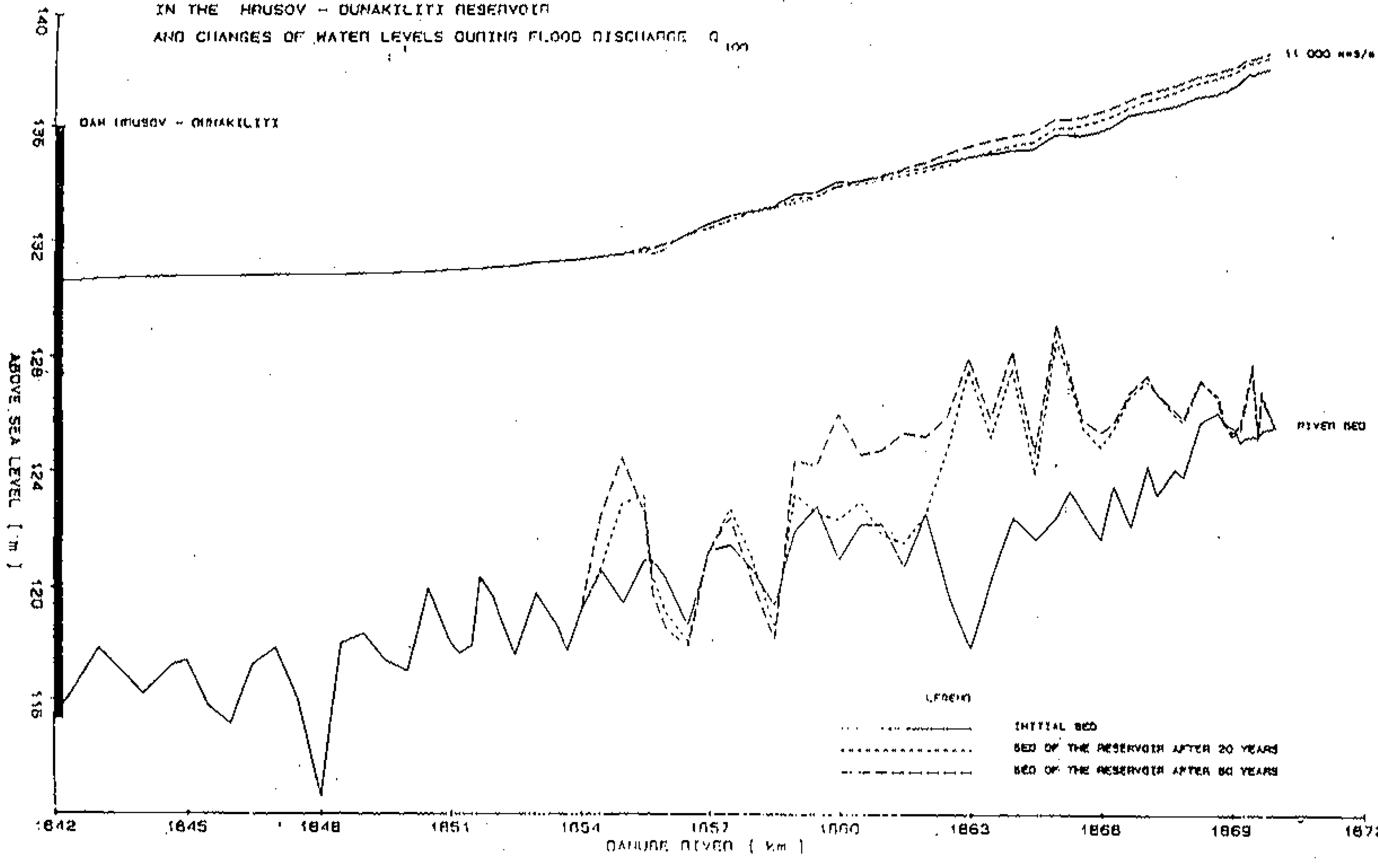


Fig. 9: DEFORMATIONS DEVELOPMENT OF OLD DANUBE CHANNEL

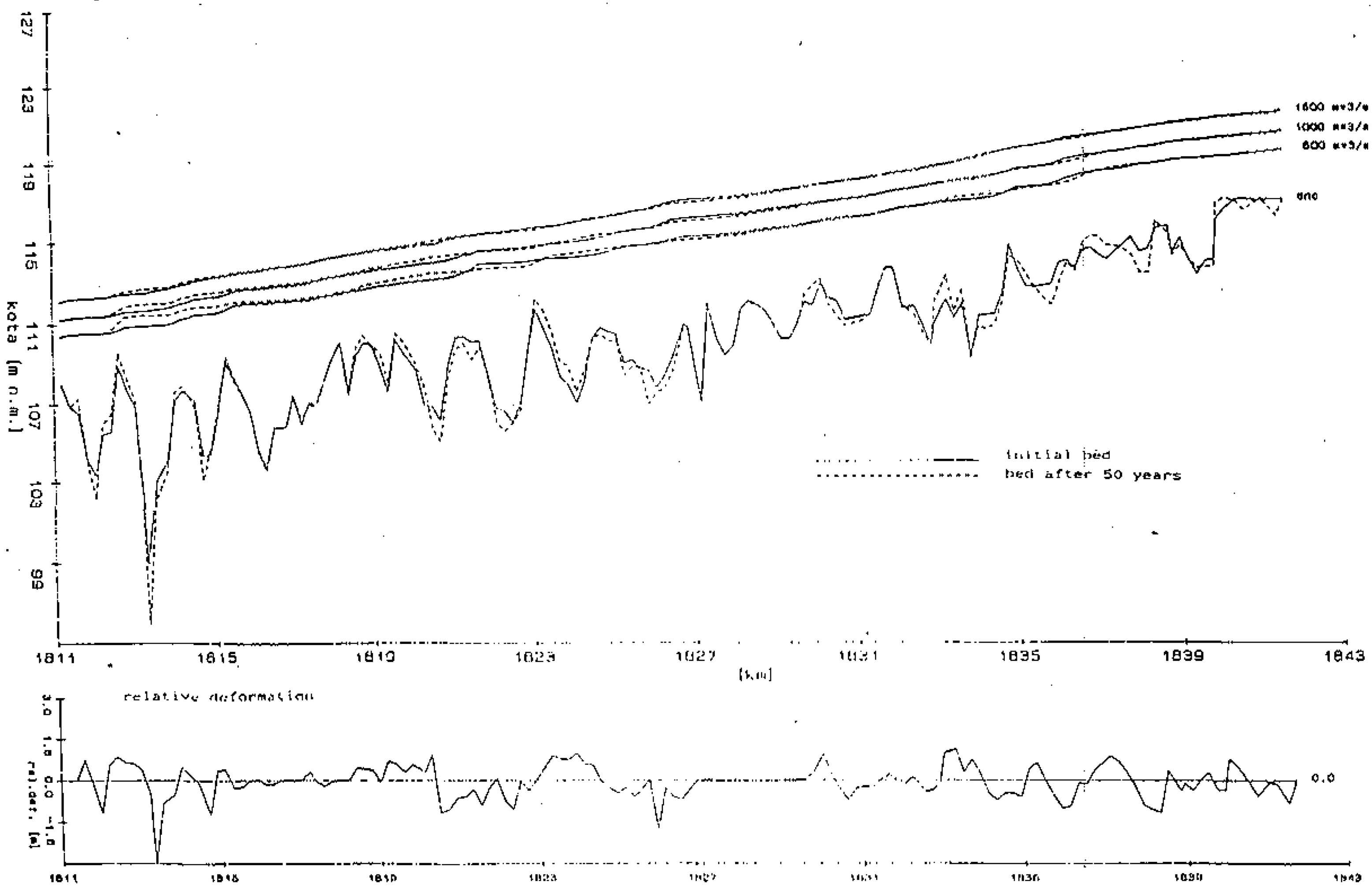
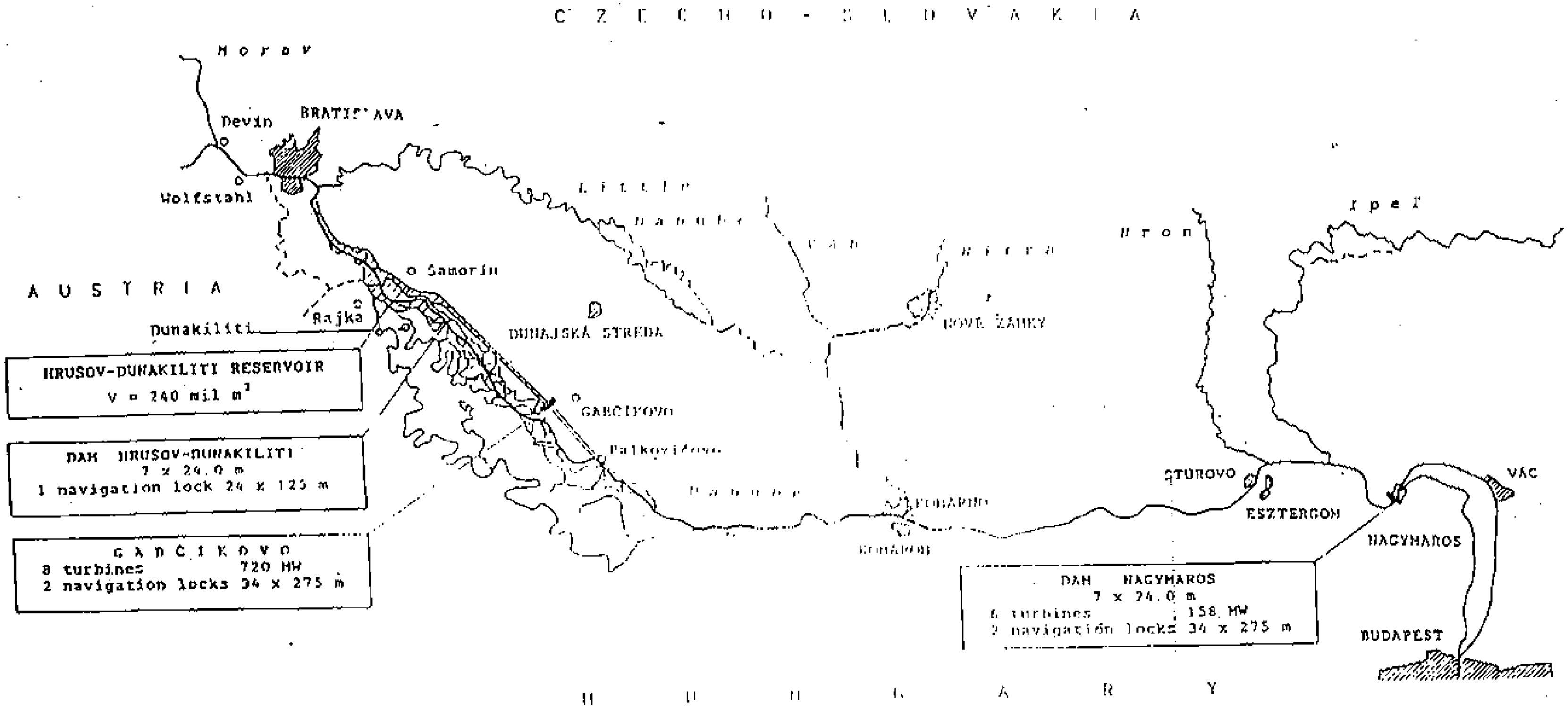


Fig. 10: SITUATION OF THE GABČIKOVO – NAGYMAROS PROJECT



Annex 6

IMPACTS OF THE GABČÍKOVO-NAGYMAROS PROJECT ON RIVER MORPHOLOGY, FLUVIAL HYDRAULICS AND HABITATS

Prepared for the
Hungarian Ministry of Foreign Affairs
International Law Department

Dr.-Ing. Klaus Kern
Consultant
Environmental River Engineering

Schlehenweg 12
76149 Karlsruhe, FRG
Tel. +49-721-712 88
Fax. +49-721-712 86

August 31, 1994

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I. Brief Description of the Area Affected by the Barrage System

GEOMORPHOLOGY [1]

Downstream of the fault gap through the Alps-Carpathians at Bratislava the Danube flows through the Kisalföld - the Little Danube Plain. All rivers flowing into the Pannonian Basin develop an alluvial cone on which the majority of sediments is deposited. The Danube together with the Váh river has formed a long alluvial cone, stretching from Bratislava to Komárom. At its edge the Danube separates into three branches forming an inner delta which is unique for European river systems. Period maps dating back to the Roman occupation reveal that the main branch of the Danube was flowing north until the 18th century following more or less the present course of the Little Danube (Annex A-1).

RIVER MORPHOLOGY

When the first comprehensive river training works started here in the eighties of the 19th century, the Danube was separating into three branches: the western Mosoni Danube, the main Danube flowing south, and the Little Danube flowing far to the east. At that time, the main channel was an unstable meandering river. Continuous aggradation was prevailing, and the river was forced to erode new branches with each major flood depositing large amounts of sediments in its previous bed. Thus a braided system of shifting side branches existed at that time, embracing numerous islands, and creating a confusing situation for navigation. The prevailing accumulation of alpine sediments resulted in a peculiar morphology: the main channel and its adjacent side branch system are situated at a higher altitude than the extended floodplain. Its large capacity for infiltration into the groundwater–even at low flow–is an essential consequence of this phenomenon.

The gradient of the Danube alters downstream of Palkovičovo (rkm 1810) from about 0.35 to 0,17 ‰, at the mouth of Mosoni Duna (rkm 1793) to 0.10 ‰ and at Komárno (rkm 1768) to only 0.07 ‰ [1].

FLUVIAL HABITATS

The ever changing system of side branches with deposition, scouring and transportation of sediments accompanied by a frequently inundated floodplain, is responsible for the very great diversity of habitats that existed and still exist in this river section. Scoured reaches of great depth, shallow fords, dissected river arms etc. are adjacent habitats. Continuous aggradation in the channel as well as on riparian ecotones and on the floodplain followed by scouring and erosion of new channels were changing the habitat pattern after each major flood. Terrestrial wetland habitats were characterised by similar diversity: raw soils caused by scouring and deposition on the banks were suitable for new vegetation growth; floodplains on different altitudes were covered with zone-specific vegetation communities. *The fluctuation of discharges and waterlevels was and still is a vital prerequisite for the existence of all types of habitats in the wetlands in this Danube section.*

The inner delta of the Danube with its characteristic features is of great significance for nature conservation on a European scale. Despite severe drawbacks to its nature by various measures addressed below, vital elements of this particular ecosystem can still be preserved or restored for future generations. The significant reduction in slope at the edge of the alluvial cone results in a distinct loss of transport capacity and quite a few islands developed in the enlarged riverbed. The riverbed structures of this reach are especially valuable because they still underlie the morphodynamic changes which were typical before the establishment of the permanent navigation channel.

2. Impacts of River Regulation and Flood Protection

The high-flow river regulation started in the middle of the 19th century with the construction of flood-protecting levees confining the inundated area to a width of about 2-6 kilometres, in the reach between Bratislava and Gönyű. This loss of inundation area has resulted in an acceleration of flood waves, an increase in peak discharges and in shorter durations of flood levels, as is well known from hydrological impacts of similar measures at the Upper Rhine. Nevertheless the remaining wetlands with the anabranched meandering river and the side branches situated within the levees, still maintained their ecological functions.

For the purpose of flood relief, especially related to ice problems, and for the improvement of navigation, mean-flow regulation works were started in the year 1886, creating a permanent navigation channel of 300-380 m width from rkm 1890 onwards [1], [3]. In 1914, the river training of the mean-flow bed in the Hungarian reach of the Danube was mainly finished, shortening its total length from 472 km to 417 km. After the establishment of a main channel, the natural diversion system on the alluvial cone with Mosoni Danube, Little Danube and the (main) Danube remained fixed. The side arm system and the active floodplain was still connected to the main channel without significant disturbance to its ecological functions.

The low flow started to meander within the then created mean-flow channel, indicating that the selected training width was oversized and excessively straightened. This secondary meandering was intolerable for navigation and required a low-flow regulation by fixing the thalweg with spur-dikes (groynes), eventually resulting in a navigation channel of 80-120 m width and 2 m depth [1].

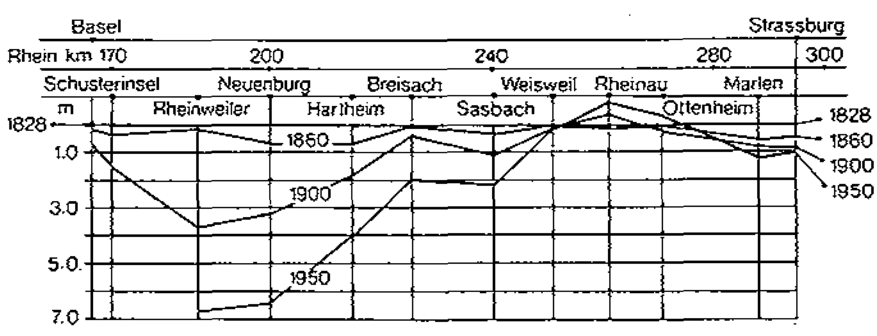


***Figure 1:** Degradation of the Upper Rhine riverbed since 1828 [4]*

River regulation works often result in the progressive degradation of bed levels. This is due to augmented sediment transport capacities, caused by increased slopes and concentrated flows at higher velocities. At the Upper Rhine, for instance, river regulation started in the early 19th century, led to a severe incision of the main channel by up to 7 metres between Basel and Breisach by 1950 (*Figure 1*).

Although the river regulation carried out in the Danube between Bratislava and Gönyü was similar to the Upper Rhine training, *aggradation* was still prevailing. Measured rates of aggradation between rkm 1800 and rkm 1841 amounted to 2.4-2.7 cm annually [5]. Dredging of fords to maintain navigation has been necessary at all times.

Until the 1960s, many of the side branches were still open and the discharge in the branch system in the reach near Gabčíkovo (rkm 1833-1816) amounted to about 20 % for a total discharge of 1,005 m^3/s measured at Bratislava (data from the year 1961) [6]. At a discharge of 1,958 m^3/s, which is exceeded on 168 days of the year (*Annex A-2*), the side branches carried up to 500 m^3/s (data from 1960, [6]). *Thus it can be stated, that until the 1960s the side branch system and the active floodplain were fully integrated in the fluctuations of discharge and waterlevels which are vital to the wetland ecosystem.*

***Table 1:** Gravel dredging in different reaches and periods along the Danube (mio = millions)*

Source	[3]	[28]	[8]	[29]	[30]	[31]
Reach	rkm 1849 to rkm 1791 (Rajka - Gönyü)	rkm 1850 to rkm 1790 (Rajka - Gönyü)	rkm 1849 to rkm 1791 (Rajka - Gönyü)	rkm 1791 to rkm 1664 (Gönyü - Komárom)	rkm 1766 to rkm 1708 (Komárom -Ipoly mouth)	rkm 1694 to rkm 1659 (main branch)
Period	1949 - 66	1963 - 79	1969 - 91	1965 - 91	1970 - 88	1970 - 79
Total gravel volume (m^3)	**no data**	**12.9 mio**	**16.4 mio**	**20.7 mio**	**27.5 mio**	**16.1 mio**
Ford dredging & river training (m^3)	6.4 mio	ca. 7 mio	8.9 mio	372,000	200,000	no data
National dredging (industry)	no data	ca. 6 mio				no data
- Slov. (m^3)			4.8 mio	19.8 mio	9.0 mio	
- Hung. (m^3)			2.7 mio	535,000	18.5 mio	
Annual dredging (m^3/yr)	350,000 (navigation)	760,000	715,000	768,000	1.447 mio	1,610,000
Specific annual dredging (m^3/rkm•yr)	6,000 (navigational)	12,600	12,300	28,000	25,000	46,000

3. Impacts of Gravel Excavation and Upstream Dams on Riverbed Morphology

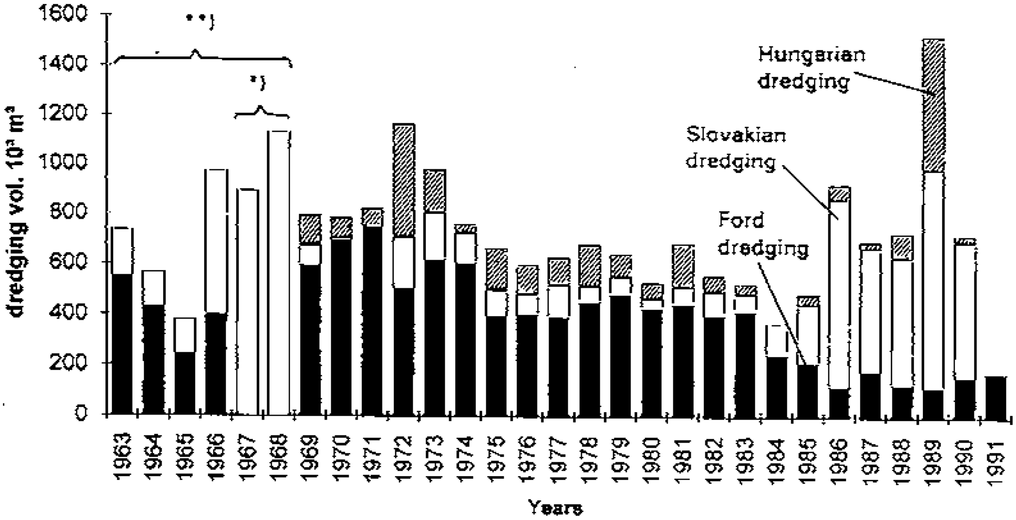
From an engineering point of view there should be an equilibrium between the amount of sediments entering a certain river section and leaving it at its downstream end, in order to maintain a constant bed and waterlevel. Since river training works, including the construction of groynes, did not succeed in balancing sediment transport capacity and sediment load, continuous dredging of fords was indispensable for navigation. In addition, growing amounts of gravel have been extracted from the entire river reach between Bratislava and Budapest for industrial purposes.

GRAVEL EXCAVATION

Table 1 gives dredging data of different Danube reaches covering different time spans. There is little information about the Slovakian Danube stretch between rkm 1880 and rkm 1850. It has been stated by the Water Management Research Institute VUVH, Bratislava, that between 1976 and 1989 a total volume of 48.3 million m^3 had been dredged from the Slovakian reach of the Danube (rkm 1880-1709) for maintenance and industrial purposes [13]. This figure refers to the entire Slovakian and Slovakian-Hungarian Danube reach down to rkm 1709 as pointed out in [33]. Unfortunately there are no data available for the Slovakian reach.

The total dredging volumes of the reach Rajka-Gönyű indicate that considerable dredging was carried out in the 1960s and the early 1970s (*Figure 2, Annex A-3*). Half of the dredging was done for the removal of fords to facilitate navigation. Downstream of Sap/Palkovičovo (rkm 1810), being a distinct break in the slope of the Danube, the excavated volumes of gravel rise sharply, and excessive dredging was carried out by both countries downstream of Gönyü (*Figure 3, Annex A-3*). The exploitation of gravel was not shared equally on all river reaches; the stretch between Gönyű and Komárom was almost exclusively exploited by Slovakia while the lower common Danube reach was intensively excavated by both countries (*Figure 4*). In both reaches navigational dredging was insignificant.

Between Nagymaros and Budapest excessive dredging was carried out for industrial purposes until 1980 when it was stopped because of negative impacts on the bank-filtered well system of the Budapest waterworks. After 1979 only minor dredging of fords was done amounting to 334,000 m^3 until 1987 [31]. *Table 1* gives the data for the main Danube only. On the 32 km-reach of Szentendre Duna 4.0 million m^3 of gravel was excavated between 1970 and 1980 and about 100,000 m^3 in the year 1987 [31].



*) no data on ford dredging **) no data on national dredging

Figure 2: Annual volumes of dredged sediments between Rajka (rkm 1850) and Gönyü (rkm 1791). Data in Annex A-3

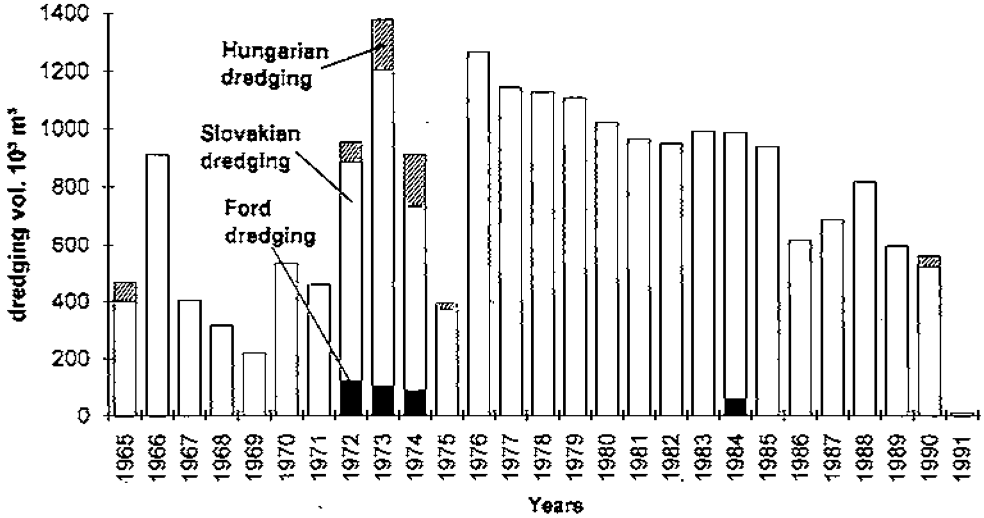


Figure 3: Annual volumes of dredged sediments between Gönyü (rkm 1790) and Komárom (rkm 1764). Data in Annex A-3

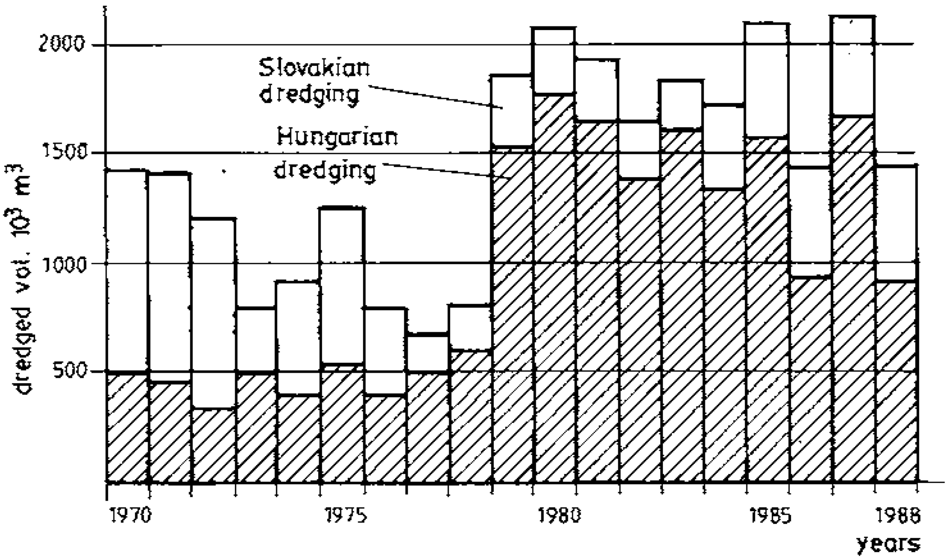


***Figure 4:** Annual volumes of dredged sediments between Komárom (rkm 1766) and Ipoly mouth (rkm 1708). Total ford dredging in this period: ca. 200,000 m^3 [30].*

BEDLOAD TRANSPORT CAPACITY AND DREDGING

Table 2 gives figures of estimated or measured bedload transport capacities at various locations along the project reach by different authors. Before the construction of dams in Austria and Germany the average bedload arriving at Bratislava per year was estimated to be about 600,000 m^3. Downstream of Bratislava the transport capacity decreases to about 100,000 m^3 in the Szigetköz. After a sharp reduction in slope from 0.35 to 0.17 ‰ (rkm 1793) and then to less than 0.1 ‰ downstream of Komárom (rkm 1768) the bedload transport capacity of the river drops to about 50,000 m^3/year and at Nagymaros to an insignificant volume of about 10,000 m^3 annually.

***Table 2:** Annual bedload transport capacity of the Danube between Bratislava and Nagymaros in m^3/year (estimates, based on scattered measurements)*

Location / Source	**Bratislava** (rkm 1868.8)	**Dunaremete** (rkm 1825.5)	**Nagybajcs** (rkm 1802)	**Zlatná** (rkm 1780)	**Nagymaros** (rkm 1694.6)
[33]	590,000	—	—	—	—
[16]	600-650,000	—	—	—	13-14,000
[32]	—	100,000	—	—	—
[28]	—		81,400	48,300	—
[14]	—	—	—	—	5-10,000

Comparing these figures to the annually dredged volumes of gravel (*Table 1*, second line from the bottom) it is obvious that all Danube reaches were heavily overdredged. Since the 1960s large scale industrial dredging was carried out in the Szigetköz reach amounting to average excavated gravel volumes of more than 700,000 m^3 per year. In single years dredging in this river stretch exceeded 1 million m^3 with a maximum amount of 1.526 million m^3 in 1989 (*Annex A-3*). Dredging of fords was necessary at all times independently of the arriving bedload, because the fluvial rearrangement of sediments in the riverbed was unfavourable to navigational requirements.

Even more dredging was carried out in the reaches downstream of Gönyü. The specific dredging volumes (*Table 1*, bottom line) are doubled in the reaches above the Ipoly mouth and even more gravel was exploited by Hungary from the Szentendre arm.

The total amount of gravel excavated from the Danube in the project reach, exceeds by far the bedload which could be expected to enter the river section from upstream even without the influence of upstream dams. This is not only true for the Szigetköz reach but also for the reaches downstream of Gönyü where tributaries could only compensate for an insignificant part of the total dredging. *So it can be stated that the entire Danube reach between Bratislava and Budapest has been heavily overdredged especially when considering reduced levels of bedload input from upstream.*

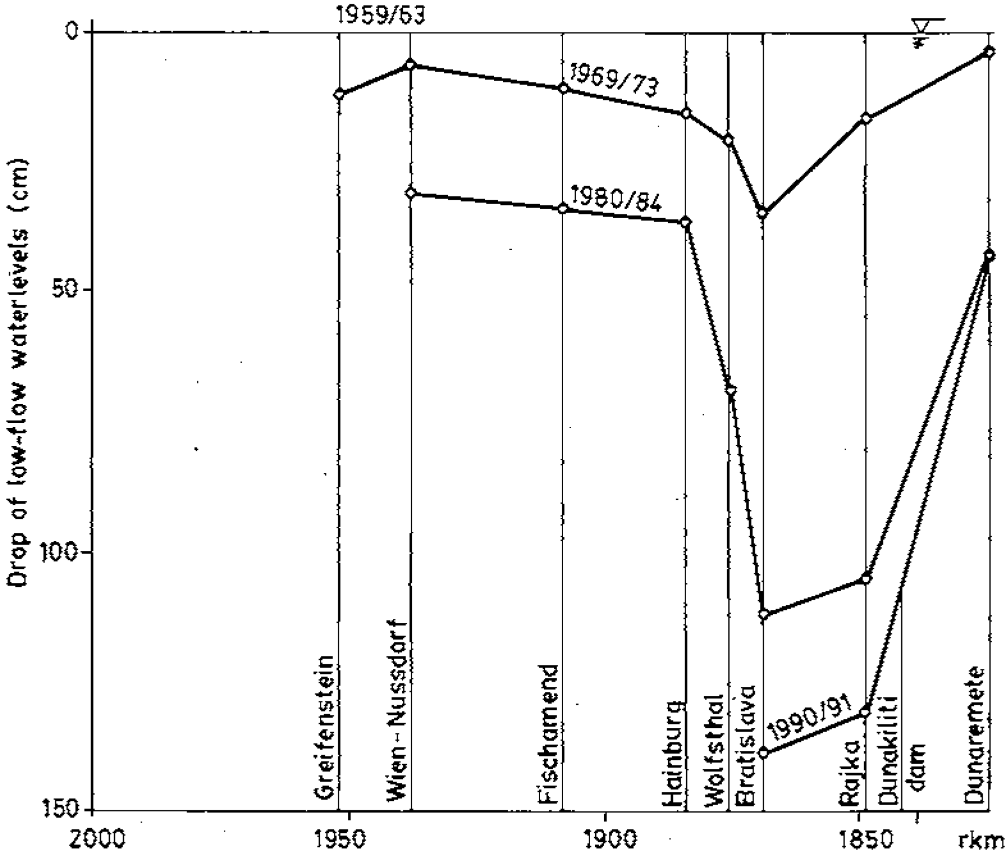


***Figure 5:** Drop of low-flow waterlevels (1,000 m^3/s) since 1959/63 in the Danube between Vienna and Dunaremete [10]*

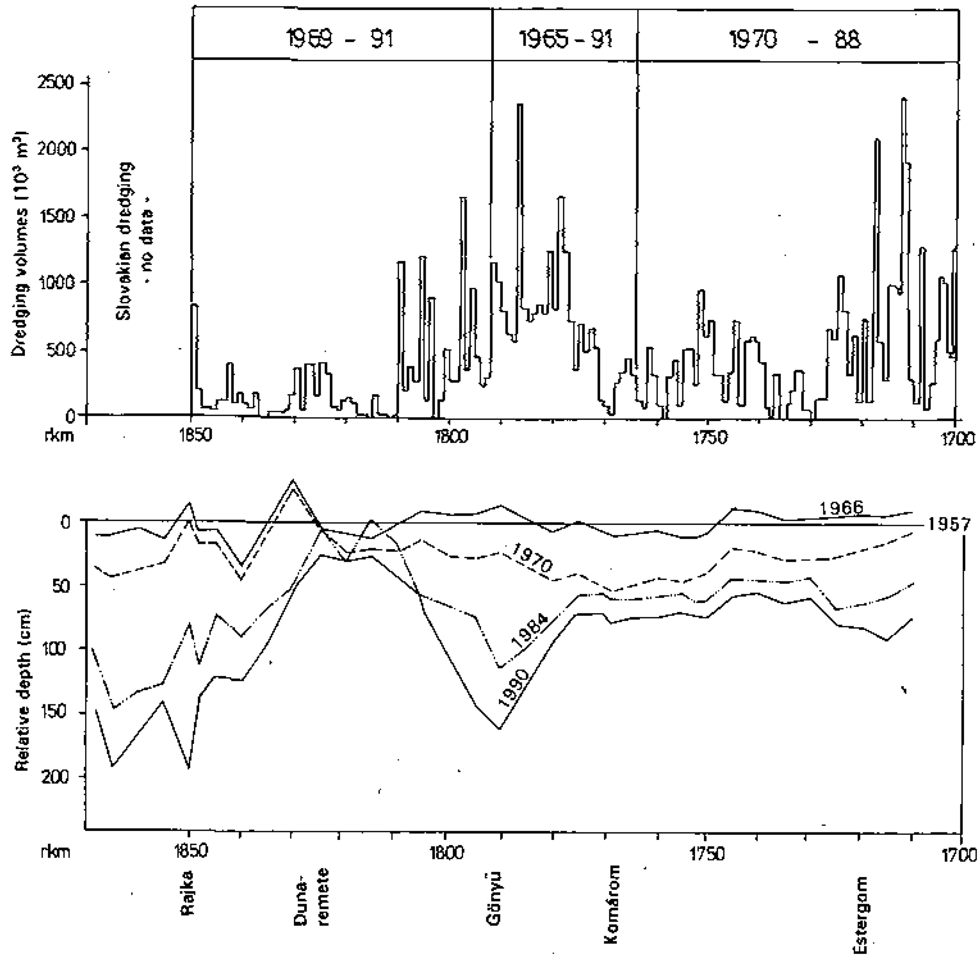


Figure 6: a) *Dredged volumes of sediments in the Danube along the Slovakian-Hungarian border in different periods of time. Data from [8, 29, 30]* ***b)*** *Lowering of the low-flow waterlevels (ca. 1,000 m^3/s) since 1957. Data from [34, 35] ("1970" corresponds to the "DC 1974/95" waterlevel which was calculated from 94%-exceedance probability based on daily discharges between 1940-70)*

DROP OF WATERLEVELS

The excessive channel dredging beyond the indispensable need of navigation maintenance has led to a severe disturbance of river morphology affecting the entire river ecosystem. Between Nagybajcs (rkm 1802) and Gönyü (rkm 1791) the low flow waterlevels dropped by more than 1.50 m. *Figure 5* shows the drop of low-flow waterlevels between Hainburg/Austria and Dunaremete (rkm 1826) with its maximum between Bratislava and Rajka [10]. Obviously the riverbed degradation increased significantly entering the Slovakian reach at rkm 1880.

The lower part of *Figure 6* shows the drop of the navigational low-flow waterlevels. The horizontal line represents the 1957 navigational low-flow waterlevel. The waterlevels of 1966 reveal that the riverbed remained rather stable until the mid sixties. Between 1966 and 1970 a considerable drop was registered between Bratislava and Rajka and especially downstream of Dunamerete. Dramatic changes occurred in the period after 1970. Apparently the drop of waterlevels was not uniform; former aggrading or rather stable sections degraded severely, e.g. in the vicinity of Rajka or Gönyű. The reasons for these phenomena will be discussed below.

Both graphs reveal a considerable drop of low-flow waterlevels in the vicinity and downstream of Bratislava after 1966. An analysis of the gauge data of Bratislava also shows that the erosion process did not start before the middle of the 1960s. The fluctuations of the waterlevel at Bratislava gauge station in the time period from 1950 to 1993 clearly show a trend (*Annex A-4*). But the downward move of the mean waterlevels, indicated by the straight line, should not start before 1967. This is sustained by the discharge rating curve of the same gauge with insignificant variations in the rating curves valid for the period from 1918 to 1967 (*Annex A-5*).

REASONS FOR RIVERBED DEGRADATION

Generally, the installation of a barrage system affects sediment transport and morphology of a river. Bedload will almost be completely retained at the first barrage and deposited at the upper end of the backwater reach. A considerable part of the suspended load will settle in the upstream reach during average and low flow. The retention of the bedload normally leads to degradation of the bed level of unbacked reaches downstream of barrage systems, as is well known from the Upper Rhine.

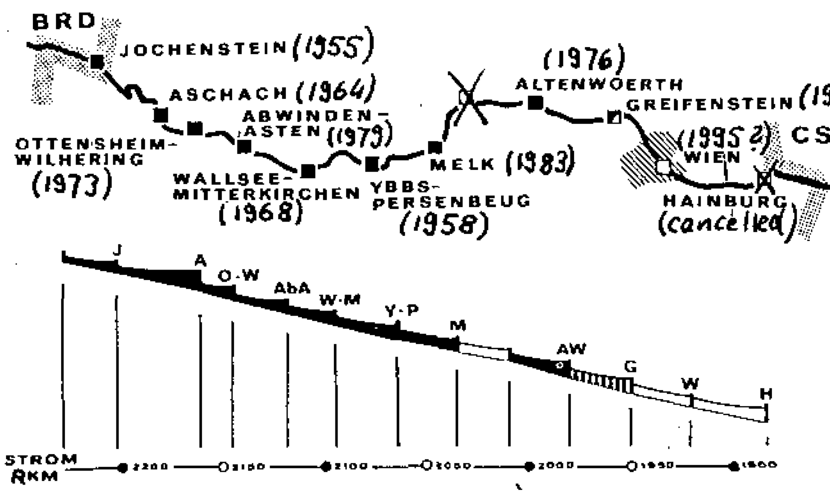


***Figure 7:** Austrian barrage system of the Danube: years of construction*

In the Austrian reach of the Danube, the first barrage (Jochenstein) was implemented in the year 1955 (*Figure 7*). The second one, being Ybbs-Persenbeug, was built in 1958, the last one put in operation is Greifenstein (since 1984). Presently one more barrage at Wien-Freudenau is under construction after Hainburg had been abandoned for the preservation of the Austrian Danube wetlands downstream of Vienna. At the river Inn, supplying a major part of the alpine bedload, barrage construction began as early as 1941 and was terminated in 1965.

Figure 8 shows the gradual alteration of the low-flow waterlevels in the Austrian Danube *before* any barrage has been constructed in this reach [17]. Even at that time, there were obvious trends towards aggradation and degradation. The drop of the low-flow waterlevels between Vienna and Hainburg was less than 1 cm/yr. After construction of the last barrages, it increased to about 2-3 cm/yr except for the region of Bratislava where a considerable drop of the low-flow waterlevels up to 10 cm/yr in single years was observed (*Figures 5/6*)[17].

The discharge rating curve of the Bratislava gauge does not indicate any significant change at least until the year 1967 (*Annex A-5*). Obviously the ten-year operation period of Ybbs-Persenbeug did not significantly affect the river morphology in this section. Downstream of Ybbs-Persenbeug no more barrage was constructed until the year 1976 (*Figure 7*); nevertheless, the riverbed degradation started in the mid sixties coinciding with the commencement of excessive industrial gravel exploitation, as stated by several sources [11], [14].

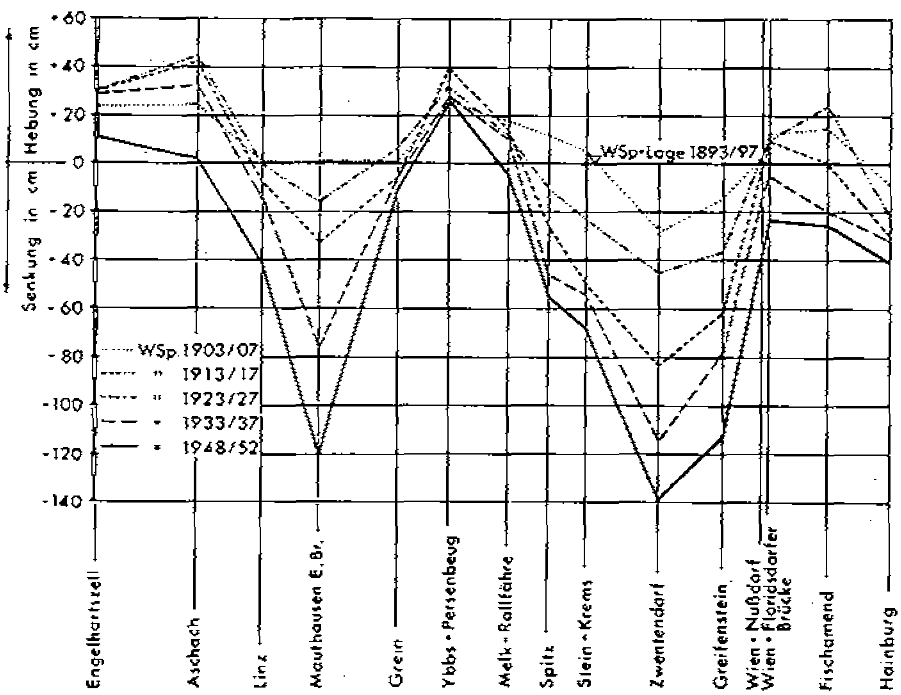


***Figure 8:** Relative change of the low-flow waterlevels of the Austrian Danube between 1893/97 and 1948/52; barrage building was started in 1955 [17]*

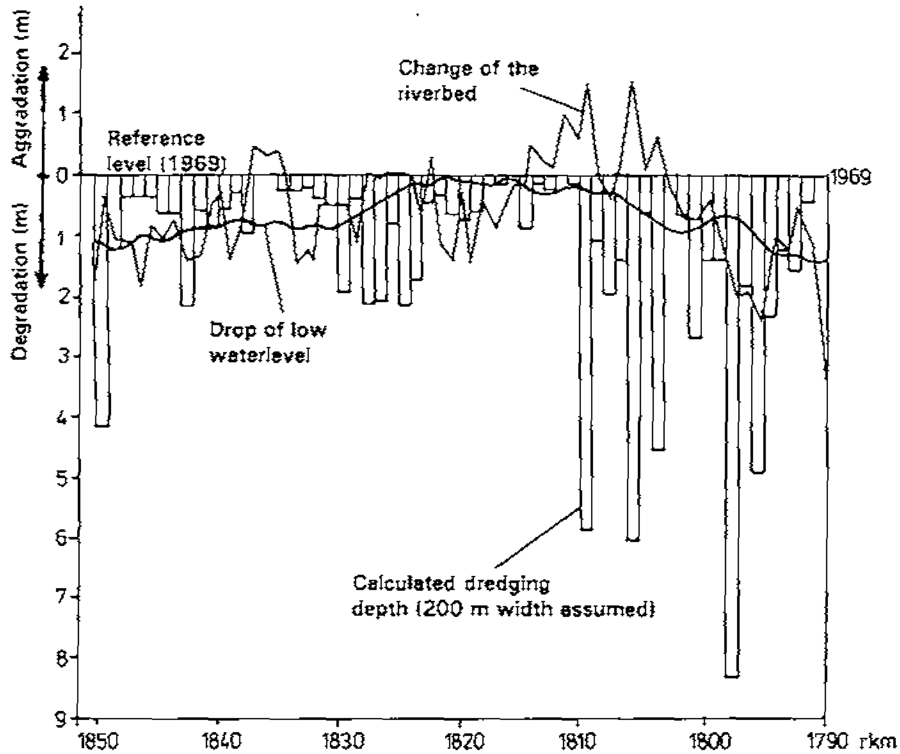


Figure 9: *Relative changes of the riverbed, drop of low-flow waterlevels and average depth of dredging since 1969 in the Danube between Rajka (rkm 1850) and Gönyű (rkm 1791). After [8].*

Figure 9 shows the change of the riverbed, the average depth of dredging and the drop of low water levels between Rajka and Gönyű in the time period between 1969 and 1991. The horizontal reference line ("0"-line) in this graph represents the riverbed and the low-flow waterlevel respectively in the year 1969. Field surveys of monitored cross-sections provided the data for aggradation and degradation of the riverbed. The dredging depth was calculated from dredging volumes assuming an average width of 200 metres [8].

The amount of gravel excavated from the riverbed in the Slovakian reach of the Danube before the year 1976 was not published, but it is well known that the new part of the city of Bratislava on the right bank of the river was built in the sixties and seventies on and from exploited Danube gravel. In other reaches of the river vast amounts of gravel have been dredged, e.g. more than 1,000 m^3/m in short stretches between Komárom and Nagymaros in single years, subsequently lowering low-flow waterlevels (*Figure 6*) [30].

Accounting for natural aggradation tendencies, the morphological behaviour of the river generally shows a distinct relationship between dredging activities and lowering of the riverbed. Between rkm 1850 and rkm 1840 the lowering of the riverbed corresponds to the amount of dredging. The lack of dredging in rkm 1835/36 resulted in local aggradation clearly indicating that the river would fill up its bed in the Szigetköz reach without dredging even with the operation of upstream dams. Provided that the dredging records are correct, then the local drop of the riverbed around rkm 1832/33 must be caused by local influences, e.g. flushing by a tributing side branch as indicated in [8], or by construction of groynes or other river training measures. Between rkm 1828 and rkm 1822 aggradation would prevail without dredging. Between rkm 1821 and rkm 1815 the lowering of the riverbed approximately corresponds to the dredging. Downstream of rkm 1815 the sharp reduction in slope causes aggradation despite considerable dredging. Downstream of Nagybajcs excessive overdredging led to a significant lowering of the Danube bed.

The changes of the low-flow waterlevels reflect the general behaviour of the riverbed rather than local irregularities. *The low water levels are obviously governed by dredging and prevailing accumulation of sediments in this Danube reach.* The drop of the low-flow water levels at the upper and lower end of the reach are caused by dredging dominating accumulation of sediments, while in the centre of the reach aggradation is still prevailing and leads to an almost stable waterlevel.

Figure 6 shows the same close relationship between dredging and lowering of waterlevels for other Danube reaches, as well. Large-scale exploitation of gravel between 1965 and 1991 in the vicinity of Győr and Esztergom led to a remarkable drop of low-flow waterlevels.

SUMMARY OF RIVERBED MORPHOLOGY

At the Upper Rhine early regulation works caused severe incision of the riverbed. The construction of a series of barrages further impaired the channel stability by reduced levels of sediment supply. Downstream of the last barrage at Iffezheim a suitable amount of gravel is continuously added to the moving sediment stabilising the unbacked river reach downstream of the barrage.

A completely different situation is encountered at the Danube between Bratislava and Budapest. Early river training did not result in channel degradation; instead of erosion, accumulation of sediments still continued, contrasting with the situation at the Upper Rhine (*Figure 1*). Riverbed degradation started in the mid sixties of this century as is evidenced by the discharge rating curve of the Bratislava gauge (*Annex A-5*). A considerable drop of low-flow water levels occurred all along the project reach ranging between 30 and 200 cm since 1957 (*Figure 6*).

Before the degradation of the bed started in 1967/68, about 20 % of the side branch system in the Szigetköz was permanently supplied with water even at low flow conditions, as evidenced by measurements at a discharge of 1,005 m^3/s [6]. After degradation the threshold for the branch system inflow increased to 2,500-2,700 m^3/s [5] which occurs for 75-100 days of the year (*Annex A-2*). In addition, the upstream ends of side branches were closed in the last 30 years in order to maintain minimum navigation water depths in the main channel. The environmental impact of lower low-flow stages and of an altered discharge regime on the wetland ecosystem has been summarized by the CEC reports [19], [20], [21].

The morphology of the river is governed by the accumulation of sediments and the excavation of gravel. Overdredging in many reaches resulted in a significant drop of waterlevels. In some reaches (e.g. around Palkovičovo) aggradation is overruling excessive dredging (Figure 9). There is no indication that the reduced level of sediment supply from Austria has significantly influenced the river morphology downstream of Rajka. Without dredging the Szigetköz reach of the Danube could *be expected to accumulate sediments even today.* Due to the lack of data no certain conclusion can be made for the Slovakian reach. The sudden drop of waterlevels at Bratislava after the year 1967 indicate excessive (industrial) gravel dredging rather than the influence of upstream dams.

Dredging and the G/N Project

Considering the detrimental impact of dredging on riverine wetlands as well as on navigation, e.g. less access to ports, or on bank filtered water supply systems, the question arises, why excessive gravel exploitation mainly for industrial purposes was allowed by both Hungarian and (Czecho-) Slovakian water authorities in the Danube channel. In the Upper Rhine area, for instance, industrial gravel mining is restricted to the floodplain. There is little doubt that the over excavation of gravel in the Danube has been done on the expectation of the construction of the Gabčíkovo-Nagymaros Barrage System GNS. In fact, excessive industrial gravel dredging was started in the mid sixties when the first steps towards the joint plan for investment were taken. In a Slovakian source it is written: "The excavation [of gravel] has rendered a drop of the low regulation and navigation waterlevels. The largest amount of sinking was registered near Bratislava and in the reach of the Hrušov-Dunakiliti reservoir. With the flooding of the reservoir to the intended waterlevel this degradation will completely be compensated." ([13], p. 39).

In this regard the riverbed degradation is closely related to the project plans. Hoping that future reservoirs would compensate detrimental effects of overdredging, huge amounts of gravel were excavated along the entire project reach.

4. Restoration of the Area Affected by the Barrage System

4.1 Removal of all Structures and Return to Pre-Dam Conditions (Period before Riverbed Degradation) - Navigation back to the Old Danube -

Restoration, as it is used here, refers to a return to the system as it existed before the mid sixties taking into account the relationship between the G/N Project and excessive dredging, as stated above. All assessment is restricted to river morphology and hydraulics. The area affected is listed in *Table 3* with a brief definition of major morphological and hydraulic impacts.

All structures used for diverting the Danube could theoretically be removed within one or two years (with the exceptions of underground sealings). The dam material of the Čunovo reservoir and the power canal could be used to fill up the degraded riverbed near Bratislava and in the Szigetköz reach. The restructuring of the riverbed – as far as the necessities for navigation allow for it - would be accomplished by the river itself within a short period of time.

With the restoration of the riverbed and full discharge back to the Old Danube, the side branch systems and the wetlands of the active floodplain in the Szigetköz regain the pre-dam discharge and waterlevel fluctuations that are vital for their existence. A longer time span for rehabilitation of the wetlands is anticipated since large-scale desiccation has occurred already.

Table 3: Major morphological and hydraulic impacts of Variant C and rehabilitation after removal of all structures (navigation back in the Old Danube)

Area affected	Major hydraulic and morphological impacts of Variant C	Rehabilitation process	Time spans for rehabilitation*)
Čunovo reservoir	• large scale dredging of alluvial sediments in both the channel and the floodplain; • total loss of floodplain soils; • destruction of floodplain morphology, i.e. side branches, oxbows, depressions,...; • severe reduction in flow velocity; • retention of sediments, i.e. a great part of the suspended load in the reservoir and all the bedload at the upstream end of the backwater reach (almost all bedload would be deposited in the gravel pits that were dredged in the channel even without the present impoundment)	• filling of the gravel pits in the channel near Bratislava with dam material • narrowing the channel to its former size with dam material or from gravel pits outside of the active floodplain; • restructuring of the riverbed by natural scouring and deposition of sediments; • reshaping parts of the floodplain on a lower level; • rehabilitation of the floodplain ecosystem by ecological succession under the impacts of natural flow dynamics	1-2 yrs. 1-2 yrs. 5-10 yrs. 1-2 yrs. 50-200 yrs.
Old Danube	• degradation of the riverbed; • severe reduction of discharge and waterlevels after diversion of the Danube; • almost total loss of the natural discharge and waterlevel fluctuations; • total loss of bedload input from upstream; • severe damage on ecotones	• compensational filling of the scoured riverbed; • opening of side arm closures; • remedial measures for restoring riverbed structures; • rehabilitation of riverbed habitats	1-2 yrs. 1-2 yrs. 1-2 yrs. 5-10 yrs.
Szigetköz floodplain	• desiccating of side branches and wetlands; • almost total loss of discharge and waterlevel fluctuations; • almost total loss of suspended sediment input	• compensational filling of the scoured riverbed; • opening of side arm closures; • rehabilitation of damaged floodplain habitats under the impacts of natural flow dynamics	1-2 yrs. 1-2 yrs. 20-50 yrs.

*) Based on general time scales for the morphological rehabilitation of river systems [22]

Table 4: *Technical necessities and rehabilitation process (navigation in the power canal)*

Area affected	Technical necessities	Rehabilitation process	Time spans for rehabilitation *)
Čunovo reservoir-Gabčíkovo barrage and locks	• maintaining a certain impoundment for navigation in the power canal; • complete removal of the weir at Čunovo; • removal of the connecting upstream dam of the power canal • completion of Dunakiliti weir with possible technical changes for operation at lower reservoir levels; • technical changes at the Gabčíkovo systems of locks for operation at lower water levels • alterations of the remedial supply system for the floodplain	• filling of the gravel pits in the channel near Bratislava with surplus dam material; • narrowing the channel to its former size with dam material or from gravel pits outside of the active floodplain; • restructuring of the riverbed in the unbacked reach by natural scouring and deposition of sediments; • reshaping parts of the floodplain; • rehabilitation of the floodplain ecosystem by ecological succession under the impacts of natural flow dynamics	1-2 yrs. 1-2 yrs. 5-10 yrs. 1-2 yrs. 50-200 yrs.
Old Danube	• continuous supply with gravel to prevent degradation of the riverbed or other adequate measures to prevent degradation of the bed	• compensational filling of the scoured riverbed; • opening of side arm closures; • removal of bank protections; • remedial measures for restoring riverbed structures; • rehabilitation of riverbed habitats	1-2 yrs. 1-2 yrs. 1-2 yrs. 1-2 yrs. 5-10 yrs.
Szigetköz floodplain		• compensational filling of the scoured riverbed; • opening of side arm closures; • rehabilitation of damaged floodplain habitats under the impacts of natural flow dynamics	1-2 yrs. 1-2 yrs. 20-50 yrs.

*)Based on general time scales for the morphological rehabilitation of river systems [22]

Major damage has been done to the river and floodplain system in the Čunovo reservoir stretching up to Bratislava. The amount of gravel to be moved for replacing the dredged volumes in this reach can not be estimated. The development of a secondary floodplain by ecological succession will take decades, and an artificial floodplain topography has to be provided in the first place.

Since this scenario suffers from numerous restrictions that are imposed by navigation in the Old Danube, a second alternative will be briefly discussed below.

4.2 Usage of the Power Canal for Navigation Only, Removal of All Unnecessary Structures and Return to Pre-Dam Conditions

This specific scenario needs studies on technical feasibility. A certain reservoir level has to be maintained in order to use the power canal for navigation. From an ecological point of view it would be desirable to lower the impounded waterlevel to the minimum depth required for navigation.

For this reason it would be favourable to use the Dunakiliti weir instead of the present Čunovo construction. In any case the total bedload would be retained in the impoundment and has to be compensated for (as is being tested at the Austrian Danube downstream of Vienna and successfully carried out at the Upper Rhine downstream of Iffezheim). Some remedial measures have to be implemented to sustain the floodplain ecosystem which partially would be beyond the dikes.

This scenario requires a basic feasibility evaluation which cannot be done in this brief appraisal.

5. Hydrological Changes to be Expected with the Implementation and Operation of the G/N Project (1977 Treaty)

5.1 Dunakiliti-Hrušov Reservoir

Construction

The construction of the Hrušov-Dunakiliti reservoir destroyed about one third of the Žitný Ostrov floodplain (as did Variant C). Through the impoundment of 200 million m^3 of water the previous river ecosystem characterised by numerous islands, side branches and wetlands would have been lost. The average flow velocity of the former river would be reduced from 2.0 m/s to about 0.3 m/s [20]. The waterlevel at Bratislava has risen by 1-2 m since the closure of the Danube, reaching its original level before degradation of the bed [19].

Operation

When operating for peak energy production the reservoir level would have fluctuated with one or two daily peaks by about one metre (*Figure 11*, upper diagram). These daily waterlevel fluctuations would result in a devastated riparian strip of land of several metres as will be described below for the Nagymaros reservoir. The backwater reach was expected to vary between rkm 1858/60 and rkm 1870/72 [11]. 90 % of the bedload was expected to be deposited at this place and should be dredged regularly; 77 % of the suspended load was expected to be deposited in the reservoir, and its life time was calculated to be about 60 years [11].

5.2 OLD DANUBE

The discharge regime of the Danube between Dunakiliti (rkm 1842) and Palkovičovo (rkm 1811) would be completely changed with the implementation of the Original Project (and was changed indeed with the operation of Variant C).

Table 5 shows the main hydrological and morphological impacts that could be anticipated in the Old Danube with the implementation of the Original Project. During 350 days of the year, 50 m^3/s would be released from the reservoir. It was vaguely agreed in the joint Contractual Plan that 200 m^3/s would be discharged in the old riverbed 'in case of need' during the vegetation period [18]. Any waterlevel fluctuations would be limited to 12 days of the year on average, when the inflow into the reservoir exceeds 4,000 m^3/s. Such an artificial discharge regime generates a low-flow bed suitable for the prevailing discharge of 50-200 m^3/s with a characteristic pattern of fluvial habitats. Once a year or every other year a larger flood would destroy all fluvial and riparian habitats that had developed and the cycle of restructuring would start again. Regular maintenance to restore the flood discharge capacity of the channel would have the same effect.

According to the project plan the low-flow waterlevel--that had been lowered since 1967/68 through excessive channel dredging--would drop by 2.50-3.00 m below the regulation waterlevel [23]. Flow velocities were reduced to less than one metre [20]. In times of high discharges (but still less than 4,000 m^3/s) and during daily peak energy production with a release of 4,000-5,200 m^3/s at Gabčíkovo (*Figure 11/12, Annex 6*) there would be a backwater reach up to rkm 1823 in the Old Danube [23].

The sharp rise of discharges at the commencement of peak energy production would result in a rise of waterlevels at the sill of Palkovičovo (rkm 1811) of about 4 metres depending on the peaking mode (*Figure 11/12, Annex A-8*) [24]. In this case the flow direction would reverse and the water would flow upstream to the end of the backwater one or two times daily. Thus there would be two different sections in the Old Danube: an upper part from Dunakiliti barrage to Lipót (rkm 1823) with no waterlevel fluctuations at all except for a few days per year, and a lower part with large fluctuations every day damaging fluvial and riparian habitats, as will be pointed out below with regard to the Nagymaros reservoir.

Since all bedload will be trapped in the Dunakiliti-Hrušov reservoir eventual degradation of the bed should be expected even with few flood discharges per year. Studies predicted up to 3 m scouring in some sections after 50 years of operation entailing a further drop of the prevailing 50 m^3/s waterlevels [36]. *Figure 10* shows the deformation of the riverbed simulated for a 50-year period of operation [36]. The calculation was presumably done on the basis of Variant C, not considering backwater effects from the power canal in connection with peak energy production.

Altogether fluvial and riparian habitats would either be destroyed or would suffer from instability caused by the imposed discharge regime. Large daily waterlevel fluctuations in the lower part of the Old Danube contrast a rather steady waterlevel regime in the upper part of the reach. The degradation of the riverbed previously caused by excessive upstream channel dredging would continue due to the total retention of the bedload at the Dunakiliti barrage.

Table 5: *Anticipated hydrological changes in the Old Danube following the implementation and operation of G/N Project (1977 Treaty)*

OLD DANUBE			
	short term (5-10 yrs.)	**medium term (10-20 yrs.)**	**long term (20-50 yrs.)**
Discharges	• 50/200 m^3/s should be released from the reservoir into the Old Danube; higher releases only at discharges exceeding 4,000 m^3/s (about 12 d/yr.); • daily flow reversal for a few kilometres upstream of the conjunction with the power canal caused by peaking operation		
Waterlevels	• sudden drop of waterlevels by several metres	• gradual lowering of the waterlevels in eroding reaches (see below)	
Flow velocities	• reduction of flow velocities from 1.2-2.0 m/s to less than 1.0 m/s at 50 m^3/s [20]; • reduced flow velocities in the backwater reach of the power canal conjunction		• minor variations of flow velocities with changes of bed morphology
Fluctuations of discharges & waterlevels	• exclusion of all discharge and waterlevel fluctuations for ca. 350 d/yr. except for the reach influenced by backwater where daily fluctuations of about 4 metres would occur (*Figure 11/12, Annex A-8*) • sudden rise and fall of discharges and flow velocities in case of flood discharge release		
Riverbed stability	• during a flow of 50/200 m^3/s, the Danube channel would eventually form an adequate low-flow bed; • high floods in the first years would yield first riverbed deformations	after 20 yrs. operation significant scouring was predicted with riverbed degradation up to 1.5 m caused by total retention of bedload in the Hrušov-Dunakiliti reservoir [5]	after 50 yrs. operation scouring was predicted to reach 3 m in some sections leading to a severe drop of the prevailing waterlevels at 50/200 m^3/s (*Figure 10*) [36]
Riverbed structures	• gradual formation of a low-flow bed; silting up of reaches with smaller velocities; • spreading of vegetation in the channel outside the low-flow bed	• total destruction of the low-flow bed structures at higher flood discharges or by maintenance with partial erosion of silted reaches; • growth of woody vegetation on higher elevations in the channel presumably causing a narrowing of the discharge cross-section (with the threat of further bed erosion), if not removed by regular maintenance	
Riparian structures (ecotones)	• following the drop of the waterlevel of several metres the banks of the old channel would become unstable and collapse partially and locally	• the formation of the low-flow bed would create a new riparian zone which would periodically be destroyed at higher flood discharges; thus the riparian habitats would suffer from instability caused by an unnatural difference between average and flood discharges	

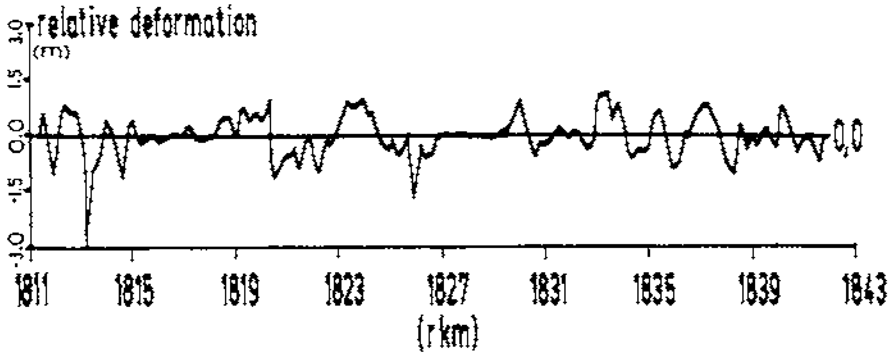


***Figure 10:** Anticipated relative change of the riverbed after 50 yrs. of operation; after [36]*

5.3 SZIGETKÖZ FLOODPLAIN

The fate of the Szigetköz wetlands generally depends on the frequency, magnitude and duration of inundations and the height and fluctuations of the groundwater table. *Table 6* indicates the major hydrological impacts of the Original Project that could be anticipated on the Szigetköz floodplain. The discharges that would be released in the side branch systems on both sides of the Old Danube could by no means compensate for the drop of groundwater tables or for the loss of frequent flushing and inundation that occurred before the 1960s.

The alluvial cone of the Szigetköz featuring a riverbed on higher elevations than the surrounding floodplain, was responsible for the unusual groundwater recharge from the river even at low-flow conditions. With the drop of the waterlevel far below the previous minimum, the system was reversed: since the diversion of the Danube, groundwater flows towards the Danube. Eventual clogging of most of the side branches might prevent the recharge necessary for sustaining the groundwater table in larger areas of the floodplain.

Due to the distribution of flows between the power canal and the Old Danube, natural flow into the side branches and the floodplain would occur only at discharges much greater than 4,000 m^3/s. There would be a flow in some side branches at 6,500-7,500 m^3/s and in almost all during inundation of the floodplain at 7,500 and 8,500 m^3/s corresponding to a 5-10-year flood and a 10-25-year flood respectively (*Annex A-9*) [21]. Waterlevel fluctuations influencing groundwater recharge and quality would be limited to an average of 10-12 days per year but not necessarily consecutive days.. Thus significant contribution to groundwater recharge by rare but long lasting floods would not occur anymore.

Floodplain habitats depending on the height and fluctuation of the groundwater table as well as on the frequency, height and duration of inundations would for the same reason be governed by the prevailing low-flow and low groundwater table conditions. In general, not the rare flood events are essential for floodplain habitat conditions in river ecosystems (except for morphological changes), but rather the frequently occurring discharges fluctuating from average low flow to the average annual flood.

The desiccation of the Szigetköz floodplain after implementation of the Original Project (1977 Treaty), would eventually alter the previous wetlands into dry habitats similar to large floodplain areas of the Upper Rhine near Breisach.

***Table 6**: Anticipated hydrological changes in the Szigetköz floodplain following the implementation and operation of G/N Project (1977 Treaty)*

SZIGETKÖZ FLOODPLAIN			
	short term (5-10 yrs.)	**medium term (10-20 yrs.)**	**long term (20-50 yrs.)**
Discharges	• constant supply for side branch systems: 15/25 m^3/s on the Hungarian side • flow in some side branches from Old Danube every 5-10 yrs., • flow in almost all side branches every 10-25 yrs. with complete inundation of floodplain		
Groundwater table	• in the vicinity of the Old Danube drop of the groundwater table to the prevailing flow level of 50 m^3/s • insufficient recharge of the groundwater by the side-arm system • gradual decline of groundwater table towards the Danube	• clogging of most side branch reaches could be expected because regular supply discharges would not be able to prevent sedimentation of fines in large areas; • effective flushing would occur only every 10-20 yrs. with higher flood dis- charges	• eventual scouring of the Old Danube riverbed would cause further drop of the groundwater table
Fluctuations of the groundwater table	• exclusion of all groundwater table fluctuations for ca. 350 d/yr.; • the duration of the flood discharges in the side branches will be too short to result in significant fluctuations of the groundwater table		
Floodplain morphology	• until 1967/68 flushing of side arms with scouring, deposition and lateral movement occurred several times a year which would be hence limited to rare flood events; • deposition of at least two thirds of the incoming suspended sediment load in the Hrušov-Dunakiliti reservoir would considerably reduce the sediment input into the floodplain		
Floodplain habitats	desiccation of almost all wetlands in the floodplain within a few years except for narrow riparian strips along those side arms that are supplied with constant discharge; stagnancy of the evolution of all habitats due to missing dynamics of waterflow and sediment input		

5.4 NAGYMAROS RESERVOIR

Construction

The Nagymaros reservoir would extend from the Gabčíkovo power station (rkm 1811+8) to Nagymaros (rkm 1696). During peak power operations at Gabčíkovo its backwater would reach up to rkm 1823 in the Old Danube, more than 20 km upstream of the Malý Dunaj (= Váh) and several kilometres upstream of the rivers Hron and Ipoly. According to the project plan, channel dredging should lower the waterlevel at a discharge of 2,300 m^3/s from Ásványráró (rkm 1816) to Gönyü (rkm 1791) by 2.00 m at Palkovičovo (rkm 1811), by 1.10 m at Medvedov (rkm 1806), and by 0.70 m at Nagybajcs (rkm 1802) [12]. Actually, the low-flow waterlevel at Gönyű dropped by 1.50 m caused by dredging beyond the demands of the project [7]. This again gives evidence that deliberate over excavation of gravel for industrial purposes was carried out anticipating the realisation of the GNS.

The construction of the barrage would cause the inundation of about two dozen islands situated between Gönyű (rkm 1791) and Nagymaros. Most of the riparian zones of these islands rendering valuable ecotones were left unprotected. In addition, established riparian zones of 300-350 km length of several tributaries and of the Danube itself would be inundated. The flow velocities (without peaking mode) would be considerably smaller than before, thus the aquatic habitats would thoroughly alter their physical properties.

Operation

Several peaking modes were envisaged in the 1977 Treaty (*Figures 11/12, Annex 6/7*). Depending on the average flow, certain peaking modes were established as operation rules for the Gabčíkovo power plant. In 1977 the operation rules were not definitely fixed but several alternatives with different rates of change and peak discharges were discussed. For instance, at an average flow of 900 m^3/s, there would be no release at Gabčíkovo for 18.5 hours per day (Nagymaros would still release 1,000 m^3/s using its reservoir capacity and discharges from tributaries). Within half an hour the discharge would rise to 3,630 m^3/s with an acceleration of 120 m^3/s per minute (*Annex A-8*). Within 4.5 hours the maximum discharge up to 5,110 m^3/s would be released followed by a sharp descent to 0 within half an hour at a rate of 170 m^3/s per minute. The alternative peaking modes for higher average discharges would operate with two peaks per day. *Figure 11* shows daily waterlevel fluctuations in the Hrušov-Dunakiliti reservoir (a) and the Nagymaros reservoir (c) for the peaking mode 1500/700, which means 1,500 m^3/s inflow into the upper reservoir produces 700 MW. The operation rules for the Gabčíkovo and Nagymaros power plant are given in (b) and (d) respectively.

The daily fluctuations of discharges, flow velocities and waterlevels as documented in *Table 7* are detrimental to the whole ecosystem in many respects: The riverbed would be endangered by erosion in certain reaches as was concluded in a study [26]. Although the numerical simulation carried out could only identify the areas prone to erosion or sedimentation, the authors assumed that the prevailing erosion would cease after 10 or 20 cm of depth due to armouring. This assumption is mainly based on representative grain-size distributions of this reach showing fractions of coarse grains that were transported by large historical floods exceeding maximum flow velocities caused by peaking.

The sudden waterlevel fall of nearly 5 cm/min at the upstream end of the reservoir with a difference in waterlevel of about 4.50 m requires carefully protected banks covered with rip-rap bedded upon sub-layers of filter material.

The ever changing flow conditions and waterlevels are very unfavourable to all aquatic and riparian habitats in addition to the unsuitable substrate for riparian vegetation. The most valuable habitats of large rivers are located in the riparian zone at the transition from water to land. The riparian zone exposed to the daily waterlevel fluctuations would stay without vegetation and lose its high ranking ecological value.

The aquatic habitats would also suffer from the ever changing flow conditions. The substrates would never be stable; suspended sediments would settle in the "low flow" periods of the peaking mode and would be flushed away during the "flood flow". The aquatic fauna would be significantly reduced in diversity and abundance, even compared to reservoir conditions without peaking operation.

Altogether the construction of the Nagymaros Barrage and the peak operation would destroy valuable habitats and generate very unfavourable living conditions for the aquatic fauna in the reservoir. The daily fluctuations of waterlevels by several metres would yield a devastated strip of riverbank instead of valuable riparian habitats.

***Table 7**: Anticipated hydrological changes in the Nagymaros reservoir following the implementation and operation of G/N Project (1977 Treaty)*

NAGYMAROS RESERVOIR			
	short term (5-10 yrs.)	**medium term (10-20 yrs.)**	**long term (20-50 yrs.)**
Discharges	• daily fluctuations from 1,000 m^3/s to more than 5,000 m^3/s depending on the mode of peak operation (*Figures 11/12, Annex A-6*); • with "peaking option 900" no release of water at Gabčíkovo for 18.5 hrs.		
Waterlevels	• at 2,300 m^3/s compared to pre-dam conditions (without peaking): +6 m at Nagymaros, ±0 at Vének, -2 m at Palkovičovo (dredging) [12]		
Flow velocities	• v_{min}/v_{max} flow velocities through peak operation (mode 2000/Annex A-8): 0.00/0.95 m/s at tailwater Gabčíkovo (rkm 1819.45), 0.02/1.94 m/s at Palkovičovo (rkm 1811.05), 0.28/1.59 m/s at the mouth of Mosoni Danube (rkm 1793.3), 0.32/1.19 m/s at Komárno (rkm 1768.3) [24]		
Fluctuations of discharges & waterlevels	• about 4,000 m^3/s daily fluctuations of discharges; • daily waterlevel fluctuations through peak operation (mode 2000/Annex A-8): 4.64 m at tailwater Gabčíkovo (rkm 1819.45), 4.38 m at Palkovičovo (rkm 1801.05), 2.65 m at the mouth of Mosoni Danube (rkm 1793.3), 1.06 m at Komárno (rkm 1768.3) [24]		
Riverbed stability	• rather high flow velocity fluctuations with peak operation would cause general scouring in the entire reach except for the last 20 km upstream of Nagymaros [26]	• according to [26] eventual "armouring" of the riverbed would be expected by selective transport of smaller grain sizes leaving a protective layer of coarser gravel on the bottom of the riverbed; therefore scouring was expected to cease after 0.1-0.2 m depth	
Riverbed structures	• all islands between Gönyű (rkm 1791) and Nagymaros would be lost with the rise of the waterlevel; • all other aquatic habitats would experience thorough changes in current, deposition and scouring; • many riverbed structures were already destroyed by channel dredging	• bank stability would be highly endangered by the sharp rise and fall of waterlevels requiring rip-rap protection with filter layers. • eventually new riverbed structures would evolve according to the governing hydraulic regime caused by peak operation; nevertheless the hence prevailing conditions would be unfavourable to all aquatic habitats; the daily fluctuations between low-flow conditions and high flood flows--naturally occurring on less than 5 d/yr.--impose instability on all riverine habitats and must be regarded as a major detrimental impact of peak operation;	
Riparian structures (ecotones)	• with the permanent inundation of numerous large islands, valuable ecotones would be lost and all riparian structures between Gönyű and Nagymaros would be inundated as well	• daily waterlevel fluctuations up to 4.38 m at Palkovičovo (rkm 1811) and 1.06 m at Komárno (rkm 1768) would produce a devastated strip of land of several metres width (about 3-12 m at slopes of 1:3); no vegetation growth would be possible in this zone; • the riparian habitats that are highly valuable in large rivers would not exist any more	

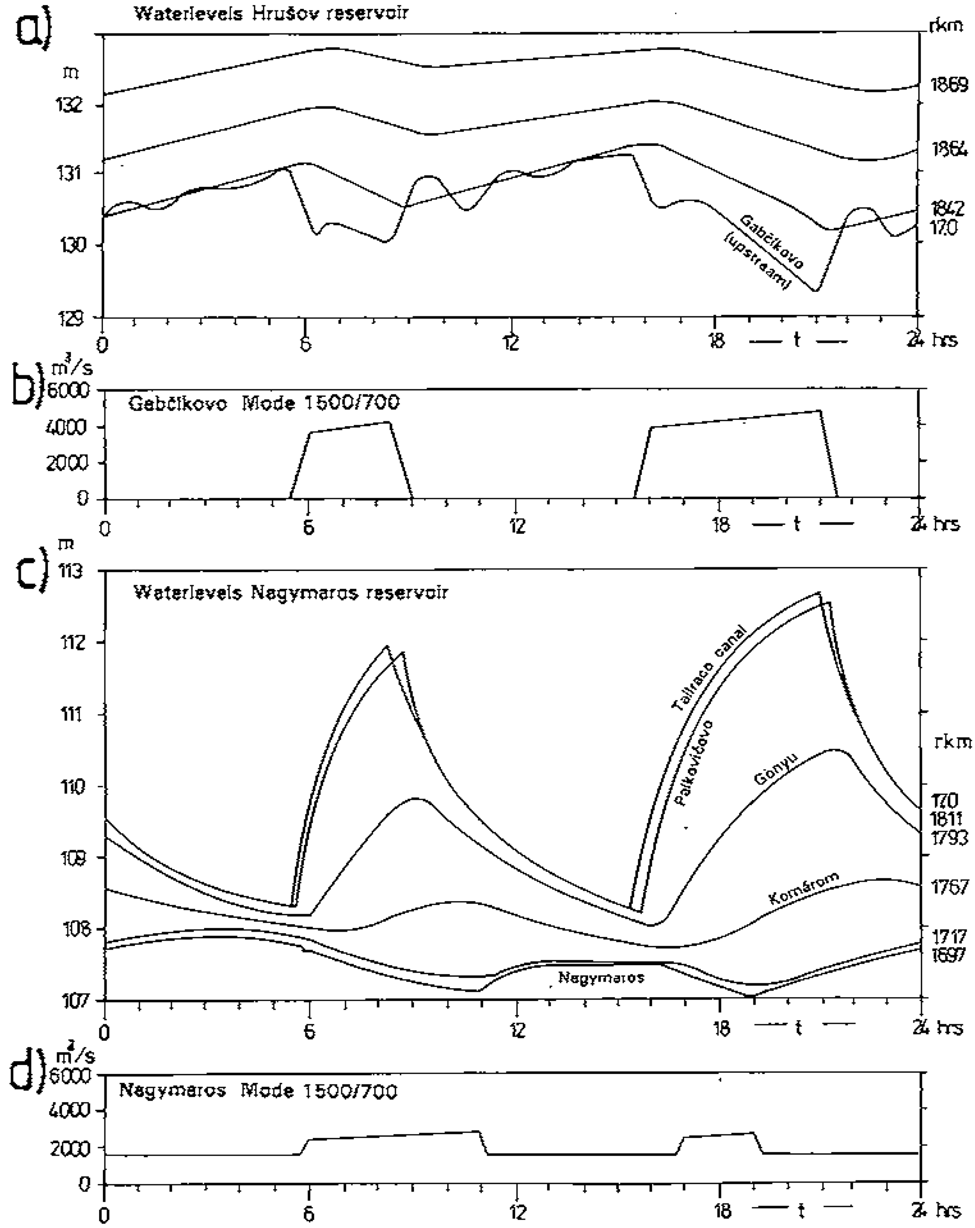


Figure 11: *Peak operation and daily waterlevel fluctuations* ***(mode 1500/700)***: ***a)*** *Daily waterlevel fluctuations at different cross-sections of the headrace canal and the Hrušov-Dunakiliti reservoir,* ***b)*** *Discharge release at Gabčikovo,* ***c)*** *Daily waterlevel fluctuations at different cross-sections of the tailrace canal and the Nagymaros reservoir,* ***d)*** *Discharge release at Nagymaros*

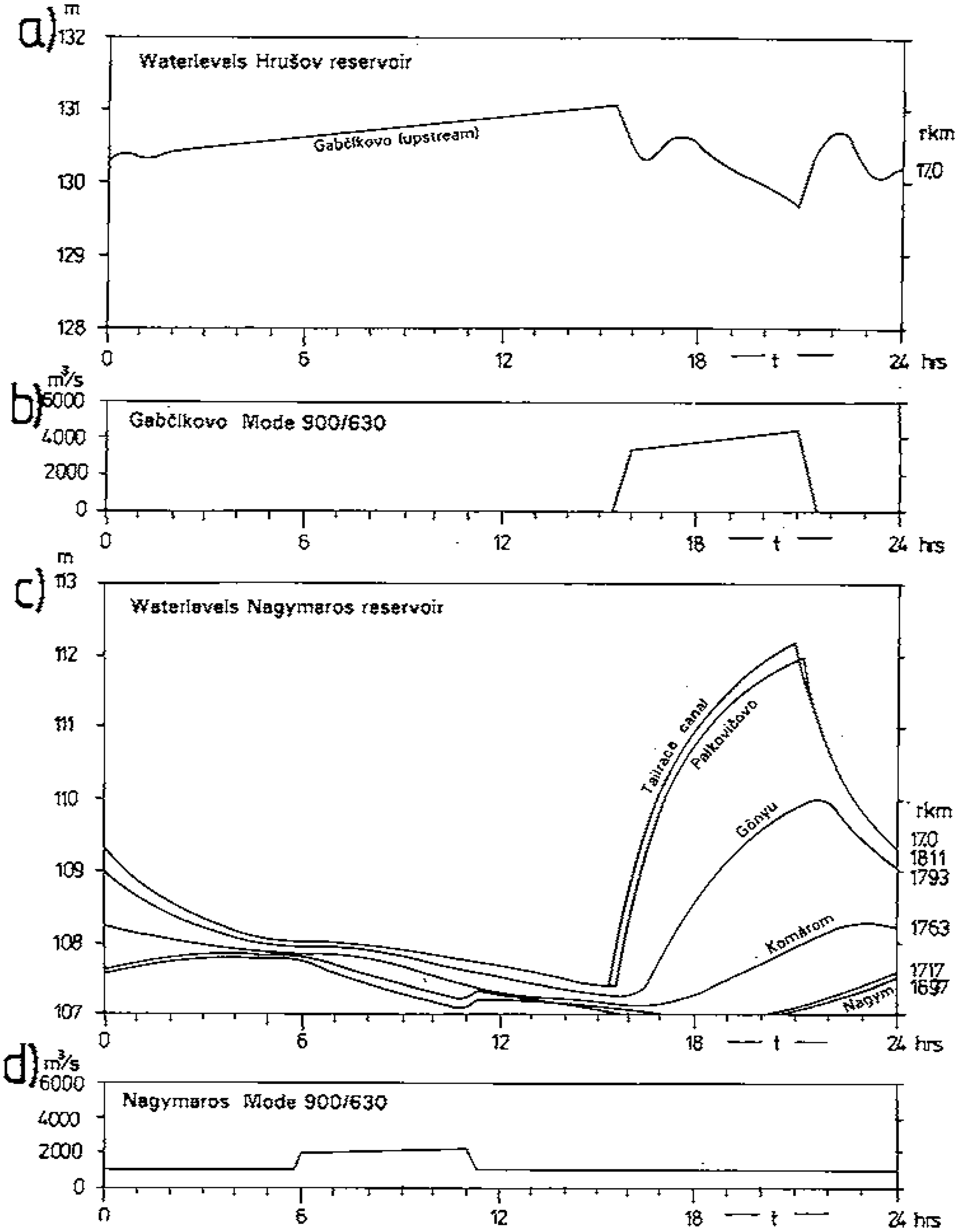


*Figure 12: Peak operation and daily waterlevel fluctuations (**mode 900/630**): **a)** Daily waterlevel fluctuations at rkm 17.0 of the headrace canal at Gabčíkovo, **b)** Discharge release at Gabčíkovo, c) Daily waterlevel fluctuations at different cross-sections of the tailrace canal and the Nagymaros reservoir, **d)** Discharge release at Nagymaros*

5.5 Downstream Section of Nagymaros

According to the project plan channel dredging along Szentendre island from Nagymaros to rkm 1656 should lower the low-flow waterlevels by 0.60-1.20 m in order to increase the head of the power plant [12], [27]. Between 1970 and 1979 about 20 million m^3 of gravel were already excavated from both branches mainly for industrial purposes before dredging was stopped because of problems with the bank filtered wells of the waterworks of the city of Budapest.

The Nagymaros power plant was also supposed to operate on a peaking mode. *Figures 11/12* and *Annex 7* show alternative modes of operation. As opposed to the Gabčíkovo operation mode, there would always be a minimum discharge of at least 1,000 m^3/s. For instance at mode 2000, the maximum difference in discharge would still be 1,300 m^3/s at a maximum descent rate of -102 m^3/s per minute (*Annex A-8*). The maximum decrease of discharge would then correspond to a waterlevel difference of 2 m at the gauge station of Budapest.

Although the daily discharge and waterlevel fluctuations would be smaller than those in the Nagymaros reservoir, the detrimental impacts on aquatic and riparian habitats would be generally the same.

Peak operation may also result in deformation of the riverbed. Preliminary results of a transport model applied by VITUKI indicate that both accumulation and degradation may be expected in different sections of the river branches along Szentendre island. Because of the danger of riverbed degradation there is no peak operation at the last station of other river barrage systems. For instance at the Rhine, EdF (Électricité de France) operates the 10 water power stations from Kembs to Iffezheim at a moderate peaking mode (maximum increase of discharge above natural flow is 300 m^3/s). Although the peaking of the discharge is one magnitude smaller than the one at Nagymaros, no peaking is allowed at the last barrage of Iffezheim towards the free flowing river. The reservoir of Iffezheim is merely used for compensation.

6. Hydrological Changes to be Expected with the Implementation of Variant C

In this chapter only those impacts will be briefly analysed which are different from the ones described above.

6.1 Čunovo Reservoir

After the construction of the temporary barrage system at Čunovo (rkm 1851.75), only a part of the original reservoir has een impounded. There is no information on the daily operation mode of Gabčíkovo, presumably the system is working as a run-of-river power plant without peaking operation. Thus, there are only minor waterlevel changes in the reservoir on a daily basis. Of course, the operation of the Gabčíkovo Barrage System as a normal low-head hydropower station would not require an operational reservoir at all, however, it requires a barrage at Čunovo in order to increase the useful head for power generation..

6.2 Old Danube

Until December 1993 the discharges, that were released in the Old Danube since the damming of the river, were kept on a base level of about 200-250 m^3/s, with an increase to 350 m^3/s in the vegetation period. Floods flowing into the reservoir were released into the Old Danube above a threshold of about 3,000 m^3/s (*Figure 13*). At the beginning of 1994 the artificial discharge regime of the Old Danube was obviously altered. The base level was kept to about 200 m^3/s without increase in the vegetation period. Although no monitoring data of the riverbed structures were available, it can be expected that the riverbed will eventually develop structures adapted to the base rate of flow and to a certain range of flood flows. Major changes in bed morphology could be expected at rare flood events.

Table 8: *Hydrological changes in the Old Danube after implementation and operation of Variant C*

OLD DANUBE	
Discharges	• base level flow releases from Čunovo (based on daily measurements at river gauge Rajka): November 1992-March 1993: 200-250 m^3/s April/May 1993: about 300 m^3/s June/July 1993: 300-350 m^3/s August/December 1993: 250-300 m^3/s January/September 1994: about 200 m^3/s • flood discharge exceeding 3,000 m^3/s were released in the old riverbed.
Waterlevels	• sudden drop of water levels by 2-3 m [19]
Flow velocities	• reduction of flow velocities from the former 1.2-2.0 m/s to about 1.0 m/s [20]; • reduced flow velocities in the tailwater of the power canal conjunction
Fluctuations of discharges & waterlevels	• 6 flood discharges up to 2,430 m^3/s were released until December 1993; one flood discharge amounting to 1,960 m^3/s was released until September 1994. • unnaturally sudden rise and drop of discharges and waterlevel during flood release
Riverbed stability	• bank failures caused by the sudden drop of waterlevels after damming the Danube; • gradual degradation of the riverbed can be expected as predicted for the Original Plan (*Table 5*) [5]
Riverbed structures	• gradual formation of a riverbed adapted to flows of about 300 m^3/s; destruction of riverbed structures could be expected at rare flood events rapidly released at Čunovo.
Riparian structures (ecotones)	• formation of a new riparian zone which is better adapted to flood discharges than it would be according to the Original Project

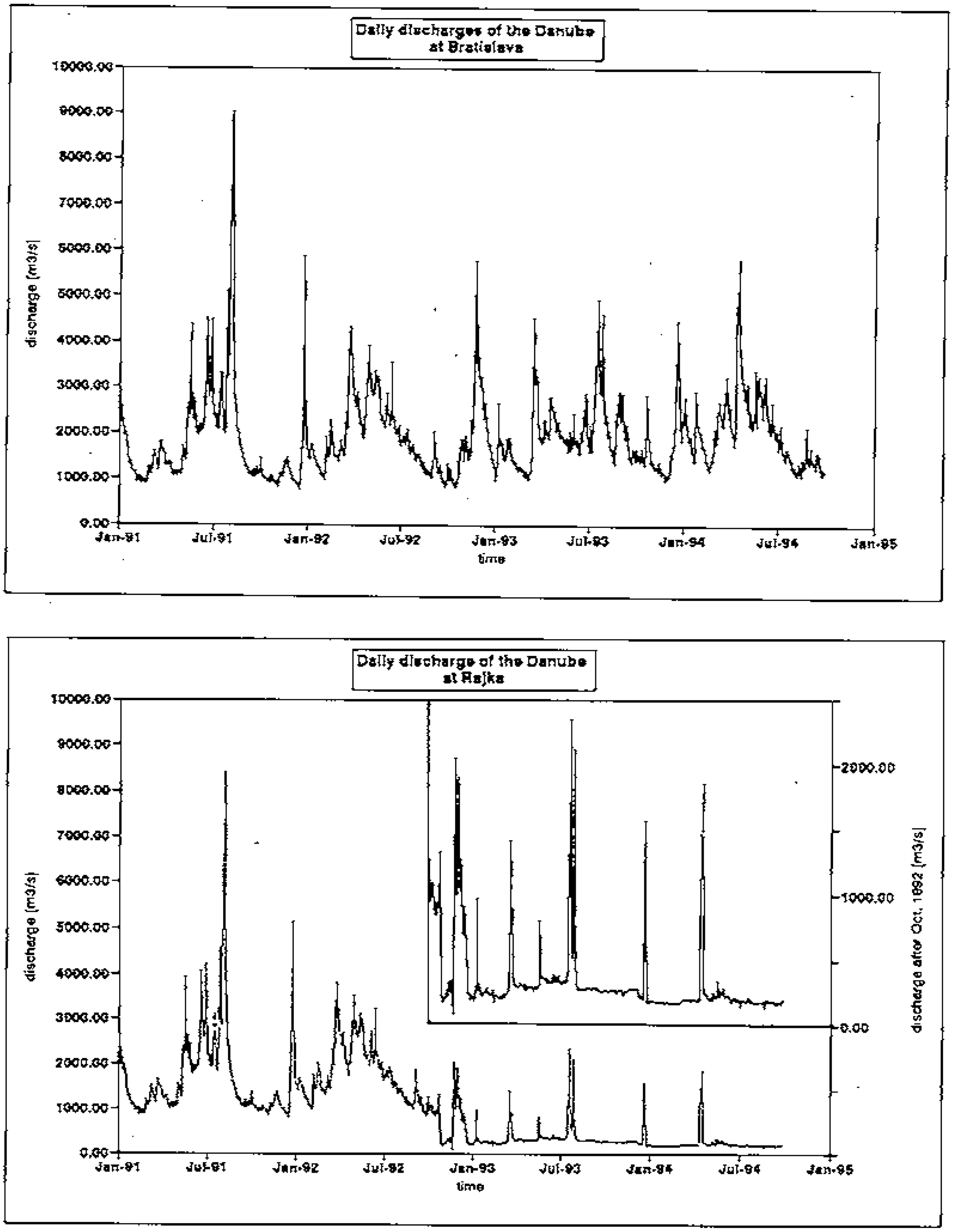


Figure 13: Hydrographs of the gauge stations Bratislava and Rajka

Although 1/10-1/5 of the discharge of the river is directed to the Old Danube, the actual, everyday waterlevels in the old riverbed are insufficient for the existence of floodplain habitats. In addition, similar degradation of the riverbed in a medium and long term has to be expected due to the total retention of the bedload in the reservoir.

6.3 SZIGETKÖZ FLOODPLAIN

The implementation of Variant C with all remedial measures will not improve the situation of the Szigetköz floodplain, compared to the detrimental impacts anticipated in the Original Project. The base discharge of about 250 m^3/s resulted in a considerable drop of the groundwater table adjacent to the river. In addition, the flood stages do not last long enough for efficient groundwater recharge.

On the Hungarian side, the desiccation that started in the mid sixties of this century with the overdredging of the riverbed, will eventually result in a total loss of the wetlands. On the Slovak side, the impoundment of the side branch system will change the riverine wetland character thoroughly.

Table 9: Hydrological changes in the Szigetköz floodplain after implementation and operation of Variant C

SZIGETKÖZ FLOODPLAIN	
Discharges	• constant supply for the side branch systems: 2-10 m^3/s on the Hungarian side • flow in a few side branches from the Danube when releasing 1,800-2,500 m^3/s at Čunovo weir gates; • flow in some side branches at a release of 2,500-3,500 m^3/s; • flow in almost all side branches at a release of 3,500-4,500 m^3/s [21]
Groundwater table	• drop of the groundwater table near the Danube to the 250 m^3/s water level; • insufficient recharge of the groundwater by the side arm system at least on the Hungarian side; • on the Slovak side a higher groundwater table is maintained by the implementation of a cascade system in the side branches; • clogging has to be expected in large areas on both sides
Fluctuations of the groundwater table	• the duration of the flood discharges in the side branches will be too short to result in significant fluctuations of the groundwater table
Floodplain morphology	• until 1967/68 flushing of side arms with more or less scouring, deposition and lateral movement occurred several times a year; this is now limited to rare events with flood discharges shared between the power canal and the Old Danube; • deposition of a considerable part of the incoming suspended sediment load in the Čunovo reservoir reduces the sediment input into the floodplain
Floodplain habitats	• desiccation of almost all wetlands in the Hungarian Szigetköz floodplain within a short period of time; • only narrow riparian strips along those side arms that are supplied with constant discharge will keep their wetland character; • on the Slovak side the previous riverine wetland habitats will lose their character due to missing relevant fluctuation of the waterlevel in the impounded side branch system; • stagnancy in the evolution of all habitats due to missing dynamics of waterflow, waterlevels and sediment input

References

[1] Stančík, A., Jovanovič, S. et. al. (1988) "Hydrology of the River Danube", [German, English, French, Russian], Publishing House Príroda, Bratislava, 1-272.

[2] Jakubec, L. (1993) "The reason for drying up of the upper Žitný Ostrov and the extinction of the branch system of the Danube" [In Slovak]. Proc. Int. Conf. 'The Gabčíkovo-Nagymaros System - Intentions and Reality', Bratislava, The Slovak Republic, Sep. 7-9, 1993, pp. 237-244.

[3] Zorkóczy, Z. (1969) "A Felsö-Duna Szabályozása", [The regulation of the Upper Danube. In Hungarian], Vízügyi Közlemények (1), pp. 54-91.

[4] Raabe, W. (1968) Wasserbau und Landschaftspflege am Oberrhein. [River engineering and landscape management. In German]. Schriftenreihe des Deutschen Rates für Landschaftspflege, H. 10, pp. 34-41, Bonn.

[5] Bačik, J., Topolska, J. & M. Lukac (1992) "Die Vorhersage der morphologischen Änderungen im alten Donauflußbett nach der Fertigstellung des Wasserkraftwerkes Gabčíkovo" [Prognosis of morphological changes in the old channel of the Danube river after the completion of the Gabčíkovo Hydroelectric Power plant. In German]. XVI. Konferenz der Donauländer über hydrologische Vorhersagen und hydrologisch-wasserwirtschaftliche Grundlagen, Kelheim, Mai 1992, pp. 599-606.

[6] Mucha, I. "Report on Temporary Water Management Regime - Independent Scenario", November 28, 1993, Bratislava.

[7] VITUKI (1993) "Hidrológiai és medermorfológiai vizsgálatok a Duna felsö szakaszán és a Szigetközi ágrendszerben. Összefoglaló jelentés". [Hydrological and morphological investigations at the upper Danube reach and in the side branch system of the Szigetköz. Summary report. In Hungarian and English]. VITUKI Hydrological Institute, March 1993, Budapest.

[8] VITUKI (1993) - as above - Appendix 1: "Medermorfológia". [Morphology of the riverbed. In Hungarian and English].

[9] VITUKI (1993) - as above - Appendix 2: "Mederanyag- és rétegvizsgálatok". [Investigations on river sediments and sediment layers. In Hungarian].

[10] VITUKI (1993) - as above - Appendix 3: "Víz- és hordalékjárás". [Bedload transport and water levels. In Hungarian].

[11] VITUKI (1985) "Sediment Regime of the Danube Stretch affected by the Gabčíkovo-Nagymaros Hydroelectric Development Project" (Informative collection of data).

[12] Hydroconsult Bratislava & Viziterv Budapest (1977) Project plan # 0-2-2

[13] Výskumný ústav Vodného Hospodárstva Bratislava (1991) "Vplyv Prevádzky Vodného Diela Gabčikovo Na Prírodné Prostredie". [Impacts of the Gabčíkovo power station on the environment. In Slovak]. Final Report/Summary, authors: J. Lehocký, M. Bačík, J. Kališ, J. Lindtner, J. Szolgay, B-P_-DOD-A56.00.00, June 1991, Bratislava.

[14] "Schwebstoff- und Geschieberegime der Donau" [Suspended-load and bed-load regime of the Danube; in German and Russian]. Die Donau und ihr Einzugsgebiet - eine hydrologische Monographie, Folgeband I, Regionale Zusammenarbeit der Donauländer im Rahmen des Intern. Programms der UNESCO, 1993, 1-83.

[15] Vodohospodárska výstavba (1993) "The Gabčíkovo project: Saving the Danube's inland delta". Bratislava.

[16] Project report of the original plan (1977) Summary # 0-3-1.2 [in Hungarian]

[17] Kresser, W. (1986) "Vorhersage von Flußbettänderungen in der österreichischen Donaustrecke" [Forecast of morphological changes in the Austrian Danube reach. In German]. XIII. Conference of the Danube Countries on Hydrological Forecasts, Belgrad 16.-19.9. 1986, pp. 191-198.

[18] Joint Contractual Plan (1977) Summary description, 0-1.

[19] CEC Working Group of Monitoring and Water Management Experts for the Gabčíkovo System of Locks. DATA REPORT. November 2, 1993

[20] CEC Working Group of Monitoring an Water Management Experts for the Gabčíkovo Systems of Locks. REPORT ON TEMPORARY WATER MANAGEMENT REGIME. December 1, 1993

[21] CEC Working Group of Independent Experts on Variant C of the Gabčikovo-Nagymaros Project: Working Group Report. November 23, 1992, Budapest.

[22] Kern, K. (1994) "Grundlagen naturnaher Gewässergestaltung: Geomorphologische Entwicklung von Fließgewässern" [Principles of environmental river engineering: Geomorphological evolution of river systems. In German]. 1-256, Springer: Heidelberg, Berlin, New York.

[23] Hydroconsult Bratislava & Viziterv Budapest (1977) Project plan # 0-3-1.7.4

[24] Karadi, G.M. & Nagy, I.V. (1993) "Optimal Operation of the Gabčíkovo-Nagymaros Hydropower System". Proc. Int. Conf. 'The Gabčikovo-Nagymaros System - Intentions and Reality', Bratislava, The Slovak Republic, Sep. 7-9, 1993, pp. 51-63

[25] "Die Donau und ihr Einzugsgebiet - eine hydrologische Monographie" [The Danube and its basin - a Hydrological Monograph. In German], Teil 1 Texte, Regionale Zusammenarbeit der Donauländer, 1-377, 1986

[26] Bognár, S., Rákóczi, L. (1988) "Prediction of scour and deposition in a river reach between two intermittently operating hydroelectric power plants" Int. Conf. on Fluvial Hydraulics, 30 May - 3 June 1988, 237-242, Budapest.

[27] Hydroconsult Bratislava & Viziterv Budapest (1977) Project plan # 0-3-2.4.4

[28] Csoma, J. & Kovács, D. (1981) "A Duna Rajka-Gönyű közötti szakaszán végzett szabályozási munkák hatásának értékelése". [Impact assessment of river training works at the Danube reach between Rajka and Gönyü. In Hungarian]. Vizügyi Közlemények, Vol. 2.

[29] EDUVIZIG Győr (1994) Data tables faxed to the Ministry of Foreign Affairs, International Law Department on June 21, 1994, 2 pages.

[30] Laczay, I. (1989) "Ipari kotrások hatása a Komárom-Nagymaros közötti Duna-szakasz mederviszonyaira". [Impacts of industrial dredging on the river morphology of the Danube reach between Komárom and Nagymaros. In Hungarian]. Vizügyi Közlemények, Vol. 3.

[31] Laczay, I. (1988) "A folyószabályoazás és as ipari kotrás hatása a Nagymaros-Budapest közötti Duna-szakasz merderviszonyaira". [Impacts of river training and industrial dredging on the riverbed morphology of the Danube reach between Nagymaros and Budapest. In Hungarian]. Vízügyi Közlemények, Vol. 4.

[32] Bogárdi, J. (1971) "Feststoffführung der Gewässer". [Sediment transport of rivers. In German]. Academic Publishers, Budapest.

[33] Csoma, J. (1966) "A vízfolyások által szállitott görgetett hordalék mennyiségének meghatározása". [Calculation of the transported bedload of rivers. In Hungarian]. Hidrológiai Közlöny, Vol. 2.

[34] VITUKI (1971) "AZ 1966. Évi Dunabizottsági vízszint a Duna Bratislava - Déli Országhatár". [Navigational Low Flow Levels of 1966 / Danube Commission. In Hungarian]. Budapest.

[35] "Jegyzőkönyv a Magyar - Cseh-Szlovák Határvizi Bizottság, LII. Ülésszakáról". [Protocol of the 52. Meeting of the Hungarian-Czechoslovakian Border-Water-Commission. In Hungarian]. Topolcianky, 1991. XI. 11-15.

[36] Kališ, J., M. Bačik. 1992. Silting problem arising with the realization of the Gabčikovo water scheme. Proceedings of the International Grain Sorting Seminar Oct 21-26, 1991, Ascona, Switzerland. Mitteilungen 117, VAW ETH Zürich, pp. 314-329.

Dr.-Ing. Klaus Kern
Consultant
Karlsruhe, FRG

Impacts of the Gabčikovo-Nagymaros Project on River Morphology, Fluvial Hydraulics and Habitats

Annexes

A-1 Period maps of the Upper Danube between Bratislava and Györ

A-2 Discharge duration curve Bratislava

A-3 Data tables: dredged gravel volumes between Rajka and Komárom

A-4 Hydrograph Bratislava 1950-1993

A-5 Discharge rating curves at Bratislava

A-6 Discharge release for peaking modes at Gabčikovo

A-7 Discharge release for peaking modes at Nagymaros

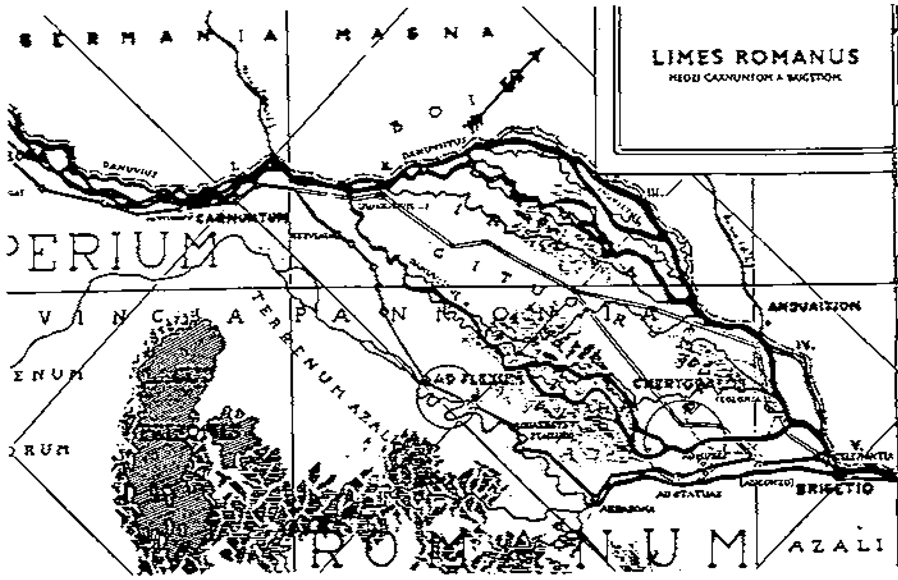
A-8 Parameters for selected peaking modes

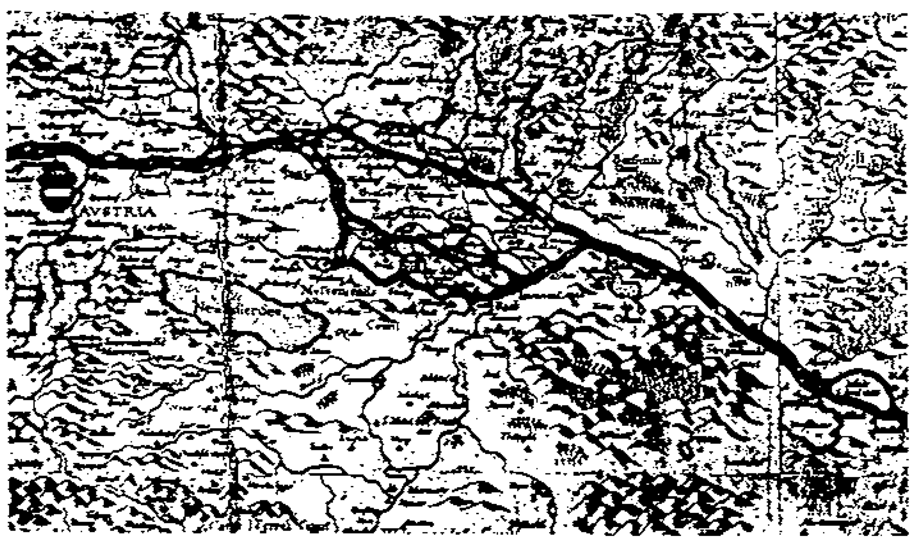
A-9 Flood discharge probability at Bratislava

August 31, 1994

Annex I

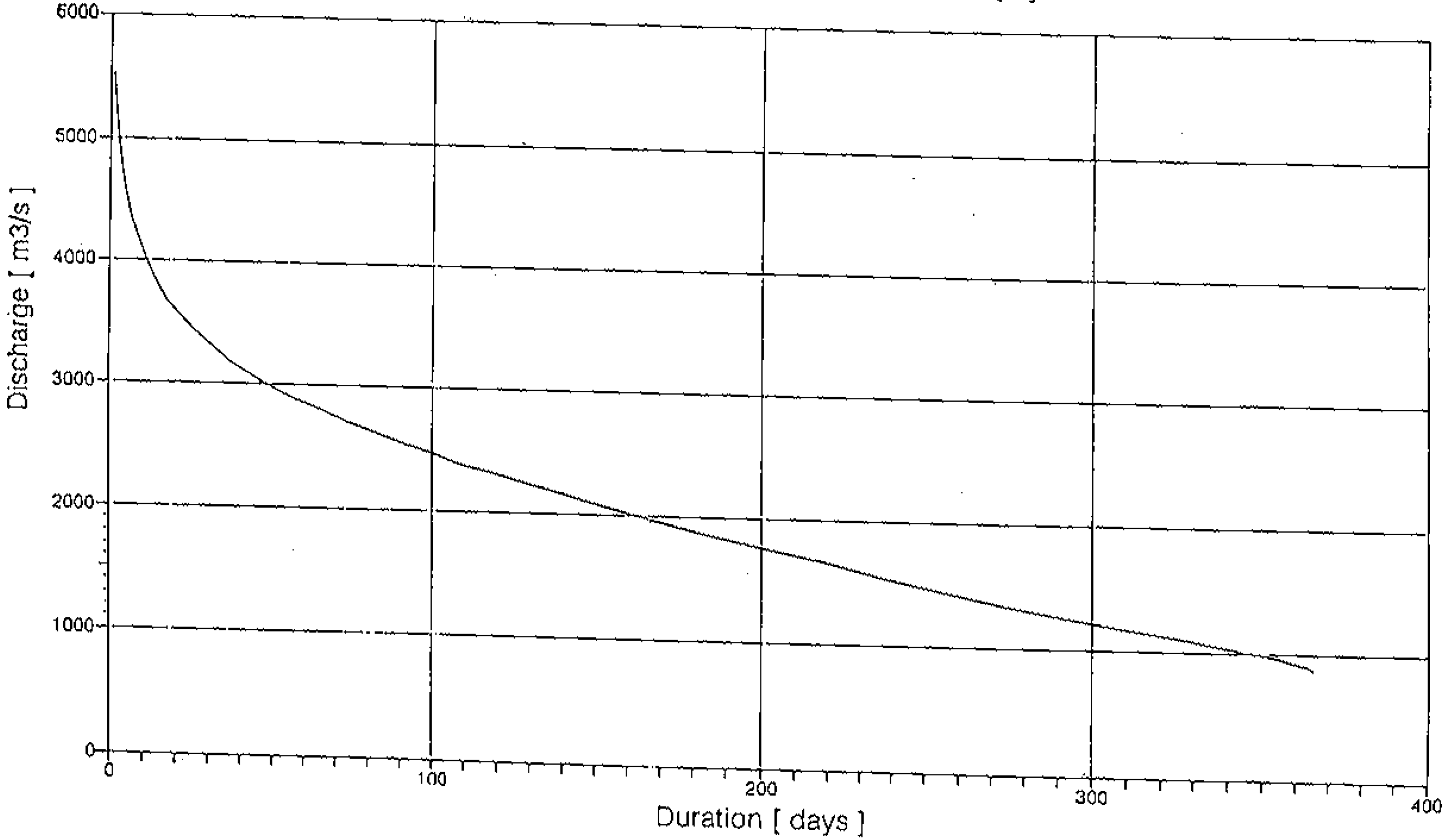
Period maps of the Upper Danube between Bratislava and Győr; upper: Roman time period; lower: 17th century [2]





Annex 2

Duration of Danube discharge at Bratislava 1901-1990 [21]



Annex 3

Years	Ford dredging $10^3 m^3$	Industrial dredging Slowakia $10^3 m^3$	Industrial dredging Hungary $10^3 m^3$	Total dredging $10^3 m^3$
1963	552	184		736
1964	430	137		567
1965	245	135		380
1966	400	574		974
1967	no data	no data	no data	896
1968	no data	no data	no data	1,134
1969	596	79	123	798
1970	694	11	80	785
1971	747	0	75	822
1972	503	202	463	1,168
1973	619	186	176	981
1974	606	117	37	760
1975	395	103	166	664
1976	401	81	118	600
1977	391	125	112	628
1978	451	64	165	680
1979	480	72	90	642
1980	425	39	64	528
1981	442	67	177	686
1982	397	95	64	556
1983	414	69	39	522
1984	245	123	0	368
1985	213	229	41	483
1986	122	749	52	923
1987	180	487	26	693
1988	129	502	98	729
1989	118	862	546	1,526
1990	161	534	24	719
1991	174	10	0	184
Total	10,530			21,132

Dredging data between Rajka (rkm 1849) and Gönyü (rkm 1791) [3, 8, 28]

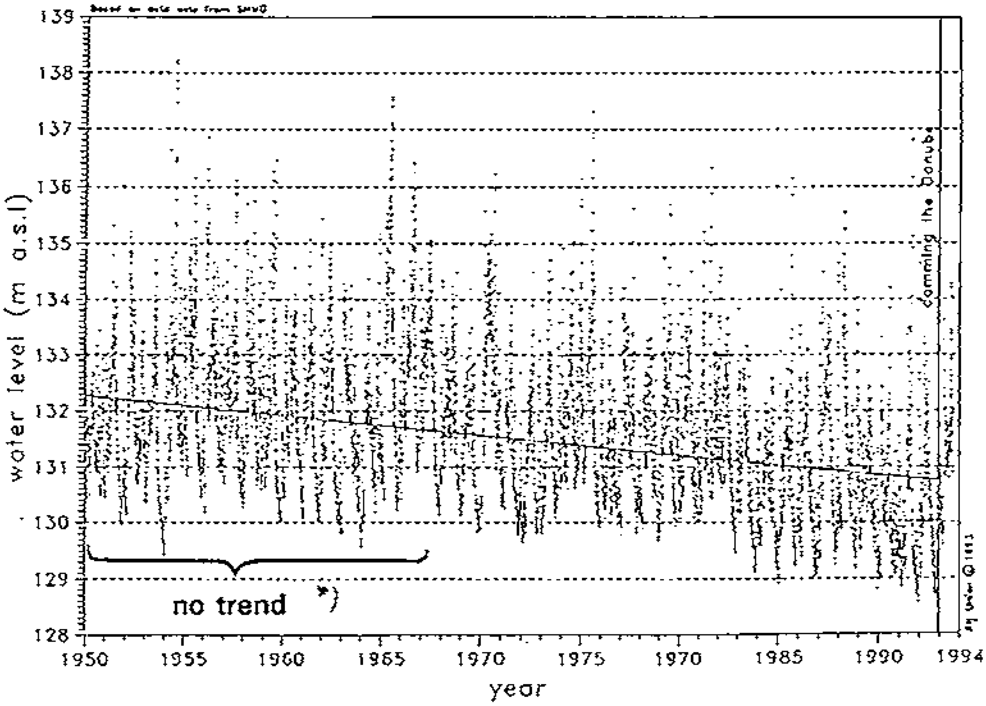
Years	Ford dredging $10^3 m^3$	Industrial dredging Slowakia $10^3 m^3$	Industrial dredging Hungary $10^3 m^3$	Total dredging $10^3 m^3$
1965		402	67	469
1966		911		911
1967		405		405
1968		316		316
1969		219		219
1970		534		534
1971		460		460
1972	122	761	70	953
1973	103	1,102	172	1,377
1974	89	648	172	909
1975		377	15	392
1976		1,265		1,265
1977		1,144		1,144
1978		1,127		1,127
1979		1,108		1,108
1980		1,021		1,021
1981		963		963
1982		949		949
1983		991		991
1984	58	927		985
1985		937		937
1986		618		618
1987		689		689
1988		818		818
1989		595		595
1990		521	39	560
1991		10		10
Total	372	19,818	535	20,725

Dredging data between Gönyü (rkm 1791) and Komárom (rkm 1764) [29]

(40)

Annex 4

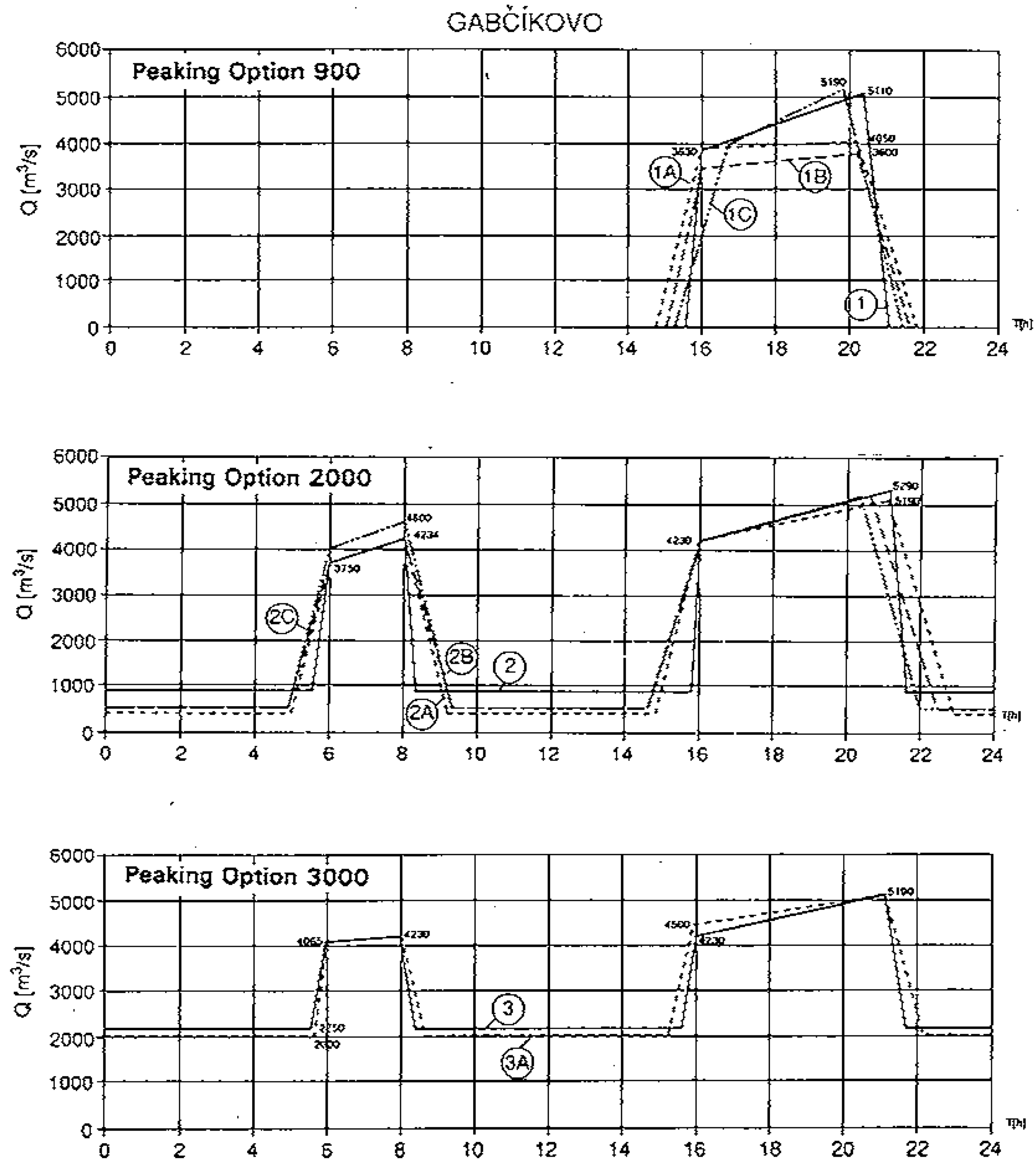
Danube hydrograph at gauge Bratislava [6]. The decline of the waterlevels obviously does not begin before the mid sixties contrasting the suggested trend line. (Compare discharge rating curve of gauge Bratislava, Annex A-5.)



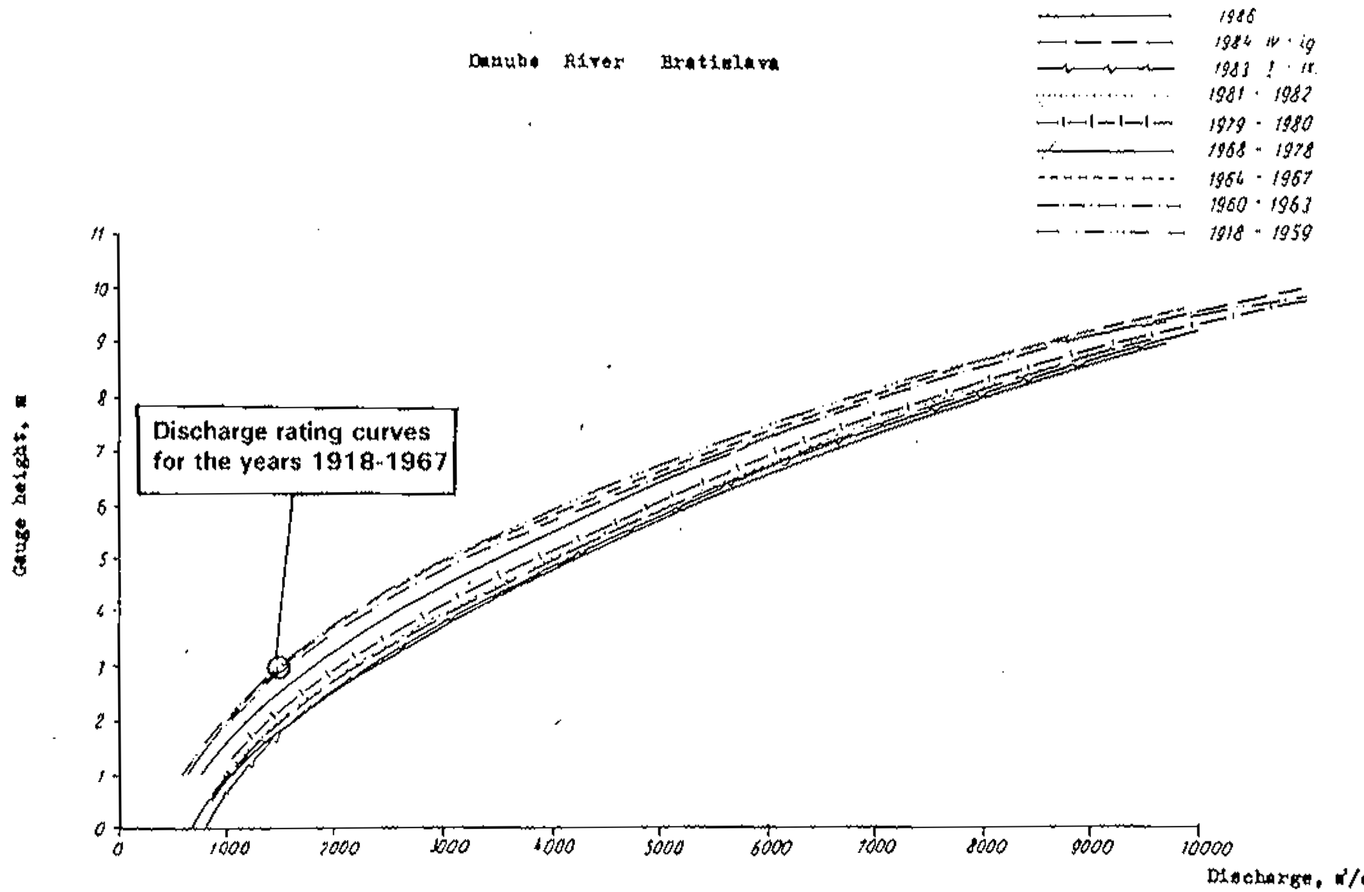
*) *added by the author*

Annex 5

Peaking modes 900/2000/3000 for the operation of Nagymaros power plant. Several alternatives were investigated (discharges for mode 900 in Figure 12 are slightly different from the ones below) [24].



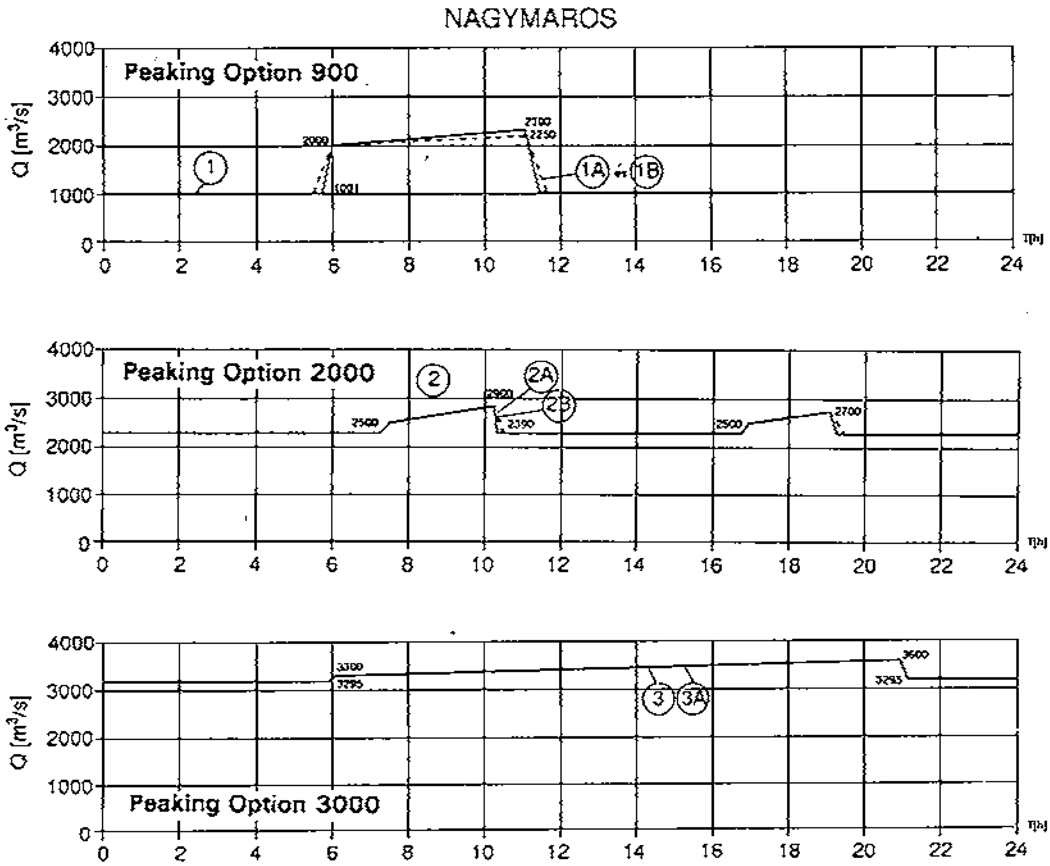
Annex 6: Variation of discharge rating curves since 1918 [11]



Variation of discharge rating curves since 1918 [11]

Annex 7

Peaking modes 900/2000/3000 for the operation of Gabčíkovo power plant. Several alternatives were investigated (discharges for mode 900 in Figure 12 are slightly different from the ones below) [24].



Annex 8

Parameters for selected peaking modes [24]

CHARACTERISTICS OF PEAKING OPTIONS (Gabčikovo)

Peaking Option	Intensity of Ascendence and Descendence ($m^3/s/min$)	Peaking Time (hr·min)‡	Peak Discharge (m^3/s)	Base Discharge (m^3/s)	Discharge of Old Danube (m^3/s)
900	120 170	4.26	5110	0	50 (Σ 115)†
2000	100 170	2.00* 5.00**	4234* 5290**	780	50 (Σ 115)†
3000	60 100	2.00* 5.00**	4230* 5190**	2250	50 (Σ 115)†

* First Peak † Including Seepage Flow
** Second Peak ‡ Peaking Time Excluding Time of Ascendence and Descendence

PEAKING OPTIONS 2000 AND RATE OF CHANGE OF DISCHARGE

	GABČÍKOVO			NAGYMAROS		
Peaking Option	Time (hr · min)	Discharge (m^3/s)	Rate of Change of Discharge ($m^3/s/min$)	Time (hr · min)	Discharge (m^3/s)	Rate of Change of Discharge ($m^3/s/min$)
	Daily Average Discharge of Turbines (2003 m^3/s)			Daily Average Discharge of Turbines (2003 m^3/s)		
2000	0.00-5.30	780-780	0.00	0.00-5.15	2390-2390	0.00
	5.30-6.00	780-3750	99.00	5.15-5.20	2390-2500	22.00
	6.00-8.00	3750-4234	4.03	5.20-10.05	2500-2900	1.40
	8.00-8.20	4234-780	-172.70	10.05-10.10	2900-2390	-102.00
	8.20-15.40	780-780	0.00	10.10-16.55	2390-2390	0.00
	15.40-16.00	780-4230	172.50	16.55-17.00	2390-2500	22.00
	16.00-21.00	4230-5290	3.53	17.00-19.00	2500-2700	1.67
	21.00-21.30	5290-780	-150.33	19.00-19.05	2700-2390	-62.00
	21.30-24.00	780-780	0.00	19.05-24.00	2390-2390	0.00

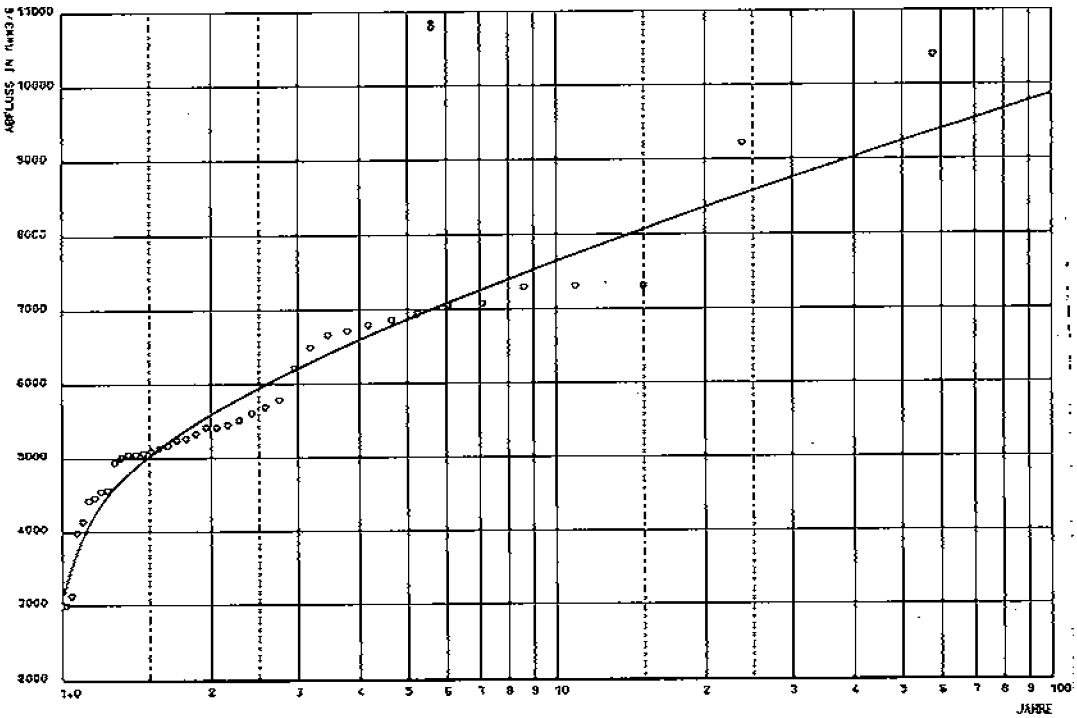
SELECTED HYDRAULIC PARAMETERS OF ALTERNATIVES 2000

Peaking Option 2000		Z max (m)	Z min (m)	dZ (m)	V max (m/s)	V min (m/s)	+dZ/dT max (cm/min)	-dZ/dT max (cm/min)
Tail Water at Gabčikovo (Rkm 1819.45)	KET	113.18	108.54	4.64	0.95	0.00	4.89	4.90
Sill at Palkovičovo (Rkm 1811.05)	KET	112.92	108.54	4.38	1.94	0.02	4.75	4.76
Upstream of the Mouth of Moson Danube (Rkm 1793.80)	KET	110.99	108.34	2.65	1.59	0.28	1.31	1.34
Komarno (Rkm 1768.30)	KET	109.09	108.03	1.06	1.19	0.32	0.29	0.30

Parameters for selected peaking modes [24]

Annex 9

Empirical probability distribution of annual flood discharges at Bratislava gauge station (period 1931-70) [25]



Annex 7

NON-STRUCTURAL SOLUTIONS TO RIVERBED DEGRADATION DOWNSTREAM OF BARRAGES – EXPERIENCES FROM THE UPPER RHINE AND THE AUSTRIAN DANUBE

Prepared for the
Hungarian Ministry of Foreign Affairs
International Law Department

Dr.-Ing. Klaus Kern
Consultant
Environmental River Engineering
Schlehenweg 12
76149 Karlsruhe, FRG
Tel. +49-721-712 88
Fax. +49-721-712 86

September 9, 1994

Preamble

The degradation of the Danube riverbed downstream of Rajka was mainly caused by excessive gravel dredging and not by regulation works or reduced sediment supply [1]. Although no detailed dredging data were available for the Slovak reach upstream of Rajka (rkm 1880 to rkm 1850), the sudden drop of waterlevels after the mid nineteen sixties, contrasting with the relative stability of the Austrian stretch downstream of Greifenstein, indicates that overdredging was the main factor in the degradation of the riverbed. After the damming of the Danube at Wien-Freudenau in 1995 the bedload supply to the downstream section will be further reduced. However the anticipated rate of incision after implementing the barrage of Wien-Freudenau is reasonably small in the Austrian reach of the Danube [2].

Independently from the reasons for riverbed degradation, it is shown below that *at the same time when the G/N Project was considered and finally stipulated in 1977, a new method of sediment management for erosion control was introduced at the Upper Rhine in order to avoid structural measures for the sake of nature conservation and flood protection.* Encouraged by the successful sediment management at the Upper Rhine, investigations were carried out to apply similar techniques at the Austrian Danube below Vienna after the abandonment of the barrage of Hainburg which was stopped by environmental protests.

Upper Rhine

Historical Background.

As a result of World War I France was granted all water rights of the Upper Rhine along the German-French border in the Treaty of Versailles. After diverting the Rhine near Basel in the "Grand Canal d'Alsace" the first barrage started to operate in 1932 [3]. Three more barrages were built along the canal up to 1959. At that time the German-French reconciliation prepared the ground for negotiations aiming at alternatives to the complete diversion of the river. *Figure 1* shows that a new solution was chosen at the beginning of the 1960s, producing less damage to the surrounding wetlands, forests and agricultural areas. The partial diversion was possible after bilateral negotiations resulted in a new treaty between Germany and France in 1956, abandoning the idea of a complete diversion all the way to Strasbourg. The last barrage of this agreement started to operate in 1970 (Strasbourg). In 1969 another treaty was signed between the two countries stipulating the construction of two more barrages, i.e. Gambsheim (1974) and Iffezheim (1977). It was agreed that riverbed degradation downstream of Iffezheim should be prevented by massive armouring of the bed [3]. Later investigations showed that massive armouring would be unfavourable to navigation, and in 1975 an amendment to the 1969 treaty was signed stipulating the construction of another barrage at Neuburgweier.

Changing Attitudes.

One of the reasons for the construction of the last barrage at Iffezheim was the downcutting of the river due to the reduced level of sediment supply. In order to avoid the construction of another barrage, alternatives were discussed in the early seventies favouring artificial "gravel feeding"

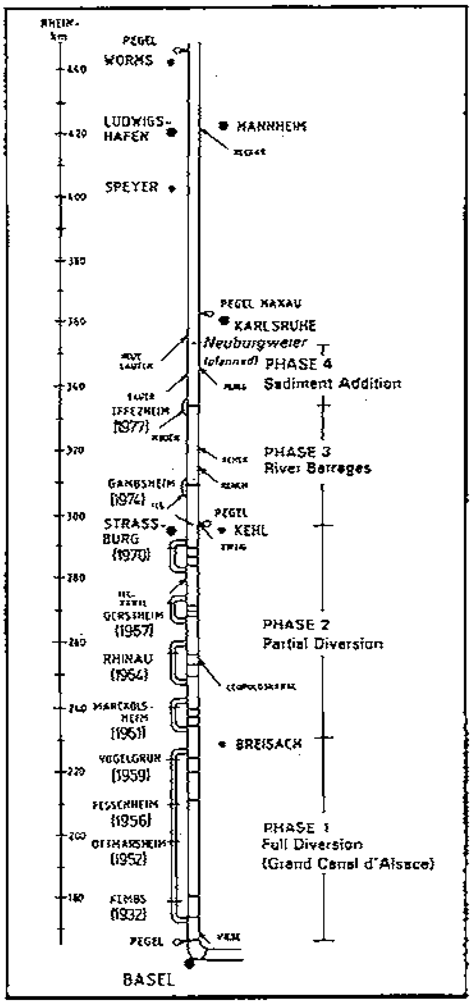


Figure 1. *Construction of barrage systems at the Upper Rhine River (year of first operation); after [3] (see Plate 3 in Volume 1, Chapter 1)*

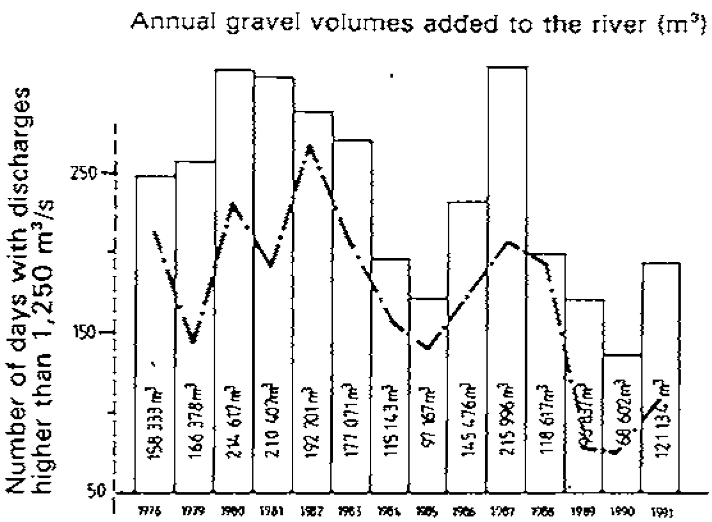


Figure 2. *Sediment addition at the Upper Rhine below the barrage of Iffezheim. Number of days with higher than average discharge at gauge Maxau/Karlsruhe; after [5]*

(addition of bed sediment) [4]. The idea was to stabilize the riverbed without endangering navigation, and avoiding the detrimental impacts of another barrage system on nature and landscape. In 1975, the first tests were carried out with sediment addition below the barrage of Gambsheim [5]. In 1978, the waterways and shipping administrations of France and Germany agreed to continue sediment addition tests below the new barrage of Iffezheim which were started in April 1978. In 1981, the German Federal Waterways and Shipping Administration published a report comparing several methods for riverbed stabilization, i.e. construction of more barrages, construction of river bottom sills and addition of sediments [5]. The conclusion was that sediment addition is the best solution with respect to both ecological *and* economical aspects. In addition, the tests proved that sediment addition could guarantee the required navigational waterlevels, that the ship traffic was not disturbed and that the natural composition of the bedload remained unchanged [5].

In 1982 both countries signed an amendment to the treaty of 1969 stipulating that sediment addition could be carried out below Iffezheim instead of the construction of a new barrage at Neu-burgweier. It was agreed that a new barrage at Neuburgweier should be built if the navigational low-flow waterlevels were to drop by more than 50 cm despite sediment addition.

Procedure of Sediment Placement

Comprehensive investigations were carried out for the sediment addition below Iffezheim including mathematical simulations [6] and physical model tests [7]. Two vessels were constructed with a capacity of 170 m^3 each for the controlled discharge of the gravel-sand mixture. A smaller boat was equipped with automatic riverbed monitoring devices to control and guide the vessels during the sediment addition and to measure cross-sections. 3 automatic and 33 manual river gauges were installed between rkm 334 and rkm 352. 355 cross-sections for monitoring were fixed in this river reach.

The grain size distribution of the material used for sediment addition corresponds to the natural sediment of the tailwater of Iffezheim. In the first years dredged sediments from the construction of Iffezheim could be used, enriched by 34 % with coarse grains. Since 1982 almost all material has come from a German gravel pit beside the channel at rkm 335.2 (the agreement of 1982 stipulates that all gravel should come from the German floodplain). The average annual demand for sediment to replace the missing bedload was calculated to be 173,000 m^3.

On every working day a certain volume of gravel depending on the actual amount of missing sediment is brought into the river over a reach of two kilometres in length. The simultaneous measurement of cross-sections guarantees that the minimum depth of 2.10 m below the fixed navigational waterlevel is maintained. After floods it might take a little longer for the missing sediment to be replaced.

The monitoring program consists of daily cross-section measurements in the gravel placement reach, bedload measurements every two weeks and topographical measurement of the entire stretch between rkm 334 and rkm 352 after each flood or at least once per year. Each year about 6,000 cross-sections are measured and compared to previous results.

EXPERIENCES

Figure 2 shows the annual volumes of gravel placement since 1978 and the number of days when the average discharge of 1,250 m^3/s (gauge Maxau/Karlsruhe) is exceeded. There is a close relationship between the discharge regime and gravel volumes. The height of the fixed navigational low-flow waterlevel has varied between +9 and -24 cm since the beginning of the sediment addition, showing no trend. Between 1978 and 1992 a total volume of 2.3 million m^3 of gravel was added to the riverbed. The costs amounted to a 5-6 million DEM per year (80 % for the purchase of the gravel and 20 % for transport, monitoring and engineering).

The sediment addition has proved to be a suitable and economic method for controlling erosion caused by missing bedload in the tailwater of Iffezheim. All requirements for navigation have been met without disturbance. The free flowing section of the river downstream of Iffezheim with valuable wetland forests remains untouched by avoiding the construction of a new barrage.

Austrian Danube below Vienna

BACKGROUND.

After the projected barrage of Hainburg was cancelled, a national park was prepared in order to protect the remaining wetland forests between Vienna and Hainburg. There was a dispute about the stability of the riverbed: according to [2] and [9] the bed is rather stable although a considerable amount of sediment is retained by the Austrian barrage system; others argued that the Danube reach below Vienna is exposed to erosion at increasing rates, e.g. 2-3 cm per year [10]. There is no doubt that the lower end of the Austrian Danube reach is influenced by the riverbed degradation in the vicinity of Bratislava [10], probably caused by excessive gravel dredging [1].

In any case the situation of the Danube is quite different from the Upper Rhine. The results from the physical and mathematical models of the tailwater of Iffezheim/Upper Rhine show that progressive erosion would occur below the barrage without compensatory gravel addition. The riverbed degradation would reach more than 6 m after only 17 years just below the barrage (rkm 335) and the wedge of erosion would spread 12 km downstream [6]. In the Austrian Danube downstream of Wien-Freudenau the maximum erosion depth *after 80 years* was calculated to be 1.1 m [2].

Although possible riverbed degradation at the Danube obviously is much less dramatic than at the Upper Rhine river, investigations for non-structural measures were carried out using physical model tests [11]. Field tests based on these results were scheduled to start in 1994.

RESULTS OF MODEL TESTS [11]

The model tests were performed as general investigations in a hydraulic flume without consideration for the geometry of the riverbed. The objective of the investigations was not to predict the behavior of the real Danube bed but to test the reliability of an artificial armouring of the riverbed under the impact of ship traffic. Unlike at the Upper Rhine a layer of coarse grains should be established to prevent further downcutting even during flood events and to resist the hydraulic jet streams of ship propellors.

The results showed that a thin layer of 10-20 cm thickness with maximum grain sizes of 120-200 mm leads to an armoured cover stabilizing the riverbed after an initial minor degradation caused by wash-away of smaller grains underneath the coarse top layer. Local deficiencies lead to local scouring without progressive erosion. Natural sediments pass over the artificial coarse layer without any disturbance. However, ship traffic can mix up the stabilizing top layer of coarse grains with the finer natural sediments underneath to a depth of 50 cm. The subsequent fluvial rearrangement will lead to rearmouring of the bed with a certain lowering of the level. Therefore a series of low water periods with frequent disturbance of the armoured top layer may result in a gradual decline of the bed level.

In order to prevent any degradation of the riverbed an artificial top layer of about 50 cm thickness and 60-120 mm grain size can be brought into the river, resisting natural flood events *and* hydraulic impacts of ship propellors. Since this layer would completely protect the finer natural Danube sediments no armouring would occur by fluvial grain sorting.

Model tests with special vessels for gravel placement proved that the protective layer can be brought into the river with sufficient reliability. Assuming that those parts of the cross-section that are exposed to ship traffic (about 100 m of the width) would be protected with a layer of 50 cm thickness and the remaining 170 m would be covered with a thin layer of 20 cm, the costs were estimated to 5 million DEM per river kilometre.

The model tests have proved that artificial armouring of the Danube reach below Vienna is feasible and efficient in protecting the riverbed from possible degradation.

References

[1] Kern, K. (1994) "Impacts of the Gabčíkovo-Nagymaros Project on River Morphology, Fluvial Hydraulics and Habitats". Karlsruhe, August 1994, unpublished study.

[2] Jäggi, M. (1992) "Effect of Engineering Solutions on Sediment Transport". In: Billi, P., Hey, R.D., Thorne, C.R. & Tacconi, P. (Eds.) "Dynamics of Gravel-bed Rivers", pp. 593-605, Wiley, Chichester.

[3] Internationale Kommission für die Hydrologie des Rheingebiets (1993) "Der Rhein unter der Einwirkung des Menschen - Ausbau, Schiffahrt, Wasserwirtschaft". [The Rhine under the influence of man-river engineering works, shipping, water management. In German]. KHR-Arbeitsgruppe 'Anthropogene Einflüsse auf das Abflußregime', Authors: W. Buck et al., 260 p.

[4] Felkel, K. (1970) "Ideenstudie über die Verhütung der Sohlenerosion durch Geschiebezufuhr aus der Talaue ins Flußbett, dargestellt am Beispiel des Oberrheins" [Reflections on the possibility of preventing erosion of a movable riverbed by adding sediment material from the adjacent floodplain into the riverbed – Upper course of the Rhine River taken as an example. In German]. Mitteilungsblatt der Bundesanstalt für Wasserbau No. 30, Karlsruhe.

[5] Kuhl,D. [1993] "Geschiebezugabe unterhalb Iffezheim" [Artificial sediment addition below Iffezheim. In German]. *Der Bauingenieur in der Wasser– und Schiffahrtsverwaltung*, No. 1, 1993.

[6] Siebert, W. (1992) "Simulation of erosion and deposition of coarse material below Iffezheim-Barrage/Rhine". 5th Int. Symp. on River Sedimentation Karlsruhe 1992, Vol. III, p. 1153-1174.

[7] Nestmann, F. (1992) "Improvement of the Upper Rhine, tailwater Iffezheim". 5th Int. Symp. on River Sedimentation Karlsruhe 1992, Vol. III, p. 1130-1152.

[8] Kuhl, D. (1992) "14 years artificial grain feeding in the Rhine downstream the barrage Iffezheim". 5th Int. Symp. on River Sedimentation Karlsruhe 1992, Vol. III, p. 1121-1129. (Annex 1)

[9] Bernhart, H.H. et al. (1987) "Analyse des Flußabschnittes Greifenstein/Wien - Marchmündung" [Investigation of the river reach Greifenstein/Vienna - March r. In German]. Commissioned by the Planning Institution of the National Park Danube Wetlands, June 1987, Vienna, unpublished study.

[10] Kresser, W. (1986) "Vorhersage von Flußbettänderungen in der österreichischen Donaustrecke" [Forecast of morphological changes in the Austrian Danube reach. In German]. XIII. Conference of the Danube Countries on Hydrological Forecasts, Belgrad 16.-19.9. 1986, pp. 191-198.

[11] Ogris, H., Zottl, H. & Erber, H. (1988) "Sohlstabilisierung durch Grobmaterialzugaber zur Deckschichtbildung - Donau im Raum Wien - Bad Deutsch Altenburg" [Riverbed stabilization by adding coarse material for armouring - Danube reach Vienna - Bad Deutsch Altenburg. In German]. Commissioned by the city of Vienna, 143 p., Dec 1988, Vienna, unpublished study.

5th International Symposium on River Sedimentation
Karlsruhe 1992

14 Years Artificial Grain Feeding in the Rhine downstream the Barrage Iffezheim

Dietrich Kuhl
Federal Waterways and Shipping Administration,
Waterway and Shipping Office Freiburg, FR Germany

Abstract: This paper provides an overview of the artificial grain feeding downstream the Rhine-barrage Iffezheim, wherewith the depth erosion and the water level reduction of the Rhine was successfully combatted since 1978.

1 Introduction

The status of the artificial grain feeding is described hereafter:

In October 1981 the Ministry of Traffic published the final report on investigations of the question, whether the bottom erosion of the upper Rhine downstream the barrage Iffezheim can be stopped by artificial grain feeding, the construction of additional barrages or via ground-sills /1/. The result was, that from 1978 until 1980 one succeeded in keeping the water level downstream the barrage Iffezheim by artificial grain feeding, that the pouring out with self-moving bottom-dump scows proved to be good, because it does not hinder the shipping, and finally that no changes compared with the natural gravel transport were observed. Furthermore, it was found out that the artificial grain feeding is the more ecologically beneficial and cost saving solution than the construction of additional barrages.

Starting in 1981 the artificial grain feeding was continued in order to increase the so far obtained knowledge and gain more experience over a longer period of time.

2 Material requirements and grain composition

It was intended to equalize the average annual bed erosion downstream the barrage Iffezheim (Rh.-km 366) by means of the artificial grain feeding.
For this purpose sand-gravel-mixtures, which correspond in their grain composition as far as possible to the natural bottom grain, have to be added to the Rhine (Table 1).

Based on numerous samples of the bottom grain of the Rhine the requirements for the delivery of the material were defined. The sand and gravel sorts have to be lightly movable.
For economical reasons they are composed of the commercial grain groups from 0 - 64 mm.

Graindiameter Kornfraktion (ø mm)	Excevated earth Baggergut	Gravel mixture Kiesgemisch (Gewichts-%)							
		1	2	3	4	5	6	7	8
Eingebaut in den Jahren	1978/81 84/87,90/91	1978/ 1979	1978/ 1981	1981	1982	1981/ 1983	1984/ 1987	1987/ 1991	1991
0/2	12			-	-	-	-	-	12
2/8	24	33 ⅓	40	-	-	-	-	-	12
8/16	34			19	33 ⅓	30	40	42	26
16/32	21	33 ⅓	40	19	33 ⅓	30	30	28	25
32/x	9	33 ⅓	20	62	33 ⅓	40	30	30	25
dm(mm)	20	24	20	35	27	26,5	25	24,5	21

Table 1: Grain composition of the artificially feeded material

From 1978 until 1981 the need of feeding material was supplied for 66 % from the necessary dredging in the river downstream the barrage Iffezheim and for 34 % from deliveries. With increasing dredging depth the too high portion of fine grains had to be compensated by adding coarser gravel material.
From 1982 to 1991 the supplied part of the feeding material amounted to 97 %. Per year as an average 3 % dredging material resulted from work performed for traffic safety reasons and were poured out.

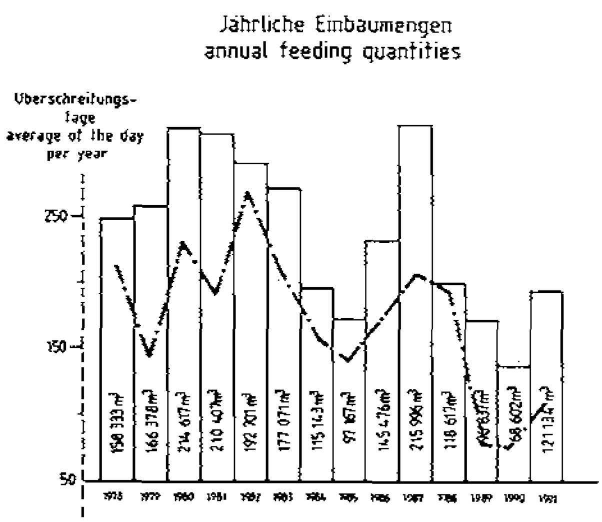


Fig. 1: Annual feeding quantities
The column graphic of the annual feeding quantities is similiar to the dotted line of the average of the days per year with increased medium discharge MQ = 1250 m³/s at the water-gauge Maxau.

Based on the German-French agreement from 1982 /2/ material for the artificial grain feeding may only be supplied from German gravels pits (being situated on the right banks of the Rhine). This resulted in contracts with the Südwest-Kies GmbH & Co. KG Iffezheim on the basis of the annual average need of 173.000 m³ with a minimum commitment and an upper limit of the gravel supply per year. The gravel is being weighed and loaded in doses into hydro bottom-dump scows at the gravel works Kern, Rh.-km 335.2.

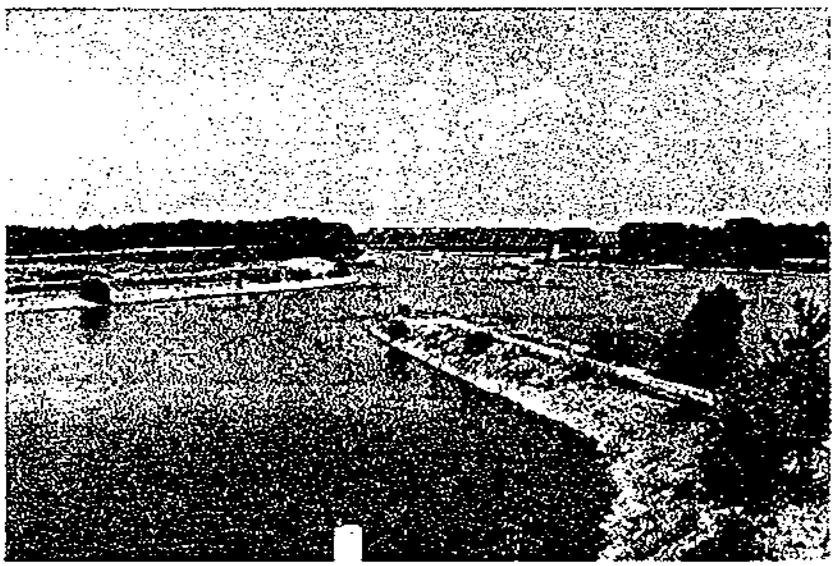
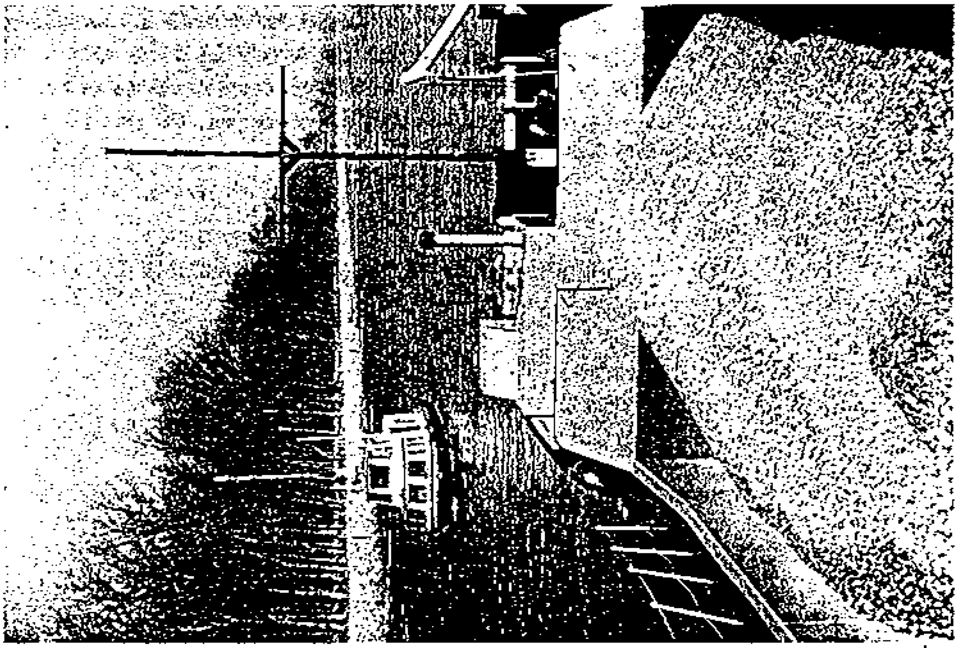


Fig. 2: Gravel loading in the harbour of gravel works Kern, Iffezheim, Rh.-km 335.2, into hydro bottom-dump scows with a loading space of 170 m³ and an engine power of 360 PS. The hydro bottom-dump scows have to be re-calibrated with every change in the grain composition.

3 Insertion of gravel

The detritus is inserted at the origin of the bottom erosion, i.e. at the place, where downstream the barrage Iffezheim the full transporting power of the Rhine is effective in the continuously flowing Rhine cross section. Within a 2.5 km long part of the Rhine the bottom erosion, which had occurred, is being filled between the stroke lines (see fig. 7), in order to guarantee a natural movement of bed material for the following downstream part of the Rhine. The pouring out of the gravel-sand-mixture out of hydro bottom-dump scows with strong engines going downstream proved as a filling procedure (see fig. 3,4). At a place which has been fixed before the hold of the hydro bottom-dump scow is being opened crack-wide, the gravel comes out and is being distributed in a 10 to 20 m width over a length of 50 to 300 m on the bottom of the Rhine. The position of the material is being checked by means of control soundings in order to guarantee that the waterway has not been limited.



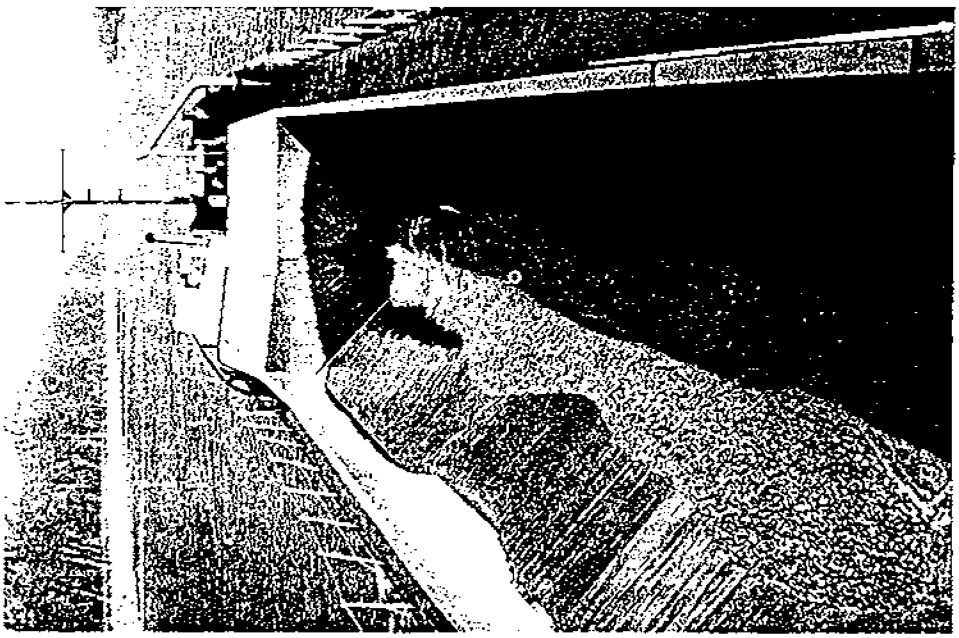


Fig. 3: The hydro bottom-dump scow -

Fig. 4: loaded with a sand-gravel mixture - approaches to the spreading site (fig. 3); the pouring out of the detritus begins, when the hydro bottom-dump scow passes the measure boat, which is used as steering mark.

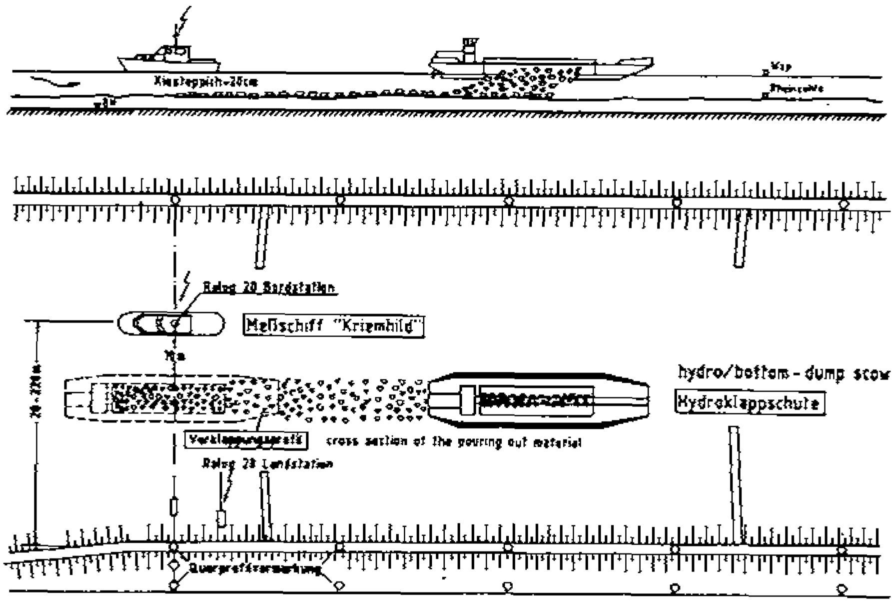


Fig. 5: Process of pouring out

To keep the waterway free, safety distances have been determined.

At the beginning of the artificial grain feeding the depth of the waterway was 1.70 m below GIW 72. The bottom erosion was filled-up to 60 cm below the lower waterway limit. Today the depth of the waterway is 2.10 m below GIW 82. The safety distance was reduced to 40 cm below the waterway box (fig. 6).

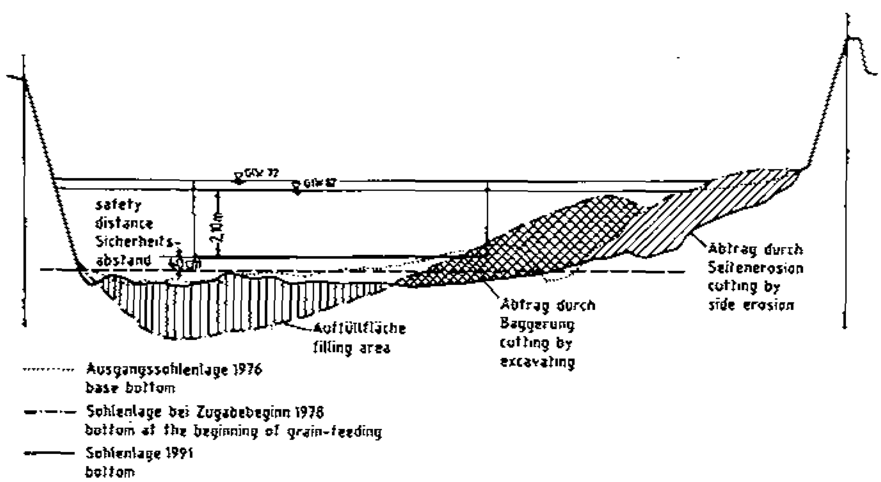


Fig. 6: Cross-section in the filling area

4 Control of the artificial grain feeding

The control of the artificial grain feeding includes the

delivery	grain composition, weight and volume of the filling material
bottom position	in the filling area and for the downstream following about 14 Rhine-kilometers
water level position	between Rhine-km 334 and 352
It is good for	the traffic safety, the control of success, the mass balance, and the calculation.

The traffic safety is guaranteed by the extensive soundings programme, which is necessary to observe the movements of the bed material. It consists mainly of the statement that there are no handicaps in the waterway in and downstream the filling area, i.e. until June 1988 at 1.70 m below GlW and afterwards at 2.10 m below GlW. The reason for the different depths of the waterway is the extension of the groynes to deepen the Rhine reack, which was agreed upon in /4/.

From 1983 until 1988 the groynes between Iffezheim and Maxau were lengthened at stroke lines distances from 155 m upstream and 160 m downstream the mouth of the Murg with uniform groyne slope 1:5 and were raised to GlW plus 30 cm (fig. 7).

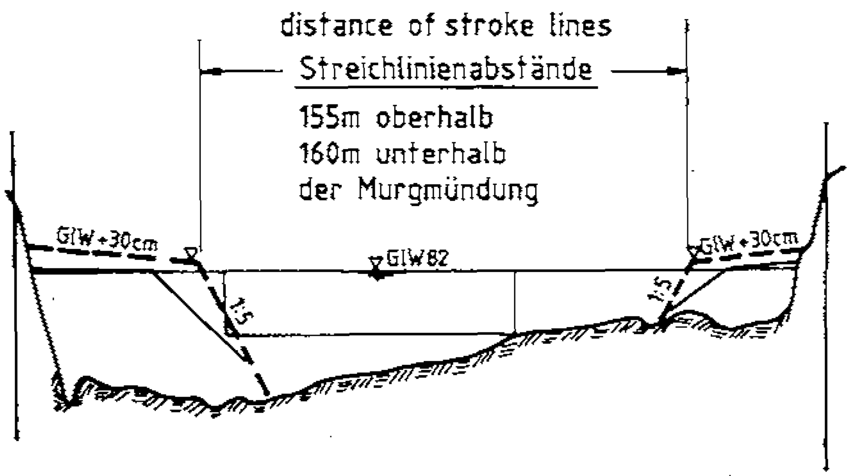


Fig. 7: Extension of the groynes - criteriae

The pouring out area of the artificial grain feeding was excluded from the lengthening of the groynes because of the sufficient depth of the waterway and the necessity of comparing observations regarding the original situation. The result of the lengthening of the groynes was that the aim of the extension - the deepening of the waterway for 40 cm - was reached at a nearly unchanged waterlevel (fig. 8).

The soundings programme comprises the daily cross section measures in the filling area in order to check the position of the material poured out. The movement of bed material is observed about 2 km downstream the filling area every fortnight and after each high water. At least once per year the total Rhine reach from km 334 (lock Iffezheim) to km 352 (German-French border, leftbank) has to be sounded and made up as bed plan. Since 1978 6000 cross-sections were measured and evaluated as an annual average.
While the control soundings supply data for mass changes in the Rhine bed, the water level statements show as sensitive indicator success or failure of the artificial grain feeding directly by position changes at the same runoffs.
The accuracy of the water level statements is guaranteed by readings at 38 water-gauges between Rhine-km 334 and 352 at constant Rhine runoffs.
The comparable water levels in the filling area differed between +9 cm and -24 cm.

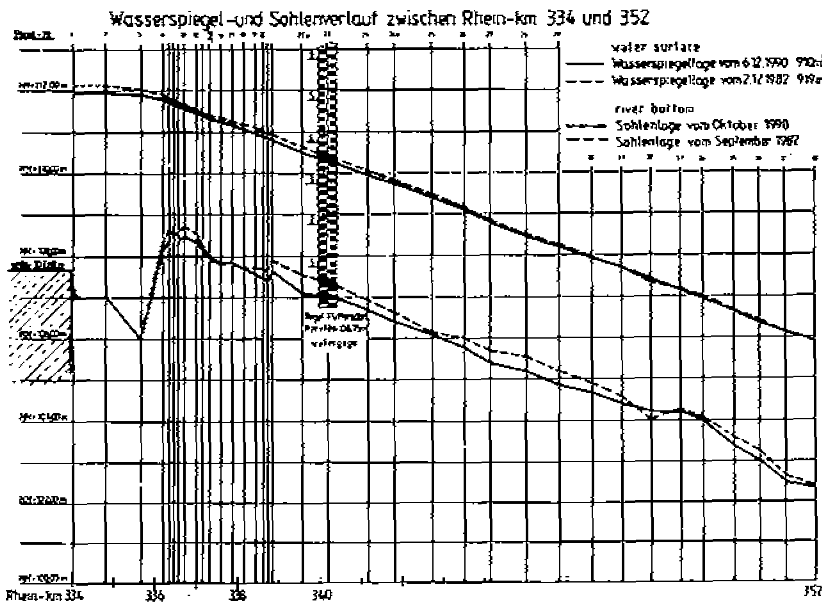


Fig. 8: Waterlevel and bed run between Rhine-km 334 and 252 before and after the groyne extension

For the purpose of mass balance the average bed position is made up from neighbouring cross-sections between the stroke lines and their changes compared to the initial sounding at the beginning of the artificial grain feeding are calculated. For the about 2.5 km filling area this result is the calculation basis for the need of gravel; exact forecasts for the gravel supply are not possible, because the movement of bed material depends on the water quantity of the Rhine.

5 Influences on the artificial grain feeding

The success of the artificial grain feeding is mainly the result of thoroughly fulfilled tasks of the staff of the Waterway and Shipping Office Freiburg. Missing engagement would surely lead to failure of the artificial grain feeding.

Below further influences on the artificial grain feeding are listed without evaluation:

1. Grain composition

   The adding material should correspond to the natural bottom grain.

   A too less medium grain average respectively a too high portion of sand and fine gravel lead to a quicker movement of the bed material and to higher material requirements. On the other hand a high portion of oversize aggregate promotes an armouring effect in the corresponding section with a too slow bed material transportation.

2. Rhine runoffs

   Measurable movement of bed load starts at medium Rhine runoffs. Big quantities of bed material are transported during a long lasting high water. If the medium discharge of many years at the water-gauge Maxau MQ = 1250 m^3/s is often lower, only small quantities of filling material have to be poured out; vice versa high material requirements have to be calculated, if the MQ is often exceeded.

   The graphic of the days below the MQ is similiar to the curve of the annual adding quantity (figure 1).

3. Weather

   If it is frosty weather, no supplies and no pouring out are possible, because the material freezes. If it is foggy, there is no artificial grain feeding for safety reasons.

4. Discharge measurements, water level statements, soundings

   The reliability and the accuracy of the discharge measurements have to be guaranteed. Problems may occur, if the measurement profiles based upon have changed because of the moving bottom of the Rhine in the discharge curve. As consequence faulty water level positions are calculated.

   A high accuracy of the soundings is mainly the result of experience and of the training in handling the instruments.

5. Safety in operation of the instruments and the vehicles.

6. Reliability and quick data processing

7. Enlarging measurements downstream the barrage Iffezheim:

   7.1 Lengthening of the groynes

   This leaded to additional bed material transports between Rhine-km 336 and 352. The bed material differences amount to about 500.000 m^3 in 1990 - compared to the first soundings in 1982, the beginning of the groyne extension.

   7.2 The construction of additional barrages

   This measurement would lead to shifting of the erosion problem and consequently to shifting of the artificial grain feeding.

6 Summary

The artificial grain feeding in the Rhine downstream the barrage Iffezheim was started in 1978 as an experiment to combat the river bed erosion with the aim to avoid the construction of additional Rhine barrages and showing a positive result after the trial period, it was continued since 1981.

During the 14 years from 1978 until 1991 about 2.100.000 m^3 of a sand-gravel-mixture was poured out without impeding the shipping or even impairing the environment. The extension of the groyne down- stream the filling area and the reduction of the equal value of the water level in 1982 leaded to small, within the tolerance values reductions of the water level at the downstream sill of the barrage Iffezheim. By means of additional extensions of the groyne the water level within the filling area can be raised.

Without artificial grain feeding additional barrages would have to be built in order to keep up the shipping traffic and to avoid water economical consequential damages resulting from water level reductions with more than 2 m.

By the way, the artificial grain feeding is one of the few procedures which can be stopped, if necessary, without showing any environmental damages.

References

/1/ Felkel, Kuhl, Steitz
Naturversuche mit Geschiebezuführung zwecks Verhütung der Sohleneintiefung des Oberrheins (Freistetter Versuch)
Wasserwirtschaft 67 (1977) Heft 5, Seiten 119-125

/2/ Kuhl
Naturversuch mit einer Geschiebezugabe im Rhein unterhalb der Staustufe Iffezheim,
Zeitschrift für Binnenschiffahrt und Wasserstraßen, Nr. 2/80, Seiten 59-62

/3/ BMV, Abt. für Binnenschiffahrt und Wasserstraßen
Untersuchung zur Frage, ob die Sohlenerosion des Oberrheins unterhalb der Staustufe Iffezheim durch Geschiebezugabe, weitere Staustufen oder Grundschwellen verhindert werden kann.
Schlußbericht Oktober 1981

/4/ Vereinbarung zur Änderung und Ergänzung der Zusatzvereinbarung vom 16. Juli 1975 zum Vertrag vom 04. Juli 1969 zwischen des Bundesrepublik Deutschland and der Französischen Republik über den Ausbau des Rheins zwischen Kehl/Straßburg und Neuburgweier/Lauterburg.
BGBL. 1984 II, Seiten 286 ff.

/5/ Felkel
Acht Jahre Geschiebezugabe am Oberrhein
Wasserwirtschaft 77 (1987), Heft 4, Seiten 181-185

Annex 8

Traditional Solutions to the Navigational Problems in the Szigetköz Stretch of the Danube

I A Laczay
Civ. Eng.
Budapest, August 4, 1994

Contents

1. Summary

The term "traditional solution" is used for engineering measures to ensure sufficient navigational conditions by means of structures built in and along the channel. Traditional river training on the Szigetköz stretch of the Danube carried out before the sixties failed to provide permanent and sufficient fairway for navigation. In the early sixties, however, a new, consistent training concept was developed. Nevertheless, construction work was not completed, since the Gabčikovo-Nagymaros system was expected to solve the problems.

Between1990-1992 on the section Rajka-Szap, at each of the confluences of the inlet and outlet canals of the Dunakiliti weir, there were two major bottlenecks to navigation caused by the construction of the Gabčikovo-Nagymaros System. In the well-known Bagomer bend and in a number of other localities, navigation was hampered by insufficient fairway-width. These difficulties were avoided in 1992 when the Gabčikovo canal came into operation and navigation was diverted.

Downstream of Szap (Palkovičovo) a number of shallows and middle bars have developed due to hydromorphological conditions. In 1992, four bottlenecks were known which needed extensive dredging. Thereafter, operation of the Gabčikovo tailrace canal induced additional local bed erosion, increasing the number of obstacles to 6 or 7.

The traditional training concept accepted in the early sixties stood on fairly sound scientific and professional grounds. By full implementation, a quite suitable fairway could have been achieved along the stretch, especially between Rajka and Szap.

Recently, a number of conditions necessary to prepare a new traditional concept for improving navigation has been outlined by Laczay, 1991. The conclusion was that some kind of traditional solution may be feasible, but especially downstream of Szap, permanent maintenance work must be projected as well.

A feasibility study for the stretch Szap to Gönyű was prepared by Dutch experts (Delft HY et al., 1994). According to the conclusions, when the local rearrangement of the Danube bed induced by the opening of the tailrace canal calms down, permanent training solutions can be defined. The concept will include further normalisation of the low-flow river bed by construction of river constriction works.

2. History

Comprehensive river training activities on the Szigetköz stretch of the Danube started back in the 19th century. However, the construction of the main channel in 1886-1896, the additional low-bed regulation for navigational purposes in 1900-1940, and the extensive reconstruction works in 1949-1963 with dredging activities: all provided no permanent and sufficient fairway for the international shipping (Zorkóczy, 1969). Principles for further activities were outlined and approved by the Hungarian-Czechoslovakian Joint Engineering Committee in 1963 as follows:

> i. To minimise the water losses from the main channel, by closing the upper ends of the side-arms and by constructing and rearranging both banklines to maintain flow discharges up to around 3,000 m^3/s in the main channel.

ii. To provide proper and safe passage of the flood flows spilling over into the side-arms, by constructing sequences of "cascades" at the closures to avoid bank and bed erosion.

iii. Finally, the width of the main channel was to be confined by spur dikes in order to improve the velocities and the sediment transport capacity.

Taking into consideration that the Gabčikovo-Nagymaros Project would be completed by 1990, the general river training plan has only been prepared for the stretch between rkm 1842-1816. Traditional works in this reach would not interfere with construction of the Barrage System. However, construction of any traditional solutions upstream of rkm. 1842 and downstream of rkm 1816 would have been in vain and would interfere with the construction of the Barrage System.

Construction work was performed in the sixties and seventies. Additional work of minor extent has also been done on the stretches upstream of Dunakiliti and downstream of Ásványráró as well. Work was also performed on the side arms while confinements of the main channel by series of groynes have only been constructed on shorter reaches at Nagybajcs, Gabčíkovo, and Rajka.

A comprehensive evaluation of the effects of works carried out was presented in a joint report (Csoma et al., 1978) and reviewed by Csoma and Kovács, 1981. In the period from 1963 to 1979 the volume of rock built in between Rajka and Gönyü for navigational purposes by the two countries amounted to 815,000 m^3. To maintain the fairway in sufficient condition and to construct the uniform banklines on this reach some 6.7 million m^3 dredging was performed between 1963-1979, and an additional 6.2 million m^3 gravel mined for commercial purposes.

Between 1962-76, the calculated yearly average volume of the bedload passing Bratislava (input) amounted to 640,000 m^3 while the same passing Gönyü (output) was 65,000 m^3. The yearly average amount of total dredging in 1962-1976 was 789,000 m^3. The calculated "overall balance" of the Rajka-Gönyü reach also contained the actual channel volume changes, based on detailed field surveys. The result was 311,000 m^3 annual volume loss, that is, degradation as yearly average. (Csoma-Kovács, 1981).

The evaluations indicated quite clearly, that starting from the early sixties, the channel as well as the fairway conditions have been governed by the various gravel-mining activities. In the overall balance, the dredging overruled the basic morphological tendency of bedload deposition, the effects of river training works and possibly other tendencies as well.

Based on the results of the evaluations, it was confirmed in the late seventies that, until the GN Project comes into operation, no further comprehensive traditional training activities were justified. Navigation was to be maintained by repeated dredging.

3. Navigability of the Szigetköz Stretch Before October 1992

Fairway and channel conditions were investigated in terms of the channel geometry (Laczay, 1991). Conditions before closing the channel at Dunacsúny in October 1992 were also evaluated using the daily reports of the Patrol Service (KHVM, 1993). Evaluation of navigability is based upon the accepted requirements of the Danube Commission and the EEC.

3.1 STRETCH RAJKA-SZAP (PALKOVIĆOVO)

The most severe upstream obstacles to navigation were caused by the excavation of the inlet and outlet canals of the Dunakiliti weir (Laczay, 1991, Figure 1). The main channel became overwidened and the flow lost its former velocities. Consequently, at rkm 1,843.6 and 1,841.5 large middle bars have developed.

An old navigational problem is the narrow and sharp bend at Bagamér (rkm. 1814). To improve the given conditions, no feasible engineering solution is at hand. Vessels passing became used to the nuisance, especially since no depth restrictions prevent passage.

Besides the problems mentioned above, no further shallows or fords of major interest were known. So, the bypass canal put into operation in November 1992 solved the discussed difficulties only on this stretch.

The daily reports of the Patrol Service indicated that during the autumn of 1992 the characteristic water depths referred to in the Navigational Low Flow Levels (930 m^3/s, Danube Commission) were 1.6 m in the shallows around Dunakiliti.

3.2 STRETCH SZAP-GÖNYŰ

The decrease in the slope of the riverbed around Szap splits the Szigetköz stretch of the Danube into two characteristic subreaches. (The inlet of the Gabčikovo tailrace canal now provides a more definite border between the two sections than before Oct. 1992). Due to the hydromorphological conditions, the lower stretch has always been the deposition place of the arriving bed load. As a consequence, the depth and width of the fairway was restricted at a number of locations. (see. Fig. 1) Farther downstream, from Nagybajcs to Gönyü the depth conditions were tolerable, but in a number of crossings the width of the fairway was insufficient.

However, the navigational restrictions have worsened due to the construction of the Gabčíkovo-Nagymaros System. In 1990, there was a crossing with 2.1 m characteristic water depth downstream of Szap at rkm 1808 (Fig. 1). Since construction of the Gabčikovo barrage, a sequence of bottlenecks has developed between rkm 1807-1803. The Patrol Service reported in October 1992 four crossings with 1.8 m draft between rkm 1808-1801. (KHVM, 1993)

3.3 DISCUSSION

Both the Danube Commission and the EEC regulations require 2.5 m draft with a minimum underkeel clearance of 0.2 m. The DC recommends a fairway width of 100 m, and the EEC regulations require a width of 80 m.

In 1990, the fairway conditions between Rajka and Gönyű did not comply at a number of locations with the DC or the EEC recommendations. Sections between rkm 1844-1837 and 1809-1801 were especially of limited navigational value.

The actual conditions of navigation and the number of days navigable with various drafts, are quite different from any kind of design values or recommendations.

4. Traditional Solutions

In the following, the term "traditional solution" is used for engineering measures to insure sufficient navigational conditions by means of structures built in and along the main channel. The goal is to provide a regular fairway with a uniform width and sufficient depth of the low flow bed. The second goal is to prevent any kind of major aggradation or degradation. The channel should be able to carry the bedload and suspended sediment arriving from the upstream sections. The definition involves smaller backwater effects caused by the transverse structures but excludes canalisation by major structures.

4.1 General considerations

Note that any considerations without knowing the design parameters of the waterway and of the vessels and fleets are of limited value. Therefore, the Danube Commission recommendations will be used for guidance.

Any kind of conflicting demands may influence, damage, or annul the feasibility of engineering measures considered. In this pre-feasibility stage no other demand will be involved.

Any kind of comprehensive river training plan should be extended to and performed on a stretch of sufficient length. Therefore, each of the stretches between Rajka-Szap and Szap-Gönyű should be considered as a whole.

Dredging can only be used as an additional, temporary measure, but the final goal is to achieve a dynamic equilibrium of the bed, i.e., a permanent, consistent solution is sought. Experience has proved the numerous drawbacks of excessive dredging. Dredging may be feasible on the short run, but not on the long run.

Possible solutions depend on the time-span involved. Conditions such as those of the channel and sediment transport, differed radically in the seventies from those in the early nineties. Therefore, boundary conditions should be selected and defined with great care.

4.2 Discussion

Those river training principles accepted in the early sixties stood on fairly sound scientific and professional grounds. Since construction work has not fulfilled those plans, there is no way to prove or deny the effectiveness and feasibility of the principles themselves. Along the stretch rkm 1842-1816, from Rajka to Szap, where training measures have been consistently performed, conditions for navigation improved and achieved a tolerable level. Apart from some localities where the width of the fairway does not fit the DC recommendations, no major obstacles or bottlenecks were found.

Laczay (1991) summarised a number of conditions necessary to prepare a new traditional concept. The recommendations included the recalculation of the relevant flows and their longitudinal profiles, to investigate the new sediment balance, influenced by the Austrian barrages and the big gravel pits, especially downstream of Bratislava, to re-evaluate the conditions of the bed material and that of the transverse training structures, to investigate the coincidence or deviation of the thalwegs belonging to the higher and lower flows in the channel, to perform proper model tests with mobile bed.

The report concluded that after performing all the preliminary works listed, some kind of traditional solution is feasible, but permanent maintenance work must be projected as well.

In the framework of the Danube Environmental and Navigation Project, financed by the Government of the Netherlands and carried out by the Joint Venture Delft Hydraulics and Frederick Harris, a feasibility study has been included for the Danube between Rajka and Budapest. Final report for Stretch B1: Szap-Ipoly Mouth was presented in August 1994.

The report (Delft, 1994) summarises the proposals for traditional training solutions for the stretch Szap-Gönyü as follows.

The navigability on this river section can be improved by dredging the shallow areas, and by the application of river constriction works. Before a final solution can be selected, it is essential that more information be collected with respect to the erosion and sedimentation in this section, i.e. the development of the shallow ford sections.

During the *interim phase* the behaviour of the river needs to be closely monitored. Shallow areas in this section are to be deepened and widened by dredging, which implies a continuation of the present strategy. In the *final* phase permanent solutions can be defined to improve the navigability. Such permanent solutions will include a further normalisation of the low-flow river bed by the construction of additional river constriction works (groynes and/or river training walls), and by dredging the shallow areas.

According to this citation, the professional advice of Delft and Harris is very close to considerations explained in this paper. It is a reasonable assumption from the Delft and Harris findings that effective and feasible traditional training solution can be found for the upper stretch between Rajka and Szap as well.

Budapest, 4 August 1994

Literature

Csoma, Laczay, Szolgay, Stančíkova, Nather: Evaluation of the effects of the river training works on the Rajka-Gönyü section of the Danube. VITUKI, Budapest--VUVH, Bratislava, Joint Report. Manuscript, 1978.

Csoma, Kovács,: Impacts of river training woks carried out over the Rajka Gönyü section of the Danube, in Hungarian, with English and German summaries. Vízügyi Közlemények, Hydraulic Engineering, Budapest, 1981, pp. 267-294.

Delft Hydraulics, Frederick Harris, VITUKI,: Danube Environmental and Navigation Project. Feasibility Study Rajka-Budapest, Stretch B1: Szap-Ipoly Mouth. Final Report, August 1994.

KHVM,: Program for developing waterways and ports, in Hungarian. Ministry of Transport Communication and Water Management. Draft. Budapest, June 1993.

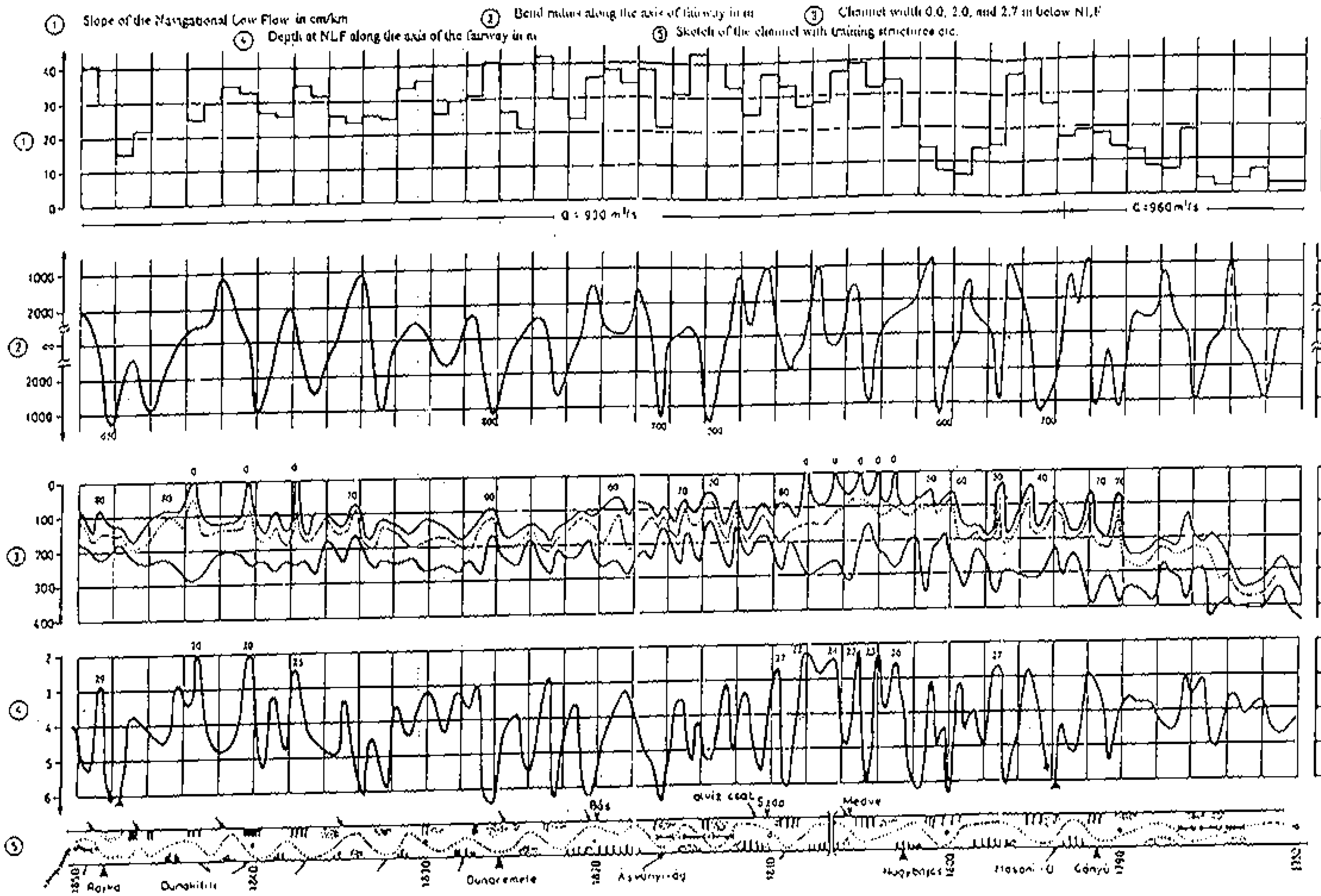
Laczay, I.: Rehabilitation of the Upper-Danube stretch. Conditions for Navigation, Rajka-Szap. in Hungarian, VITUKI report no. 7613/1/1966. Manuscript. Budapest, May 1991.

Zorkoczy, Z.: River training on the Hungarian Upper-Danube, in Hungarian. Vízügyi Közlemények, Hydraulic Engineering. Budapest, 1969, pp. 54-96.

FIG. 1

Channel Characteristics on the Szigetkoz Stretch of the Danube

Lacsay 1991



Annex 9

FLOOD PROTECTION AND THE GABČÍKOVO-NAGYMAROS PROJECT

I. Laczay
Civ. Eng.
Budapest, 5 October 1994

1. Summary and Conclusions

The historical flood of 1965 was successfully retained by the levees along stretch of the Danube within the Hungarian Szigetköz area. No levee breaks or major failures occurred.

By 1977, when the Gabčíkovo Treaty was signed, the levees along the Szigetköz had been reinforced to meet the requirements of the 100 year design flood with sufficient freeboard. An exception was made between Rajka and Dunakiliti where the construction of the planned Hrušov-Dunakiliti reservoir dike was foreseen.

From the mouth of the Mosoni-Danube down to the Ipoly river and the Nagymaros region, floods are mainly contained on the Hungarian side by high banks. The exceptions are the Komárom-Almásfüzitő and Esztergom protecting lines of 18 km in length: two small open areas, 10km long in total, are inundated by higher floods and the crest elevations in the Komárom-Almásfüzitő region do not meet the design requirements.

As part of the G/N Project, a 9 km long section of the Rajka-Dunakiliti reservoir dike was erected on Hungarian territory. The elevation and the dimensions of the dike far exceed those of the protecting levees and cannot be justified by the traditional flood protection standards.

Since the end of 1992, the Čunovo (Dunacsuny) complex is able to divide the floods between the Danube and the Gabčíkovo headrace canal. Therefore, from Rajka to the mouth of the tailrace canal, the Hungarian side faces a lower flood burden. However, the levees downstream from Dunakiliti must be maintained in the proper condition since, in the case of an emergency, the whole 100 year flood is planned to pass the "traditional" route.

To protect the two small, low lying open flood areas, during the G/N Project constructions, dikes for the Nagymaros reservoir were built between Almásfüzitő and Dunaalmás and between Tát and Esztergom. The dikes have not been tailed at both ends and therefore, the areas remain open to floods and so the dikes are useless for protection. Other construction works in the two regions have also been abandoned at an early stage.

In order to retain the stored water upstream of Nagymaros, reservoir dikes and pumping stations have been built on the lower Ipoly river. Without the barrage these structures are of no use and the pumping stations must be substituted by other means of protection for economic reasons.

The Komárom-Almásfüzitő and Tát-Esztergom protection lines must be reinforced. The question is to what degree of safety. On the Northern bank, the reservoir dike has been constructed to a higher level than the traditional design requirements. If Hungary complies with the old, jointly agreed rule of "equal safety on both sides", unjustified excess levels and safety standards will have to be achieved with higher investment costs.

When the Danube was closed at Čunovo in October 1992, the flood release structures were in various stages of construction, far from operational standards. This was clearly shown by the uncontrolled release of the November 1992 flood.

According to Slovak statements, the total nominal capacity of the structures of Variant C, Phase I, (both the Gabčíkovo and Čunovo complex), is sufficient to release the 100 year and 1,000 year floods. However, taking into consideration the originally planned safety factors (structures partly closed owing to breakdown), in Phase I there is a 17% shortage in capacity when releasing the design floods.

Moreover, the Čunovo complex in Phase I cannot release by itself the 100 year flood as the Dunakiliti weir could in the case of an emergency.

Apart from the distribution of the floods along the Szigetköz area, there are no other benefits for the Hungarian side from the G/N Project structures. A sufficient degree of safety could have been and also will be achieved by traditional means of flood protection.

In Phase I, the structures at Čunovo are not even equivalent to the Dunakiliti weir in terms of its ice release capacity. Actual procedures of operation are unknown, flood fighting information presented to the Hungarian partners is insufficient and refers to preliminary measures only. These shortcomings were proven by the dangerous events during the ice flow in January 1993. Until Phase II comes fully into operation, ice release remains the worst aspect of Variant C, Phase I.

Due to its various shortcomings, insufficient information, etc., the Čunovo complex in Phase I, is and will remain provisory. Hope and luck are the two key words of operational orders until Phase II is finished. Thereafter, flood and ice release may fulfil the original capacities for the Gabčíkovo complex and the Dunakiliti weir.

2. Historical Review

2.1 FLOOD PROTECTION PRIOR TO 1977

Inhabitants of the Carpathian Basin learned to protect their settlements and assets from flooding as early as the 13th century. More comprehensive work started in the 19th century. Construction in this region has not and will never be finished.

Great plains such as the Szigetköz area were protected from flooding by constructing levees along the rivers. The early engineering measures were more or less based on a "trial and error" method. Dikes were usually built to resist the greatest flood observed. When a flood overtopped or damaged the levees, reconstruction work adapted them to resist the latest conditions. This continued for many decades until the dimensions of the construction reached an equilibrium.

Along the Danube in the Szigetköz (*Figure 1*), the first continuous levee system was built after the 1883 flood. It had a 1.0 m freeboard and 4.0 m crest. Due to the backwater effects of the Danube floods, the left bank of the Mosoni Danube was also protected along a length of about 30 km.

The levees, both along the Danube and the Mosoni Danube, were damaged by the 1887 and 1899 floods. The reconstruction work, finished in 1906, raised the crest level to 1 m above the 1899 flood level.

Decades later, the 1954 flood caused four levee breaks along the Danube. About 200 km^2 of the Szigetköz area (roughly 300 km^2) was inundated including 21 settlements where 1,394 houses were destroyed.

The basic data from the event is summarised in *Table 1*. The cost of flood prevention was 141 million HUF, the damages in the Szigetköz area amounted to 383 million HUF. This means that in the Slovak Memorial (chapter. 1.31), the damages are seriously overestimated (1.5 billion U.S.$ roughly equals 15 billion HUF).

After the 1954 flood, reconstruction and improvement of the levee system were founded on a more comprehensive statistical basis. The 100 year flood levels were calculated and named as design standards.

Depending on the possible effects of the changes in the channel and floodplain morphology and in the vegetation cover on the watershed, etc., the 100 year flood levels were regularly revised. The official design flood levels from 1957, 1964 and 1976 are provided in *Table 2*, the latter is still in use (see the consequences and the contradictions with the G/N Project requirements when discussed later).

Note that all the design levels were discussed, amended, etc., in the Danube Subcommittee of the Hungarian/Czech/Slovak Border Water Committee and approved by the Plenipotentiaries.

According to the new guidelines, reconstruction of the levees was performed in 1955-1961. The structural development of the levees is given in *Figure 2*.

Owing to the reinforced levees and to the effective flood fighting, the historical Danube flood of 1965 caused no major failures or breakthroughs along the Szigetköz reach of the Danube.

During the flood, the maximum number of labour force needed between Rajka and Nagymaros was 4,500 persons and a total of 130,000 workdays. The costs of flood fighting in the stretch between Rajka to Esztergom were 56.3 million HUF (Toth, 1994). Along the Hungarian reach of the Danube, flood fighting costs amounted to 350 million HUF, the total cost of the damages was 366 million HUF and the estimated production loss was 290 million HUF. This gives a total of about 1,000 million HUF (Sipos, 1966).

The data above clearly proves that the costs/damages given in the Slovak Memorial (Chapter. 1.33) are again seriously overestimated (164 million U.S.$ equals 1,500 million HUF).

In 1965, 94 % of the levees (in length) did not meet the safety requirements of the 100 year flood. They lacked 0.4 - 0.6 m in height and about 25 m^3/m in "bulk" (Toth, 1994). Apart from these facts, it is not clear why the Slovak Memorial in Chapter 2,81 compares the situation in 1965 with the G/N Project improvements.

The levees along the Szigetköz Danube were reinforced during 1967-1977. By 1977, they fulfilled the requirements of a 1.2 freeboard above the 100 year flood level (1964, *Table 2*). Sufficient cross-dimensions and the necessary auxiliary structures to prevent seepage had also been built. The exception was along the stretch Rajka-Dunakiliti, where construction of the Dunakiliti-Hrušov reservoir dike was foreseen.

Along the left bank of the Mosoni Danube, only minor reconstruction works took place after the 1954 flood. In 1965, damages could only be prevented by heavy fighting and with great difficulty. In 1977, the flood prevention system did not meet the design requirements.

Downstream of the mouth of the Mosoni Danube to Nagymaros, the right bank of the Danube is fairly high. That is why flood prevention works have been constructed and flood fighting is necessary along 18 km only.

Since the middle of the 19th century, a protective line 14.3 km long has been established from Komárom West to Almásfüzitö East. The protected area is 22.6 km^2. Adjacent on the downstream side is an open floodplain of 7.2 km^2.

By the mid-sixties, after repeated reinforcement, railway construction, etc., the flood prevention system consisted of 4.5 km high banks, 0.6 km public road, 4.6 km railway line, 0.4 km flood walls and a 4.2 km levee. In 1977, only 1.0 km of the levee met the design requirements. For example, the railway line equalled more or less the 100 year flood level with no freeboard.

The open floodplain between Almásfüzitö and Dunaálmás is cut through by the Esztergom to Komárom railway line as well as receiving the discharge of two creeks. Owing to the backwater effects of the Danube floods, dikes along the creeks of some length had to be built. Lower floods can be localised along the railway line.

Between Tát to Esztergom, (about 10km in length) another open floodplain is situated. Lower floods can be localised along the Tát-Esztergom public road protecting roughly half the 12.4 km^2 open area.

In Esztergom a protecting line was built in 1913. It runs along the right bank of the Danube arm embracing the Primas island. The eastern part of the line consists of a protecting wall, 1.5 km long, connected to a 1.9 km long levee which ends at the high bank away from the town. The protected area is 1.6 km^2 within the town. By the mid-sixties, both structures had been reinforced and met the requirements of the 1957 design flood with 1.2 m freeboard.

The 1954 and 1965 floods were successfully fought although with enormous effort. Nonetheless, the low-lying unprotected riparian parts of Tát and the recreational and other facilities on the Primas island suffered serious damages. Until 1977, no further protecting works were performed.

2.2 The G/N Project: Plans and Flood Protection Works

2.2.1 Background

The history of planning, designing and constructing flood protection levee systems with the auxiliary structures necessary, the experiences gained whilst fighting the floods, finally led to accepted levels of safety. Nowadays, these are supported by economical considerations, cost/benefit analyses, etc., as well.

The accepted design level for these traditional systems is mostly based on the event with a probability of 1% i.e. the one in 100 year flood. On smaller rivers and/or along less valuable areas some countries use the 50 year or even the 25 year flood as their design requirement.

Following these traditional measures, large river engineering systems, (hydropower plants, reservoirs, etc.), have become more prominent. Considering the life span of these structures and the greater risks possible, the design requirement went up to the 1,000 and 10,000 year flood levels/discharges.

Operational reservoir levels may exceed the flood levels (Nagymaros and Dunakiliti as planned). A number of uncertainties necessitate a higher freeboard (e.g. 2.5 m) as opposed to the traditional levees (0.5-1.5 m).

When a river is exploited using new methods, the traditional levees are reinforced to reservoir dikes, floods are partly diverted etc.. It is true that the growing value of assets on the plains protected by levees may validate a higher degree of safety but surely not a leap of a factor of ten from the 100 year flood to the 1,000 year flood.

To reinforce a traditional flood protecting system beyond a realistic degree of safety cannot be justified "suo jure". The interests of other kinds of river exploitation may, as a side benefit, improve the flood protection system, but primarily it is constructed for the other river use.

2.2.2 G/N Project works performed affecting flood protection

In compliance with the Mutually Agreed Plan (MAP) of the G/N Project, the dike of the Dunakiliti-Hrušov reservoir was constructed on the right side of the Danube. The dike crosses the border at Rajka and has a 9.9 km long section on Hungarian territory. The parallel old levee was demolished and substituted as a protection line by the reservoir dike.

The crest of the dike is 2.5 m higher than the maximum operational water level in the reservoir (*Figure 3*). Therefore, it exceeds the presently valid, traditional design flood level (including the freeboard) by 5m at Dunakiliti and by 2.5 m at the border.

The cross-section, the "bulk" of the reservoir dike is around 175 m^3/m on average, that of the traditional levee in the same section was 50 m^3/m. In the lower Szigetköz, where the protected ground is lower, the traditional bulk (meeting the traditional design requirements of course) is around 90 m^3/m (see *Figure 3* for a visual comparison).

To provide a safe access to the Dunakiliti weir, a 2.3 km long road raised above the design flood level was built across the right flood plain. The road crosses the side-arm Szigeti-Duna over a 300 m long bridge.

At the inner end of the access road, an earthfill plateau with the weir operation building on top was built. The road and the plateau restrict the original flood conveying cross-section. An additional backwater effect comes from the hydraulic resistance of the weir itself.

The consequences have been proven by the 1991 high flood with a peak-flow of about 9,000 m^3/s. This was the last big flood passing the "traditional route".

The peak levels along the Dunakiliti stretch were some 0.3-0.4 m higher than those in the upstream and downstream sections (VITUKI, 1992).

Between Dunakiliti and the Mosoni Duna mouth, the flood protecting levee has not been reinforced during the construction of the G/N Project.

Along the lower stretch of the Mosoni Danube, reinforcement work started in 1981 and is finished on a 9 km long section. The work was a national investment from the flood protection budget and is due to continue on the 21 km line, as yet unfinished.

In the Nagymaros reservoir, the calculated 100 year retained flood levels and the crest heights exceeded the traditional design requirements (*Table 3*). Reinforcement works were planned and partly completed to these higher levels.

Along the Komárom-Almásfüzitő protection line, works had been started but were then abandoned at an early stage in 1989. The partly built structures did not improve the former protection. At Almásfüzitő, along the housing development, the former seepage control structures were removed and only partly replaced. Therefore, the 1991 flood caused more seepage problems than before.

The new dike built along the open flood plain between Almásfüzitő and Dunaálmás has not been finished and cannot be put into use.

On the Tát-Esztergom section the calculated G/N Project flood level exceeds the 1976 design value by 0.5-0.6 m (*Table 4*). A reservoir dike was planned from Tát to Esztergom with a water intake/pumping outlet to and from the excluded side-arms.

By 1989, the dike with its full dimensions was complete along a 7 km length without being tailed at both ends. Neither have the control structures been built, so the former flood conditions have not changed, the open plain will flood and the unfinished dike has no protective value.

According to the G/N Project plans, the Ipoly river was to be dammed for 15 km by the Nagymaros barrage. By 1989, a 9.7 km long dike with the necessary rip-rap protection, seepage canals and pumping stations were completed.

2.3 State of affairs after abandoning the G/N Project

Due to the G/N Project activities on Hungarian territory, a number of flood protecting and/or flood influencing structures have been partly constructed.

After abandoning the G/N Project, those responsible for flood protection measures on the Danube immediately started to assess the new situation in order to provide proper investment plans for the decision makers and to prepare/perform reinforcement works where urgent.

If we consider the traditional protection system along the right bank of the Danube from Rajka to Esztergom and on the lower Ipoly river, the following main problems have to be faced.

i. Since the early seventies some flood protection investments have been postponed. Most of these works were restarted during the G/N Project activities. To fulfil the decades-old requests of the inhabitants in the affected communities, these works must be finished.

ii. The Agreement on the Border Waters Management signed on 31 May 1976 declares in Articles 3 and 9 that, "... without mutual understanding no such water management activity should be commenced that would cause unfavourable changes in the flow/water conditions agreed upon.". This statement involves the principle based on decades old common experience that flood protection levees require equal crest heights on both banks. Otherwise, the lower levee would face more failures, seepage problems and/or breakthroughs during high floods.

After Hungary abandoned the G/N Project, the reservoir dike along the left bank upstream of the Ipoly mouth was fully implemented. Consequently, when Hungary finishes the reinforcement works in the Komárom-Almásfüzitö and Tát-Esztergom areas to traditional standards there will be a 0.2-0.6 m deficiency in the levee crest levels (*Table 3*).

For those responsible there are two alternatives: either to accept the unfavourable situation described above, or to pay unjustified investment costs to achieve an equal level of safety.

iii. Between Rajka and Dunakiliti, the reservoir dike provides excess safety against floods. In the long run, the earthfill structure will cause additional maintenance problems as described under iv.

iv. Downstream of Dunakiliti the flood conditions are/will be influenced by the following factors:

- the Čunovo reservoir operation i.e. the distribution of the flood waves (discussed in Chapter. 3);
- the prospective regulation of the main channel (the "old" Danube) including some kind of stabilisation of the characteristic shallow fords;
- the rapid growth of vegetation on the point bars, caused by the long-lasting insufficient water release;
- the confluence of the distributed floods at Palkovičovo (tailrace canal and the Danube), etc.

v. In the case when extreme hydrological events coincide with extreme operational failures at the Gabčikovo plant, the 100 year flood is planned to take the traditional route along the Danube. That means that the flood protection levees from Dunakiliti to the Mosoni Danube and back up the Mosoni Danube may have to face the 100 year flood as before. Therefore, the flood distribution between the bypass canal and the Danube does not reduce the responsibility, the costs etc. to maintain the protection system in its former condition. On the contrary, earthfilled levees, when not wetted for a long time, are more liable to deteriorate.

vi. A special problem arises along the Ipoly river where structures were implemented assuming long-lasting high storage levels. Due to the ommitance of the effects of the Nagymaros barrage and according to the economic and operational/maintenance reasons, some rip-rap should be removed and the two pumping stations should be replaced by simple gravitational inlets

vii. The 100 year flood levels have been recently recalculated using the 1921-1990 time series instead of data from 1901-1970 used for the 1976 design levels. The resulting levels are higher at Bratislava by 19 cm, at Rajka by 25 cm, at Dunaremete by 39 cm and at Komárom by 19 cm. The upper limit of significance was exceeded at Dunaremete only, in agreement with the peak levels of the 1991 flood. At Gönyű, a decrease of 15 cm was calculated (Laczay, 1991)

viii. The traditional design values are valid now and will be in the future. Assessing the results of the various calculations and approving the prospective design values is the task and responsibility of the bilateral Border Waters Committee, just as before.

Considering the history and the current situation of flood protection works as presented, one may conclude that the G/N Project is/was not the only way/tool to solve the problems of flood protection and/or to improve the safety of the levee system. Apart from the flood distribution between the Danube and the bypass canal, not many benefits for the Hungarian side can be found. On the contrary, when releasing the floods/ice from the Čunovo reservoir, dangerous situations may ensue. These are discussed in the following sections in more detail.

3. Reservoir Operation

3.1 FLOOD RELEASE

3.1.1 Dunakiliti weir (original plans)

The Mutually Agreed Plan of the G/N Project specified the flood release, under various operational conditions, through the Gabčíkovo complex and/or the Dunakiliti weir. The first distribution of the design floods between the Gabčíkovo Complex and the Dunakiliti Weir was presented in the "Preliminary Operational Order" in 1978 (OVIBER, 1994).

In the release, the Dunakiliti Weir with seven openings (six gates and the ship lock) and the Gabčikovo Complex with 8 turbines, 2 ship locks and their filling/releasing systems would have taken part. The safety regulations were divided into two groups. One was the minimum freeboard available in the reservoir between the actual retained flood level (i.e. the 100/1,000/10,000 year flood) and the crest of the dike during the release process. The second was the rate of closure of the structures at both the Gabčíkovo Complex and the Dunakiliti Weir when releasing the given flood. There is a certain probability that a given design flood occurs and also a probability for each structural failure. The two types of events may be taken as statistically independent, and so the recurrence interval of the joint occurrence is much longer than that of the two independent events.

For these safety reasons, the Gabčíkovo Complex release was planned to pass primarily through the power plant with 8 turbines. The navigation locks served as emergency reserves. The Dunakiliti Weir was planned to operate with 5 openings during the 100 year flood, 6 openings during the 1,000 year flood and with 7 openings during the 10,000 year flood.

Based on these considerations, the Gabčíkovo Complex/Dunakiliti Weir quotas for the design floods were properly calculated.

The operational levels of both the Gabčíkovo Complex and the Dunakiliti Weir as well as the safety policy was later reconsidered and the results were presented in the "Temporary Order of Operation" in 1989. The Gabčikovo Complex release was planned to pass through 4 turbines and one ship lock with the filling-releasing system during the 100 year flood and through 4 turbines and 2 ship locks during the 1,000 year flood. The Dunakiliti Weir safety closures remained as before but the operational levels were changed.

Note that the number of turbines taking part in the flood release was 50% of the Gabčíkovo Complex capacity, the ship locks were used to 50% and 100% capacity and the Dunakiliti Weir was supposed to be closed at 28.6% and 14.3% respectively. (The release of the 10,000 year flood was not rechecked.).

According to the calculations, the Gabčíkovo Complex and the Dunakiliti Weir provided a suitable release of the design floods, with proper safety in the case of coinciding structural failures and with sufficient freeboard available.

It was also checked by calculations and by hydraulic scale model tests whether in the case of an emergency the Dunakiliti Weir alone could release the 100 year flood. It was found possible either at 131.1m asl. operational level with a minimum freeboard of 1.5 m in the reservoir using 7 openings, or at 132.1 m asl. level with a minimum freeboard of 0.78 m using 6 openings (navigation lock closed).

3.1.2 The Variant C, Phase I

When Hungary abandoned the G/N Project, the Dunakiliti Weir was practically ready to use and took part in the release of the 1991 flood. The Dunakiliti-Hrušov reservoir could have been finished and brought into operation by completing the final task i.e. by closing the Szigeti- Duna branch and the main channel itself.

In contrast to the MAP, the Danube has been closed at Čunovo, named as Variant C, and the new reservoir came in to operation in late 1992.

There is a basic difference between the two solutions: the Dunakiliti weir was ready to release all the floods as planned, while the structures at Čunovo were in various stages of construction when the Danube was closed.

Information on the Variant C is presented in the Independent Experts Report (CEC WGR, 1992).

The structures are described in the Slovak Memorial in detail.

The closure of the riverbed started on October 23 1992 and was completed on October 27. By November 9, the crest level of the dam had risen to the full height of 133.8 m asl. with a width of about 40 m. Thereafter any kind of flood could only be released through the Gabčíkovo complex and through the structures under construction at Čunovo.

Closing the Danube caused a very rapid and drastic water level drop of about 3 m in the downstream section (WGR Annex H). As an immediate consequence a number of bank slides, slope protection damages etc. occurred along the right bank and in the side arms. The estimated damage i.e. the cost of repair amounted to 10 million HUF (Report of the District Water Authority).

The Working Group visited the site of works on November 22. On November 21 the Slovak experts (Mr. J. Binder) presented a written statement about the release capacities of the various structures. These facts and statement became more important since at the same time the biggest ever November flood was developing along the Szigetköz Danube.

The WGR stated (page 7) that on November 22 "... a barge about 50 m long sank in front of the bypass weir closing two-and-a-half of the openings". Some water was spilling through these three openings while the fourth one was completely closed.

The stated capacity in WGR Annex D was "...at present after repairing the damage" 300 m^3/s and after stabilisation of the spillway, that is after January 1993, 600 m^3/s.

Referring to the flood plain weir (WGR p. 8): "Fifteen of the sector gates were mounted, but the concrete work was not done. Five of the gates were lying behind the openings on the ground. Ten of the openings had about 10 m wide bed protection on the downstream side.... The rest of the gates had no tail-water protection.... The protective earth dam upstream of the structure was widened and heightened to about 131 m asl."

As stated in Annex D: Twenty segments at water level 129.0 asl. from January 1993 (760 m^3/s), at 131.1 m asl. from April 1993 (4,800 m^3/s). "These values are only valid if weir spillway is completely fortified."

At the Gabčíkovo complex (WGR p. 5): "One of the ship locks was operating while the other one was being tested after a period of repair. Two of the turbines were operating with a discharge of 500 m^3/s and 100 m^3/s respectively.

As stated in Annex D: according to the operational conditions and using one or both locks to release the flood, capacity varies from 510 m^3/s to 3,440 m^3/s. The value given in Annex F is 1,970 m^3/s. The capacity of the hydropower plant is given "presently" as 1,060 m^3/s and by 24 November 1992, as 1,560 m^3/s. Annex F states that the capacity on 21 November 1992 was 1,220 m^3/s.

As the peak flow of the flood was approaching the site, without any warning to the Hungarian partners in flood fighting, the inundation weir was somehow opened on 23 November 1992 (one day after the above findings!). That is, the provisional dam on the reservoir side must have been removed or was simply washed away. An absolutely uncontrolled release began to fill up the downstream main channel and the side-arms.

Three of the gates lying on the ground were lifted up and washed away. The flood damaged the structures that had not yet been finished, especially the downstream floor of the bypass weir and that of the flood plain weir. The flood caused more damages in the bank protecting structures, the rip-raps, cross dikes in the side-arms etc. The damages on the Hungarian side have been estimated at around 11 million HUF (Report of the District Water Authority).

Downstream of the Čunovo complex at Rajka, the former release of 250 m^3/s increased by 25 November to a peak flow of 2,250 m^3/s in the Danube. That means that a discharge of 2,000 m^3/s found its way somehow through the inundation weir. The total peak of the flood has been estimated as about 6,000 m^3/s at Čunovo. If so, about 3,500-4,000 m^3/s peak discharge was released through the Gabčíkovo complex. Taking into account both ship locks and two or three turbines, the task could be achieved but with some difficulties.

The experience of the November 1992 flood clearly proves that the structures at Čunovo, after hastily closing the Danube, were in no condition to control the flood release. More serious damages were escaped by mere luck.

The Slovak experts stated (WGR Annex F) that by January 1993, the Gabčíkovo complex would be able to release 5,200 m^3/s (no quota for the ship locks was specified) and that the Čunovo complex would be able to release 6,085 m^3/s.

In July 1993, there was a lower flood with a peak flow of about 5,100 m^3/s at Bratislava, about 2,300 m^3/s at Rajka and about 4,900 m^3/s at Medvedov. That means that the maximum release through the Gabčíkovo complex was around 2,600 m^3/s.

Just as in November 1992, on 18 July 1993 around noon without any warning, the gates of the flood plain weir were so rapidly opened that by nightfall the former 350 m^3/s release exceeded the discharge of 1,600 m^3/s. At that time, the discharge at Bratislava was around 3,200 m^3/s. The release through the gates decreased the next day to 750 m^3/s but then, on the morning of 21 July, the release increased again to 1,600 m^3/s.

The rapid changes in the water levels severely damaged the right-side branches to the same extent as in November 1992.

As presented in Chapter 2.3, the Agreement on the Border Water Management declares the need for joint actions and mutual understanding when fighting floods on the Danube. This co-operation ceased unilaterally when the Variant C, Phase I came into operation.

Hungarian officials in the Danube Subcommittee initiated a discussion on this topic where the following measures were agreed upon.

From 25 January 1993, the Slovak partners were to submit the daily discharge data released into the Old Danube, the Mosoni Danube, the seepage canal and through the Gabčíkovo complex into the Danube at Palkovičovo (Szap).

The experience of the flood release in July 1993 proved that the Slovak officials did not consider the data of the flood plain weir operation as included in the above agreement.

After repeated requests from the Hungarian side, on 20 October 1993, Slovak officials agreed to submit the data of modifications to operational measures immediately after they are performed. Note that, Hungary has still not been informed of the operational levels of the reservoir.

After the commissioning of Variant C, Phase I, the guidelines for joint flood fighting in the Dunakiliti region were revised and approved by the Border Water Commission in 1993. As part of the revision, Slovak partners presented operational guidelines to distribute the floods between the Gabčíkovo and Čunovo complexes. Between a total discharge of 5,000 m^3/s and 8,500 m^3/s, the quota for the Gabčíkovo complex remains at 3,000 m^3/s and at the discharge of the 100 year flood 10,600 m^3/s, the quota is 4,820 m^3/s.

This data is in agreement with the fact that since the November 1992 flood, the ship locks at Gabčíkovo have not been used for flood release. Taking into account the well known failures and breakdowns in the ship locks, it is quite understandable that up to the capacities of the six turbines, the locks are not involved in flood release.

The release quotas presented for the 100year flood fit with the capacities of the structures in Phase I (WGR Annex F) with a safety margin of 400 m^3/s and 300 m^3/s at Gabčíkovo and the Čunovo complex respectively. If we take these capacities as granted and then compare them to the requirements in the original plans, some problems arise.

Considering the possible breakdowns of the various structures, a distribution of the design floods has been calculated including some safety factors (see Chapter 3.1.1). No similar calculations for

Variant C, Phase I are known or have been presented to the Border Water Committee for approval.

Based on the same safety considerations, subsequent calculations have been carried out by Hungarian experts (OVIBER, 1994).

The assumption was made that 25% of the openings at the Čunovo complex would be closed due to breakdowns during a 100 year flood 25% of the bypass weir and 10 % of the floodplain weir during a 1,000 year flood. The Gabčíkovo complex (now with 6 turbines, 2 ship locks and the filling-releasing systems) was assumed to operate at the same percentage of safety as in the original plan. Taking also into consideration the minimum freeboards i.e. the permissible headwater levels, the calculated capacities during a 100 year flood are 5,310 m^3/s for the Čunovo complex and 3,530 m^3/s for the Gabčíkovo complex. The total is therefore 8,840 m^3/s as opposed to the 10,600 m^3/s design flood.

The same values for the 1,000 year flood are: 6,150 m^3/s (Gabčíkovo) and 4,630 m^3/s (Čunovo) which gives a total of 10,780 m^3/s as opposed to the 13,000 m^3/s design flood.

This means that the calculated release capacities in Phase I are only 83% of both design floods.

The fact that in the case of emergency, the Čunovo complex cannot release alone the 100 year flood (as could the Dunakiliti weir) qualifies the Variant C Phase I as a provisional solution. An additional reason for its provisionality is proven above: neither Čunovo nor the whole complex can handle the 100 year flood with the original safety precautions.

By the end of 1995, all structures of Phase II at the Čunovo complex should be installed with an additional capacity of 6,300 m^3/s (WGR Annex F). The total discharge capacity will then be about 17,600 m^3/s (and not 19,000 m^3/s as written in the WGR, Annex F), including the 5,200 m^3/s release capacity at Gabčíkovo. By then the Čunovo complex and the whole system will fulfil the release requirements of the original plans.

However, in the meantime, higher degrees of uncertainties and flood dangers are to be faced. On the Hungarian side, due to the lack of information about the operation of the reservoir, a number of additional problems can be foreseen. Therefore, a higher than necessary level of flood alert must be applied during "normal" flooding conditions, with all the additional costs, more manpower, etc. that this will entail.

3.2 Ice Release

3.2.1 Background

Ice-floes usually develop on the tributaries and on the upper section of the Danube and then drift downstream. If the densely drifting ice stops for some reason, a solid ice cover builds up upstream. If the upstream end of the ice cover catches more and more ice-floes, an ice jam blocking the channel may develop. The arriving flow is forced to gain more hydraulic head to pass i.e. the water level will rise. If the ice jam starts moving before the water rises to a dangerous level nothing serious will happen. If not, the flow levels can exceed the top of the protecting levees, high banks etc. and flooding will develop.

Over the Szigetköz Danube, the climate, bed morphology and slope conditions reflects the changing ice regime. Due to the favourable effects of the river training activities performed since last century, the danger and the frequency of the icy floods have significantly decreased.

The last big icy flood occurred in 1956, the last solid ice cover on the Szigetköz reach developed in 1963/1964 (VITUKI, 1989). During the break-up of the solid ice in February 1964, a couple of smaller ice jams formed between 1,826-1,760 rkm with no major consequences. Since then, up until 1987, only ice drifts of various densities occurred, except during five winters when there was no ice. During the last seven winters, no ice phenomena was observed on the Szigetköz Danube.

The more favourable ice conditions are due to the reduction of ice discharge by the river dams in Austria, as well as the observed changes in the water quality and in the water temperature (Deri, 1985, 1993).

From the point of view of icy flood prevention or protection, there was and there is no reason to consider the structures of the G/N Project as necessary. On the contrary, reservoirs provide lake-like conditions for freezing and the developing ice can amount to enormous volumes. Ice release from reservoirs is the hardest operation to perform, it must be planned and executed with great skill and care. For this reason, ice release is discussed in the following sections in greater detail.

3.2.2 Dunakiliti weir (original plans)

The ice conditions of the planned Dunakiliti-Hrušov reservoir and the ice-release through the Dunakiliti weir have been investigated for many years by both analogue and hydraulic scale models (Starosolszky, 1989).

The reservoir, starting from the coastline freezes inwards just as a lake. During almost every winter, a solid ice cover up to 10-30 cm thick would have developed. Dangerous situations were foreseen at Bratislava at the upstream end of the reservoir where drifting ice may have caused ice jams.

Due to the planned power generation, downstream of the power plant in the tailrace canal and on the Danube down to 1,805 rkm, ice was not likely to develop.

The tailrace of the Dunakiliti weir (the Old Danube) was also regarded as ice free or at least only frozen in at very low water levels. This meant that sufficient channel capacity would exist to carry the ice released through the weir if the bed was kept free from vegetation and in a stable condition.

The procedure of ice release depends on conditions during the break-up period. Accordingly, the Order of Operation (1978) prepared in the process of planning dealt with the following measures. (OVIBER, 1994)

After the solid ice cover in the reservoir has developed, it must be kept undisturbed as long as possible. The water level is raised by 0.5 m above the 131.1 m asl. No peak power generation is allowed, which would cause water level oscillations breaking up the ice.

If possible, the ice cover must be left to thaw on the spot.

In case of a considerable increase of water discharges and/or strong ice drifts from upstream, an ice free corridor in the reservoir along the former main channel must be provided by ice-breakers.

In this case the further procedure is as follows.

The broken ice can only float downstream at sufficient velocities, estimated at about 1.0 m/s. Velocities can be generated by providing a greater water surface slope. Therefore, the reservoir level (including the headrace canal) must be lowered to 128.0-128.5 m asl. i.e. the appropriate rate of flow must be released. Thereafter the power generation stops.

The broken ice must be gradually let down through the open Dunakiliti weir. The water level must be kept as low as 128.0 m asl. or must be energetically utilised when rising.

The number of open gates at various discharges and the precise timing of the releasing cycles were also specified.

A releasing cycle was planned to last about 8 to 12 hours at 900-1,500 m^3/s arriving flows. The main cycle consisted of a rising-falling discharge diagram with a peak release exceeding the arriving flow, "carrying" the ice-floes below the raised-up sector gates through the weir. Due to the peak operation, at the end of a cycle the reservoir level was planned to decrease below 128 m asl. Thereafter all structures were closed until the level increased back to 128 m asl. and the new cycle began.

There is no need to mention that such a process requires precise and faultless handling of the gates.

In order to direct the broken ice towards the Dunakiliti weir, a "ridge" or a dike along the left bank of the Danube up until 1,847.5 rkm had been built. The outlets of the Dunakiliti weir as well as the downstream floor have been shaped to meet the requirements of ice release.

Based on the results of further hydraulic scale model tests, in front of the Dunakiliti weir in the reservoir, so-called ice catching islands have been built. The aim was to break up the very large sheets of ice avoiding the possible danger or failures when handling these too large ice-floes at the weir.

In case of emergency, ice from the headrace canal was planned to be led downstream through the ship locks at Gabčíkovo.

The main principles of ice release provide some idea about the planned procedure. These are to be compared with the measures prepared for ice release operations at the Čunovo complex in Phase I.

3.2.3 Ice release: Variant C Phase I

Slovak experts presented to the Danube Subcommittee of the Border Water Committee on 19 March 1993, information about the release of icy floods at the Čunovo complex. The information has been included in the Flood Fighting Guidelines of the Dunakiliti region in para. 3.3 as follows.

(Translation from the Hungarian version.)

"In the present status of the structures at 1,857.750 rkm, in winter operation mode for flood release four basic situations are possible:

1. ice-free water surface in the reservoir and in the headrace canal while ice drift begins from Austria;

2. the reservoir and the headrace start to freeze in until the possible development of a solid ice cover; no ice drift from upstream;

3. as before but with ice drift starting from Austria;

4. ice jam develops downstream of Bratislava.

In all cases the water level in the reservoir is assumed to be raised to ensure higher specific discharges through the barrages and in the last case an additional 1.0 m level increase with the aim to lift up and to release the ice jam"

Note that

- raising the water level is a preliminary measure only (see 3.2.2). The starting operational level and the additional height is not specified. The meaning is possibly 131.1 m asl. + 0.5 m + 1.0 m. = 132.6 m asl.

- Reservoir level of 132.6 m asl. means 1.2 m freeboard at Čunovo. The flow is certainly retained in the reservoir. In case No. 4, the ice jam develops further upstream where the freeboard may be unsatisfactory i.e. less than 0.5 m.

- There is no information on the actual planned operation of the structures. "Barrages" may refer to the openings of the floodplain weir and the bypass weir.

Supposing a similar release operation as originally planned at Dunakiliti, the following problems arise.

Sill levels of the structures are: 120.7 asl. at Dunakiliti, 126.5 m asl. at the Čunovo bypass weir and 128.0 m asl at the inundation weir. For comparison: the Dunakiliti sill equals roughly the level of the 930 m^3/s low flow (in the "original" or pre-Čunovo conditions), the bypass sill is higher by roughly 3m and that of the inundation weir is higher by 4.5 m i.e. equals more or less the ground level.

Ice release at Dunakiliti was planned in detail for an arriving flow of 900-1,500 m^3/s, after the reservoir level was lowered to 128 m asl. During the release cycle, the discharge diagram went up to 3,000 m^3/s at a 1,500 m^3/s arriving flow which caused a level decrease to below 128 m asl as well.

For precise handling of the flows, on top of the head control gates (sector gates), tilting gates have been mounted. During the actual release, according to the flow 2/4/6 gates were planned to be raised above the water and ice. That provides at least 7 m water depth above the sill.

At a tentative release level of 130 m asl at Čunovo the total capacity including the bypass weir and the Mosoni weir was stated as much as 3,400 m^3/s (WGR, 1992, p.13). Higher operational level is not likely since the slope and the generated velocities to carry the ice would not be enough, in addition the retained flow could cause insufficient freeboards. A lower operation level does not fulfil the original order of operation (to release a peak flow of 3,000 m^3/s), and would provide less than 2 m water depth above the sill. Insufficient water depth can be very dangerous if the ice floes stop and "sit down" on the sill. The 2 m depth as opposed to the 7 m at Dunakiliti is not really comforting.

Moreover, at Čunovo there are no tilting gates mounted. Therefore the whole operation must be performed by lowering/raising the sector gates themselves, not constructed for such delicate water level control.

In the information submitted, there is no word about the ice-breaker actions to provide a corridor for the broken/drifting ice. The fact is, no ridges have been built upstream of Čunovo to divert the ice floes towards the releasing structures. The route of the arriving ice is therefore uncontrolled or rather only influenced by the route of the flow.

Together with the weak operation procedures, the lack of ridges could have been the reason for the events in January 1993 (ÉDUVIZIG, 1994). When the Gabčíkovo plant is in operation, the main route of the flow is directed towards the headrace canal and the Čunovo structures are in "shadow". Therefore on 4 January 1993, when the ice drift began and attempts were made to release the floes through the weir, the ice accumulated in front of the structures and the ice flow turned to the headrace canal as well. Upstream of the Gabčíkovo complex between 11.2-13.4 km a 1.5-2 m thick ice jam developed. The Slovak Navigational Authorities in announcements 87/131/93 and 136-131/93 suspended the navigation between 1,862-1,852 rkm, that is on the 10 rkm upstream of Čunovo from 8 January to 15 January. The reason is unknown why only here, since the ice jam was some 20 km more downstream in the headrace. The problem was finally solved by the thaw. Ice floes ceased to develop and the ice jam slowly disappeared. Former actions by ice-breakers were unsuccessful.

From the above comparison of the Čunovo structures and the Dunakiliti weir, it can be concluded that in terms of ice release, the Variant C Phase I structures cannot fulfil the requirements and the operational orders of the original plans. Therefore, Phase I is not only provisional, but with regards to ice release, it is a weak provision. The most important order of operation is the HOPE that no major icy flood would occur until Phase II comes in to operation.

Thereafter, with the new structures, the system may be adequate to comply with the original standards. However, proper and detailed orders of operation must be prepared and approved by the joint Committee and by the Plenipotentiaries.

4. Acknowledgements

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References

CEC/CSFR/HU: Working Group Report of Independent Experts on Variant C of the Gabčikovo-Nagymaros Project, (manuscript). Budapest, 23 November 1992.

Déri, J.: Changes in the ice regime of the Danube river, (in Hungarian with English summary). Vizügyi Közlemények (Hydraulic Engineering), Budapest, No. 4, 1985.

Déri, J.: Ice regime of the Hungarian rivers, in Hungarian. VITUKI Report, No. 7661/1/2379, Budapest, 1993.

ÉDUVIZIG: General Survey of flood control taking into consideration the completed and planned projects of G/N system of locks, (manuscript). Noth-Transdanubian District Water Authority, Győr, 1994.

Laczay, I: Actualisation of design flood levels, (in Hungarian). VITUKI Report No. 7611/1/28, 1991.

Oviber, Hydraulic evaluation of the Slovak Variant "C". National Investment Enterprise for Hydraulic Projects, Budapest, manuscript, 1994.

Sipos, B.: The Danube flood in 1965 (in Hungarian). Vizügyi Közlemények (Hydraulic Engineering), Special issue, Chapter 3.1, Budapest, 1966.

Starosolszky, Ö.: The effect of river barrages on the ice regime, (in Hungarian with English summary). Vizügyi Közlemények (Hydraulic Engineering), Budapest, No. 3, 1989

Tóth, S.: Expertise on flood protection issues concerning the GNP, (manuscript). 1994.

VITUKI: Exploration of the ice regime over the Danube reach influenced by the Gabčíkovo-Nagymaros Project, (in Hungarian). Project Report, Budapest, 1989.

VITUKI: Changes in the water management of the Szigetköz area, (in Hungarian). Project Report No. 711/6/2455, Budapest, 1992.

VITUKI: Evaluation of extreme events concerning the Čunovo-Gabčíkovo subsystem of the GNP, (in Hungarian) Project Report No. 711/6/2455, Budapest, 1993.

Zorkóczy, Tóth: Long-term development plan of the flood protection system of Hungary, (in Hungarian with English summary). Vizügyi Közlemények (Hydraulic Engineering), Budapest, No.4, 1985

Protocols of the Hungarian-(Czecho)Slovak Border Water Committee and the Danube Subcommittee Mutually Agreed Plan of the GNP.

Table 1: Major data of the 1954 flood control in Szigetköz

Beginning of flood control:	8. July 1954.
End of flood control:	4. August 1954

Breaks in the dykes:	*Date*	*Time*
1./ Ásványráró upstream	15. July 1954	10.20 h
2./ Kisbodak	15. July 1954.	12.40 h
3./ Dunakiliti	16. July 1954.	03.40 h
4./ Ásványráró downstream	16. July 1954.	15.40 h
5./ Révfalu	20. July 1954.	03.30 h
Opening of Mosoni-Danube left-bank levee:	20. July 1954.	02.30 h
Beginning of water return:	19. July 1954.	23.30 h

Materials used for flood control:

Sandbag	330,000 pc.
Stock /wood/	50,000 pc.
Plank, board	900 m3
Sand, earth	2,500 m3
Rock	1,000 m3
Fascine	50,000 pc
Cost of flood control:	**141 million Ft**

Damage caused:

Building collapsed:	1.394 houses
Building damaged:	2.165 houses
Agriculture:	184 million Ft.
Agricultural buildings, utilities:	129 million Ft.
Traffic works:	31 million Ft.
Flood control works:	27 million Ft.
Industry, trade:	6 million Ft.
Ind. materials:	6 million Ft.
Total:	**383 million Ft.**

Grand total:	**524 million Ft.**

Table 2: Design flood level between 1957-1976.
Danube Rajka-Nagymaros

Danube rkm	Design Flood Level m asl.			Remarks
	1957	1964	1976	
1694.6	107.01	107.01	107.01	Nagymaros gauging station
1708.2	107.63	107.63	107.65	Ipoly mouth
1716.0	108.13	108.13	108.09	Garam mouth
1718.52	108.18	108.18	108.18	Esztergom gauging station
1737.8	109.23	109.36	109.37	Lábatlan gauging station
1751.86	110.37	110.52	110.57	Dunaalmás gauging station
1758.63	110.87	111.02	110.07	Almásfüzítő gauging station
1967.83	111.54	111.71	111.79	Komárom bridge
1768.3		111.87	111.87	Komárom gauging station
1791.32	114.15	114.32	114.32	Gönyű gauging station
1794.0	114.61	114.78	114.65	Mosoni-Duna mouth
1802.3	115.66	115.82	115.82	Nagybajcs gauging station
1805.4	116.23	116.39	116.39	Medvedov /Medve/ gauging station
1809.96	116.88	117.08	117.08	Palkovičovo /Szap/ gauging station
1816.8	117.70	117.87	118.09	Ásványráró gauging station
1819.8	118.71	118.84	118.84	Gabčíkovo /Bös/ gauging station
1825.49	120.31	120.44	120.42	Dunaremete gauging station
1840.18		125.40	125.47	Doborgaz gauging station
1841.54	126.04	126.07	126.07	Hrušov /Körtvélyes/ gauging station
1848.33	128.96	129.11	129.12	Rajka gauging station
1850.25			129.82	Border

Table 3: Traditional end GNP design flood levels

Danube rkm	Design flood 1976	* GNP 1 %head water level	Regular levee crest m.asl.		Difference (cm)	Remarks
			DFL + freeboard	* GNP + freeboard		
1694.6	107.01	-	108.01	-	-	
1708.2	107.65	107.91	108.65	109.38	-73	
1716.0	108.09	108.53	109.09	109.73	-64	
1718.52	108.18	108.73	109.38	109.92	-54	
1737.8	109.37	110.01		111.29	-	
1751.86	110.57	110.85		112.14	-	
1758.33	111.07	111.30	112.27	112.59	-32	
1767.63	111.79	112.01	112.99	113.26	-27	
1768.3	111.87	112.09	113.07	113.29	-22	
1791.32	114.32	114.54		115.75	-	
1794.0	114.66	114.75		116.07	-	
1802.3	115.82	115.26	117.02	117.04	-2	
1805.4	116.39	115.60	117.59	117.70	-11	
1809.96	117.08	115.90	118.28	118.39	-11	**
1816.8	118.09	116.56	119.29	118.78	+51	
1819.8	118.84	117.57	120.04	119.10	+94	
1825.49	120.42	119.45	121.62	120.95	+67	
1840.18	125.47	124.38	126.97	125.88	+109	
1841.54	126.07	124.77	127.57	126.27	+130	***
1848.33	129.12	129.56	130.62	133.71	-3.09	
1850.25	129.82	129.86	131.32	133.73	-2.41	

Remarks:

* Conventional Plan /VIZITERV 0-2-2/77./
** Bypass canal outlet 1811.0 rkm.
*** Dunakiliti weir 1842.0 rkm.

Akadémiai Nyomda, Budapest, 1994
Printed in Hungary

Fig. 1.

GENERAL PLAN

1 : 360000

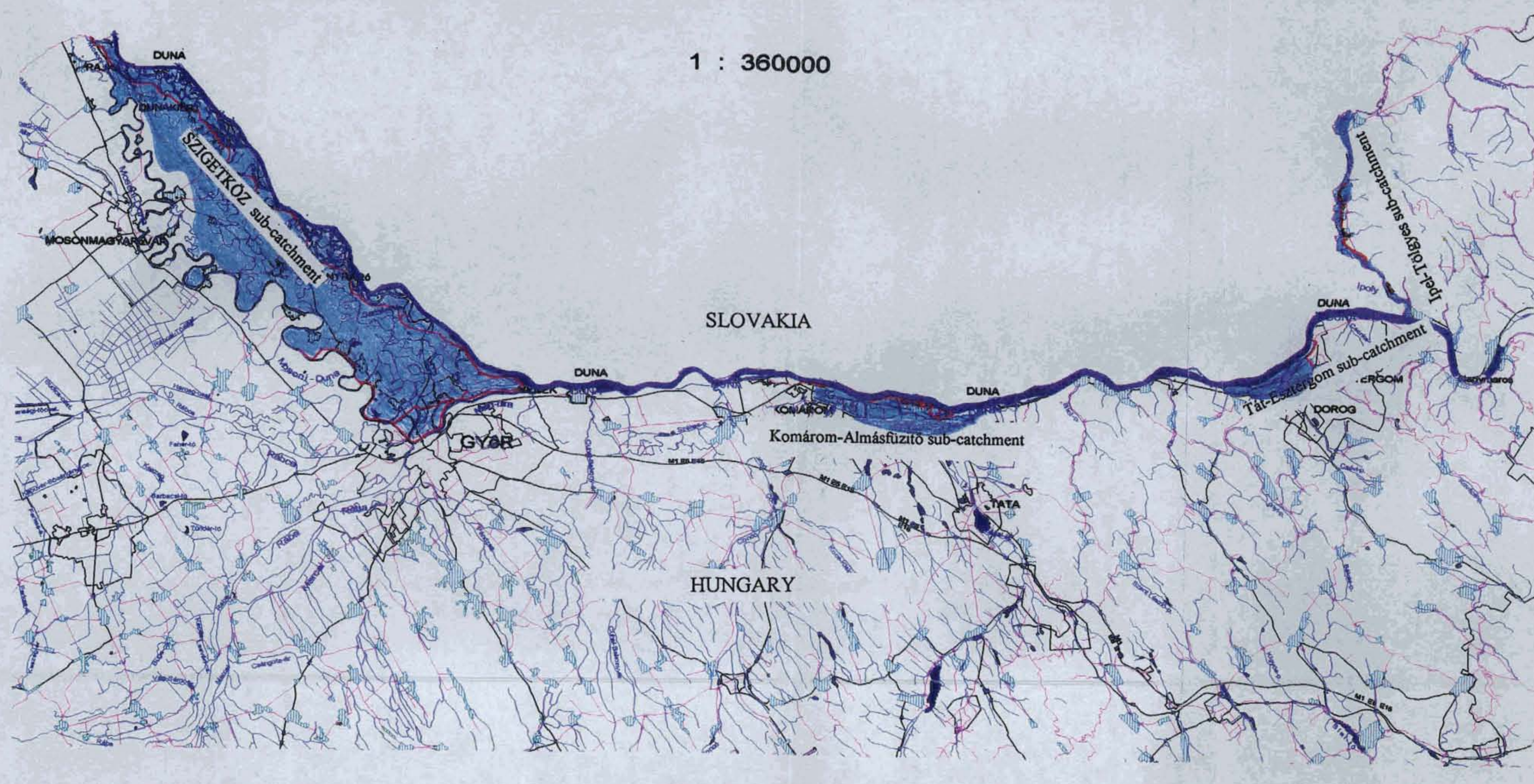


Fig.:2

Change of the cross-section of Szigetköz-Danube right-bank flood levee from 1896 to nowadays

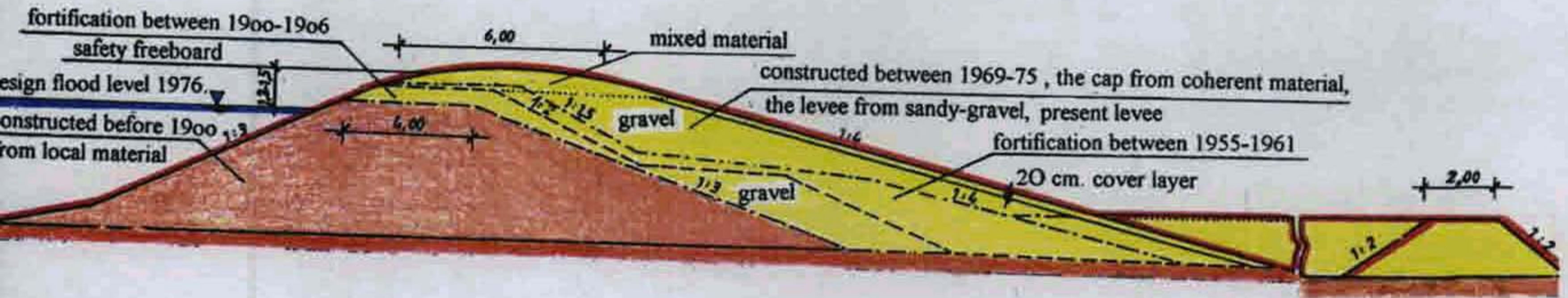
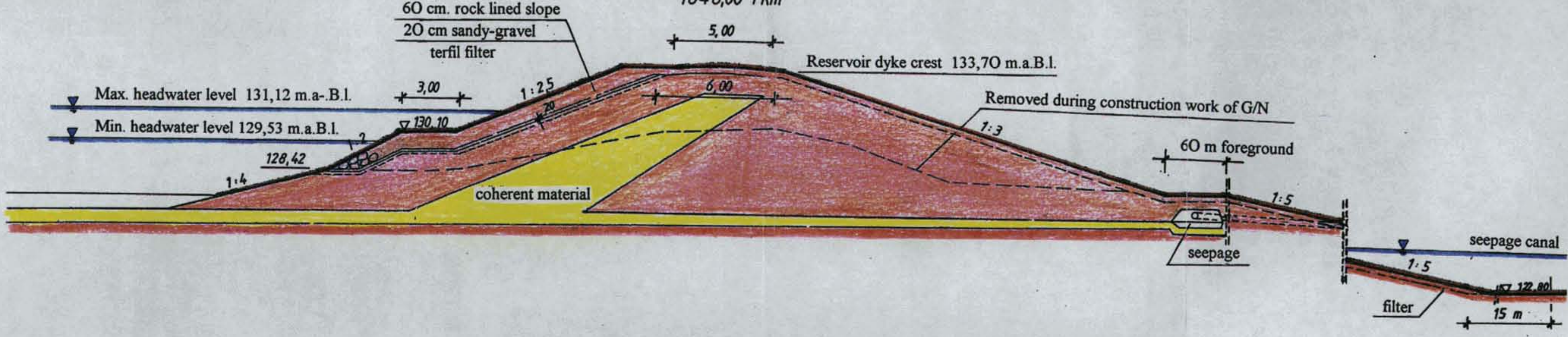


Fig.: 3.

Dunakiliti reservoir dyke

1 : 200

1848,00 rkm



Danube right-bank levee section

1801,50 rkm