INTERNATIONAL COURT OF JUSTICE

GABČÍKOVO-NAGYMAROS PROJECT

(HUNGARY/SLOVAKIA)

REPLY

SUBMITTED BY THE

SLOVAK REPUBLIC

REBUTTAL OF VOLUME 2 OF THE HUNGARIAN COUNTER-MEMORIAL

ANNEXES 1-12

VOLUME II

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PART I

REBUTTAL OF VOLUME 2 OF THE HUNGARIAN COUNTER-MEMORIAL

Introduction

1. This Volume (Part I) forms one part of Slovakia's response to Volume 2 of Hungary's Counter-Memorial, the "Scientific Evaluation". The purpose of Part I of this Volume is not to provide a line by line rebuttal of the "Scientific Evaluation", this not being possible in the limited time available. It is rather to show the Court that the "Scientific Evaluation", although well put together in the editorial sense and seemingly well researched with its scientific vocabulary, graphs and figures, does not stand up to a close and truly scientific inspection. That this is the case is absolutely clear from Volume III to the Slovak Reply - a volume of studies written by 45 Slovak scientists and experts (in their individual fields) and both analysing actual impacts and providing balanced conclusions. It is therefore to Volume III that the Court is invited to turn for a more full exposition of the research on which, inter alia, Slovakia's scientific consideration of the G/N Project is based. This Volume II (Part I) seeks merely to take the findings of Volume III (or those findings of the EC Working Group of Experts or even of Hungary's own scientists) and to juxtapose these with particularly untenable contentions made in the "Scientific Evaluation" so as to demonstrate the fundamental flaws in this last document.

2. Perhaps the most serious of such flaws is the lack of balance in the "Scientific Evaluation". As commented on in detail at paragraph 1.12, et seq., and paragraph 11.06, et seq., of Volume I to this Reply, Hungary introduces and focuses to an unwarranted extent in its "Scientific Evaluation" on the concept of uncertainty. Slovakia considers that this focus in itself constitutes a basic flaw (as discussed at paragraph 14 below). The point here, however, is that "uncertainty" surely implies elements of both good and bad: it would be uncertain whether the Project will have an adverse impact, no impact, or a positive impact. But this balance is wholly absent from Hungary's "Scientific Evaluation", irrespective of the repeated allegations of uncertainty. For Hungary, Project impacts are either bad or potentially bad.

3. This approach is scientifically untenable, and calls into question the whole purpose of Hungary's evaluation. For example, it does not even seem worth contesting the fact that the G/N Project offered benefits in terms of navigation and flood control. And, yet, this is contested in the "Scientific Evaluation". It appears, quite simply, that a small group of scientists and foreign consultants have been required to call into question and criticise adversely every aspect of the Project, an exercise which is very different from an evaluation. Slovakia has not deemed it useful at this stage to turn to "experts" from other nationalities, as Hungary has done, in the hope that this would give an aura of impartiality to the overall scientific assessment. It seems obvious that the best and most detailed scientific evaluations are those carried out by the scientists who are most expert in their field and have spent many years (if not decades) studying, for example, the flora and fauna of the Danube floodplain.

4. Slovakia believes that a balanced evaluation is to be found in Volume III hereto. This records the primarily beneficial (or, in certain areas, insignificant) impact of Variant "C", but also points to certain adverse impacts. For example, in Chapter 4 thereof the Slovak scientists Somšák and Kubíček note the current adverse affects of the implementation of Variant "C" on the so-called dry triangle (just above the Dobrohošť intake into the Slovak side arms) and along the banks of the old Danube. It is not that these impacts are without remedy (by the construction of the underwater weirs in the old Danube); but for Slovakia it is necessary to present all aspects of Project implementation, both good and bad, to the Court.

5. It is because Volume III is not aiming to prove any particular point of view, but is rather concerned with recording actual impacts, that it is far more balanced in its approach. Hungary's "Scientific Evaluation" is rigid in its consideration of the "Original Project", which it examines in its least environmentally adapted form, insisting on minimum discharges into the old Danube and the side arms and maximum peak operation modes. This does not reflect the Project's expected operating conditions when Hungary abandoned works in 1989-1990; it denotes a wilful blindness in terms of not seeing how, where an adverse impact is predicted, this can be remedied. By contrast, in Chapter 6 of Volume III, Eng. Kirka is not merely content to record the monitored impact of Variant "C" on fisheries, but states how he considers the current (1994-1995) environmental conditions for ichthyofauna might be improved. For Slovakia this denotes a truly scientific approach: the aim is to establish what the environmental conditions are and how they might be improved, not to offer the right kind of evidence for use before an international tribunal.

6. Volume III hereto is not just different from the "Scientific Evaluation" in its approach, it is different in terms of the depth of the research demonstrated. At one level, this means it is more difficult for the non-expert to understand: the studies contained therein are highly technical and require careful reading for the non-scientist. But, at the same time, this also means that the conclusions are based on a thoroughly scientific evaluation by acknowledged experts in the field.

7. In mentioning this general lack of a truly scientific analysis in Hungary's evaluation, Slovakia does not mean to question the calibre of Hungary's scientists or the quality of their background research. The defect is rather a reflection on the way that the data has been assembled and presented and the slant given to the conclusions drawn from the data. Three illustrations serve to demonstrate this point.

8. <u>First</u>, Hungary's lack of balance leads it to contradictory conclusions. For example, the "Scientific Evaluation" predicts the silting up of the old Danube riverbed (Table 2.2, at p. 20) and, at the same time, the erosion of the riverbed of up to 3m (at p. 21); it predicts the sedimentation of the bed load and suspended load in the <u>upstream</u> reservoir (at pp. 21 and 144) and, at the same time, increased sedimentation problems in the river stretch <u>downstream</u> of the Gabčíkovo section (at p. 5) together with the clogging up of the Szigetköz side arms <u>downstream</u> of the reservoir (at p. 22).

9. <u>Second</u>, in Chapter 6, where earthquake risk is discussed, Hungary's "evaluation" refuses to accept the irrefutable evidence that, in building the dykes under the Project, the Treaty parties replaced materials that might be prone to liquefication with high quality gravel: the author of Chapter 6 offers as evidence the fact that he personally examined some Danube gravel and found it unsatisfactory. This sort of informal and wholly unsubstantiated science is hardly acceptable.

10. <u>Third</u>, in an almost magical way, Hungary's 1994 studies now support the view that Nagymaros is located in a seismically active earthquake zone and subject to the sort of damage that would result from a recurrence there of the 1763 Komárom earthquake (whose estimated size and intensity it bases on a study 25 years old, ignoring the generally accepted re-evaluation of this event, lowering its magnitude and intensity). Hungary concedes

that the "evidence" was not known in 1989 when it suspended and then abandoned Nagymaros, using earthquake risk as one of the justifications for this action. The tenuous route leading to the finding that Nagymaros is in an earthquake zone is as follows:

- A new fault line is postulated or supposed for the first time in 1994;
- Then it is further hypothesised - based largely on the the 1763 Komárom earthquake - that this must be a seriously active fault;
- Then a rectangular zone is constructed around this east/west postulated fault line so as to include the region on either side (including Nagymaros);
- Then it is assumed that anywhere within this zone an earthquake could occur of the magnitude and intensity of the 1763 event - but based on 25 year old discredited estimates that, in a widely accepted 1991 study, were substantially lowered;
- Thus, Nagymaros is suddenly in an earthquake zone, leading, finally, to a scientific justification, ex post facto, of Hungary's suspension and abandonment of Nagymaros.

As demonstrated in the Comments to Chapter 6 below and Chapters 9 and 10 of Volume III, such an analysis is scientifically invalid.

11. A question is therefore posed as to who has written the "Scientific Evaluation"[1]. Certainly, where the authors are Hungarian scientists - for example, Professor Somlyódy, whose professional qualifications and extensive publications in the field of

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[1] A general point must also be made as to the references that appear at the end of each chapter of the "Scientific Evaluation". The lists appear impressive but, on close inspection, it may be seen that the studies referred to generally do not form part of the huge amount of scientific research of this stretch of the Danube river. For example, of the 64 references to Chapter 4, only 17 relate to this stretch of the Danube and, of these, some 10 are either pre-1986 Slovak studies (i.e., pre-development of many of the remedial measures, so of doubtful relevance) or specially prepared by Hungary for the purposes of this case (i.e., not impartial). The majority of the other references relate to other rivers - the Rhine, the Mississippi, the Missouri - and are not of obvious relevance.

hydrology are well known - the answer is clear. But Hungary has had recourse to several authors unknown to Slovakia, who are credited with preparing a large part of Volume 2. It is certainly a significant gap in Hungary's "Scientific Evaluation" not to know the qualifications of some of the principal authors of Volume 2 in the fields of science dealt with and what they have published[2]. Hungary has also had recourse to scientists, such as Professors Lösing and Roux, who have been engaged for some years in opposing the G/N Project on behalf of such environmental groups as WWF and Equipe Cousteau.

12. It therefore appears clear - and, indeed, Hungary does not actually claim otherwise - that this "Scientific Evaluation" is in no sense prepared by an independent group of experts. This is particularly important since Hungary states that the aim of the "Scientific Evaluation" is "to assist the Court"[3]. What does this mean?

13. Hungary appears to be saying that Slovakia has submitted and relied on certain reports (the Bechtel report, the HQI report and the reports of the EC Working Group of Experts), whilst Hungary has relied on reports that come to different conclusions (the Ecologia studies, reports prepared by WWF and Equipe Cousteau), and hence the "Scientific Evaluation" can now assist the Court in assessing which of these series of reports is correct. But given that the "Scientific Evaluation" is prepared by authors who subscribe to Hungary's points of view and who have even contributed to the earlier evidence on which Hungary relies, in what way can it provide any such assistance to the Court? The "Scientific Evaluation" has been submitted to assist Hungary's case, and it is foolish to suggest otherwise.

14. Slovakia also considers that it is scientifically invalid to place such a focus on the uncertainty of the environmental and water quality risks allegedly posed by the G/N Project. There is no basis in fact for the degree of uncertainty relied on so heavily in the "Scientific Evaluation". No doubt, if the Treaty parties had put the G/N Project into operation and then totally ignored any monitoring and microanalysis of its effects on the environment and on water quality, it might well be that - after (say) 10 years - unpredicted impacts would be recorded. However, a river engineering project such as this, which is certain to have many

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[2] It is unclear in Volume 2, where Chapters attributed to these authors are said to be "based on" someone else's work, just what that means: do the authors just put the background studies into better English, or do they purport to evaluate and make their own assessment?

[3] HC-M, para. 1.49.

effects (even if mainly good, as Slovakia contends) on the surrounding flora and fauna, agriculture and forestry, as well as on ground water levels, necessarily requires the microanalysis of the effects through constant or frequent monitoring.

15. The minute, frequent monitoring of the effects on ground water levels (in respect of more than 300 quality parameters at around 600 monitoring points in Žitný Ostrov alone) and on flora and fauna yields immediate results. It is absolutely certain that if, in a short period, certain adverse effects start to appear, certain predictably disastrous results will be seen in (say) 10 years - if no preventive or mitigating measures are taken. But monitoring allows for these measures to be taken and for their effect to be immediately determined (and for the measures to be altered if necessary). Where no adverse changes of even the most minor kind are detected by monitoring, it can be predicted with a high degree of certainty that there will be no long term impacts.

16. The dubious relevance to Hungary's legal case of the "Scientific Evaluation" as a whole has been considered in some detail in Chapters I and II of Volume I of this Reply. And, since the signing of the Agreement of 19 April 1995 (providing for the construction of an underwater weir at rkm 1843, the utilisation of the Dunakiliti offtake and the consequent flow of surface water into the Hungarian side arms), the majority of the individual findings of the "Scientific Evaluation" in relation to surface and ground waters, flora and fauna, forestry, fisheries and agriculture have become of doubtful relevance also. For, the Chapters of the "Scientific Evaluation" in question rely on the assumption of a ground water decline in Szigetköz and poor water conditions in the side arms. As this will no longer be so, and as Hungary has accepted that direct recharge is of benefit, much of the "Scientific Evaluation" has become outmoded.

17. By way of conclusion, Slovakia considers that Hungary's "Scientific Evaluation" reflects the negative characterisations of the G/N Project that became current in 1989-1991 when Hungary was seeking ways to escape from the Treaty. But, as Volume III hereto shows, from a scientific, engineering and technical standpoint, the G/N Project was a well conceived project (decided on after many years of considering alternatives). The Treaty parties in 1977 selected a hydroelectric power scheme under which not only would valuable energy be produced but also the many navigational problems in this stretch of the river and the serious flood problems would be solved in one fell swoop - by the construction of a bypass

canal, but a canal not running through the floodplain (and therefore causing environmental havoc there) but outside of it, in the low-lying Slovak farmland, thus allowing the floodplain to "develop more naturally". It was a good solution to multiple problems which the electricity to be produced at Gabčíkovo and Nagymaros would pay for.

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18. This Part is organised so that the pages of Hungary's "Scientific Evaluation" being commented upon are reproduced on the left hand page (in series of 4 pages), with individual assertions circled and numbered and then reproduced (in itallics) on the right hand page. Slovakia's comments appear on the right hand page, underneath the itallicised reproduction of Hungary's assertions.

CHAPTER 1

INTRODUCTION

The Gabčíkovo-Nagymaros Project represented a massive development, the implementation of which could create a serious environmental impact along a 250 km stretch of the Danube. 1 This area encompasses a rare and endangered ecosystem and contains Central Europe's largest underground aquifer. This is not merely a landscape of beauty and rich historical significance, but is the primary source of water for Hungary's capital city. 2

The assessment of the relative importance of economic benefits and environmental impacts is ultimately a political issue. However, it is the task of science to provide an objective assessment of the potential consequences of any project, and to identify any uncertainty in that assessment and risks associated with it. Political acceptance of risk is fundamentally related to the potential significance and level of damage. In the present case, the assets at risk are obviously of national strategic importance and, in a wider context, are of European significance. 3

For the Original Project, the scientific issues are particularly complex, multi-faceted yet strongly interrelated. 4 The purpose of this Science Evaluation is to present these issues with clarity, to explain the functioning of the natural system, to indicate the potential impacts of the Original Project and the associated uncertainties, and to describe the observed short-term and potential long-term consequences of Variant C. 5

On both sides of the issue, there has been, and continues to be, a large investment of resources in the evaluation of the Project's various consequences. 6 The availability of new data, new methods, and the hindsight of experience of Variant C have heightened our awareness of the processes involved. There is therefore also a historical perspective to this document. The extent to which risks were perceived and quantified in 1990 is shown, and progress in reducing the uncertainties of impact assessment reported. 7 The topic of environmental impact assessment is itself discussed, in order to place the evaluation of the project in its historical (and rapidly changing) context.

Underlying the project is the recent history of bed degradation, both at Bratislava and elsewhere. Here the morphological development of the Danube is of fundamental importance. It is necessary to understand the causes of bed degradation to develop an appropriate solution, and to consider all potential management options, both structural and non-structural. 8 In *Chapter 2*, the history of morphological change is reviewed, causes of recent degradation identified, and alternative solutions discussed. Morphological change is intimately connected with

river flow and sediment transport, and so this chapter also incorporates a discussion of sediment dynamics, flood management, and the hydraulic constraints on navigation.

The interrelationship between surface water and groundwater is a crucial issue in terms of understanding not only the natural, physical, chemical, and geological functioning of the region, but also the impacts of the Original Project and Variant C. In *Chapter 3* surface water flows and water quality are considered (in particular, eutrophication), as are the processes of sediment deposition and chemical degradation, all of which affect the physical processes of groundwater recharge and its quality. The evolution of groundwater aquifers is related to the history of river morphology, and the groundwater system (and groundwater resources) of the region are primarily controlled by Danube flows. 9 This chapter also includes an analysis of the physical and chemical properties of the various groundwater systems, including their relationship to ecology, agriculture, and water supply.

Chapter 4 outlines the outstanding significance of the area, with respect to biodiversity and nature conservancy. In these respects the area has significance on a European scale. The aquatic and riparian habitats of the main channel and its numerous side branches, as well as the ecology of the wetland habitats in the floodplain, depend heavily on the discharge, sediment and nutrient regime of the Danube. The anticipated impacts, in addition to changes observed after the diversion of the river in October 1992, are described in *Chapter 4*, with special regard to the effect of the Original Project's peak power operation. 10 Assessments are included of the remedial measures which were considered after the signing of the Treaty in 1977, including weirs in the Danube section alongside the power canal and impoundments of side branch systems as carried out on the Slovak side. 11

Chapter 5 concentrates on the consequences for agriculture, forestry and fishery. 12 Agriculture is directly affected by any change in soil structure, hence the introductory part of the chapter describes the effects of the altered groundwater regime on sub-irrigation and soil physical and chemical conditions. Interpretation of observed impacts on agriculture is difficult, due to concurrent changes in climatic conditions and agricultural management practices. Nevertheless, attempts are made to quantify losses and the costs that could be resolved to mitigate these effects. Many of the wetland forests are situated on the active part of the floodplain and were exposed to a large drop of groundwater levels after the diversion of the Danube. 13

Fishery largely depends on the flow and sediment regime of the river and the spawning conditions in the side branches of the Szigetköz. Immediate damage occurred after the diversion of the water into the power canal, but long-term effects due to siltation and changes in physiochemical properties are also anticipated. Considerable detrimental effects on fishery are predicted in the case of peak operation. Due to the dissection of the river by the barrage system the fish fauna is affected in large reaches both upstream and downstream of the Project. 14

Many effects described both in *Chapter 4* and in *Chapter 5* must be considered as long-term consequences, especially those related to alterations in groundwater quantity, quality and dynamics.

The seismic zoning of the Project has been considered in *Chapter 6*. Since 1965, when the zoning was established, there have been considerable advances in risk assessment and design methods. A review, based on a simple application of current practice, suggests that risk associated with the Project has been underestimated in the past, and that there is potential for the impounding capacity of dykes to be lost in worst-case scenarios. It is concluded that there were substantial grounds for concern over design standards and other unresolved issues when Hungary suspended construction in 1989. 15

Chapter 7 analyses environmental impact assessment in an international context. Particular attention has been paid to EIA for dams and reservoirs. 16 The data show how aims, scope, processes and procedures, contents and regulations have changed during the last 25 years. This framework provides a context for the evaluation of both the Hungarian and Slovak studies on the G/N project which have been performed during that period.

The abundance of issues and data on the one hand and the lack of knowledge and information in certain fields on the other leaves a great deal of uncertainty over the extent to which the environment will be affected in the short and long term by the Project, and whether or not these changes can be considered acceptable. 17

1. COMMENTS TO HUNGARY'S "SCIENTIFIC EVALUATION", CHAPTER 1: INTRODUCTION

(1) *The Gabčikovo-Nagymaros Project represented a massive development, the implementation of which could create a serious environment impact along a 250 km stretch of the Danube.*

"A massive development": Dam projects, by their very nature, involve development of a significant hectarage of land. However, it must be remembered that the G/N Project is not, according to Hungary's own technical evaluation, a large dam project. It "is more like a medium scale project" - HCM, Vol. 4, Annex 23 (at p. 893). This is very significant within the context of the technical evaluation contained in that annex, for it is explained (at p. 916) that: "The social and environmental effects of largescale projects are much greater than those of small and medium size projects."

"Implementation": It is important to remember that the "development" of the G/N Project was a reality by 1989, that is when Hungary suspended works on the ground of environmental concerns. At that date the Gabčíkovo section of the Project was already 90% complete. The most "serious environmental impact", i.e., deforestation of the reservoir zone and the construction of the bypass canal in a prime agricultural area, had already been felt.

"A 250 km stretch": Hungary consistently tries to give the impression that the area of the Project's environmental impact is huge. But a close analysis of its "Scientific Evaluation" reveals that Hungary only devotes serious attention to a demonstration of environmental impact in Szigetköz - along a 40-50 km stretch of river - and in the bank filtered well section downstream of Nagymaros. The idea of "serious environmental impact" along the 250 km stretch is untenable. Hungary's plates 1.1 and 1.2 (HCM, Vol. 5) are unacceptably misleading in this respect, depicting vast areas of "Environmental Impact" that even Hungary has never purported to envisage. See, Illus. No. R 4, appearing in Vol. I, before Ch. XI.

(2) *This area encompasses a rare and endangered ecosystem and contains Central Europe's largest underground aquifer. This is not merely a landscape of beauty and rich historical significance, but is the primary source of water for Hungary's capital city.*

As part of its attempt to show that a huge area is threatened, Hungary deliberately confuses the different areas of impact and the areas where these impacts might potentially have an effect. In the first sentence here, Hungary refers to Žitný Ostrov/Szigetköz - the only area in the Project where the "largest underground aquifer" is to be found and where there is a "rare and endangered ecosystem". While this area may be a "landscape of beauty", its aquifer is not (and most probably never will be) even a minor source of water for Budapest which is located 200 km downstream. It supplies not a single drop of drinking water to the Budapest population. See, e.g., HM, p. 411. By contrast, it is of vital importance to Bratislava as a primary source of drinking water. See, SC-M, para. 7.24 and SR, para. 12.02.

(3) *Political acceptance of risk is fundamentally related to the potential significance and level of damage. In the present case, the assets at risk are obviously of national strategic importance and, in a wider context, are of European significance.*

"Political acceptance of risk" presupposes the existence of a risk. As SR, Vol. III demonstrates, the environmental risks in this dispute have either been invented or are greatly exaggerated by Hungary. If there are "assets at risk" in this case which are "of national strategic importance" and "of European significance", these are: utilisation of the

Danube's hydroelectric potential by Hungary and Slovakia, the guarantee of flood protection for both States and the establishment of troublefree navigation along the Rhine-Main-Danube link, for all of which the G/N Project is essential.

(4) *For the Original Project, the scientific issues are particularly complex, multifaceted yet strongly interrelated.*

"The Original Project": This new concept is essential for Hungary's criticism. Its claims of risk are tested against a version of the Project that fails to take account of all the modifications that evolved to address precisely those risks of environmental impact which Hungary now cites. The flow into the old Danube is stated as 50 m^3/s or 200 m^3/s in spite of the evidence (by 1989) of the willingness to increase this to 350 m^3/s; and the direct recharge into the Hungarian side arms is limited to 15-25 m^3/s in spite of the Dunakiliti offtake's capacity of 250 m^3/s. No account is taken of the agreement to construct underwater weirs in the old Danube; nor is account taken of the greatly increased flows - currently up to 40 m^3/s - which the Project enables to be diverted into the Mosoni Danube (for the sole benefit of Hungary), which under pre-dam conditions was mostly without water. Further, it is wrongly assumed by Hungary that a maximum peak operation mode would necessarily have been adopted.

(5) *The purpose of this Science Evaluation is to present these issues with clarity, to explain the functioning of the natural system, to indicate the potential impacts of the Original Project and the associated uncertainties, and to describe the observed short-term and potential long-term consequences of Variant C.*

As even this explanation shows, the purpose of the "Scientific Evaluation" appears not at all to be to present issues with clarity, but to offer confused predictions that always have "associated uncertainties". The uncertainty is to a considerable degree invented precisely because the Gabčíkovo section of the Project has been implemented starting from October 1992. As a result, almost three years of information on <u>actual</u> impact is available for analysis - an analysis that has in fact been carried out by a wide range of Slovak scientists and experts and which forms Vol. III hereto. And from this available data, scientific conclusions can be drawn with a perfectly acceptable level of certainty. But Hungary, in truth, goes to considerable lengths to avoid describing "the observed short-term ... consequences of Variant C". The ample data actually collected does not support either its claims of serious environmental impact or the spectre of uncertainty Hungary describes.

While Hungary's "Scientific Evaluation" also contains some evidence of actual impacts in Hungarian territory, this is mainly of little or no value as it is based on specifically non-Project operating conditions. For the larger part, Hungary's approach has anyway been deliberately more theoretical than that of Slovakia. Indeed, Hungary has even gone so far as to question the value placed by Slovakia on monitoring, pointing out that monitoring alone cannot ensure the quality of groundwater. Of course, this is true; but monitoring records the impact that factors such as discharge rates or flow velocities, which are easily influenced variables, have and enables these to be modified or for other remedial steps to be taken as necessary.

To take an example, for ground water quality alone up to 300 different quality parameters are measured on a constant or weekly basis at literally hundreds of different sites in Žitný Ostrov. These sites are located in <u>Illus.</u> No. R 5, appearing in Vol. 1, para. 11.20. Changes in the monitoring results, though apparently insignificant to the non-scientific observer, can indeed indicate with a high degree of certainty significant long term effects. But Slovakia, has found, after the most closely observed monitoring, that there are no significant changes - small or large scale during the period of operation of the Gabčíkovo section And where there have been no short term changes, long term changes cannot

magically manifest themselves out of nothing. Hence, it is scientifically incorrect to say that the "potential long-term consequences of Variant C" cannot be predicted with sufficient certainty.

(6) *On both sides of the issue, there has been, and continues to be a large investment of resources in the evaluation of the Project's various consequences.*

This contention must be contrasted with Hungary's earlier claim that "fundamental research and investigations were neglected and not carried out" - Declaration of 16 May 1992, HM, Vol. 4, Annex 82 (at p. 168). Hungary appears to have been reluctant to make any appreciable investment in research, save for the purposes of the present case. Contrast also its assessment: "Between 1989 and the summer of 1992 there were no investigations of appropriate detail into the problems related to the hydropower scheme" - HM, p. 408 (applicable only to Hungary, not to Slovakia).

(7) *The extent to which risks were perceived and quantified in 1990 is shown, and progress in reducing the uncertainties of impact assessment reported.*

This is wrong. The "Scientific Evaluation" purports to assess risks in 1994; it makes no effort at all to analyse how risks were perceived in 1990 or to evaluate such documents as the Bechtel and HQI reports, which do reveal how risks were then perceived by independent experts in their reports to the Treaty parties. Hungary, as discussed at SR 1.12 <u>et</u> <u>seq</u>., also appears to aim at showing an <u>increase</u> in the "uncertainties of impact assessment".

(8) *It is necessary to understand the causes of bed degradation to develop an appropriate solution, and to consider all potential management options, both structural and non-structural.*

"The causes of bed degradation": For Hungary, the cause of bed degradation is very simple: commercial dredging. Chapter 2 of its "Scientific Evaluation" places huge emphasis on this (save for in the Nagymaros - Budapest stretch, where the excess dredging was carried out <u>solely</u> by Hungary). And other causes - riverbed erosion, sediment retention in upstream dams, dredging for navigation and flood protection - are largely ignored. Also, different stretches of river with different morphologies are confused. It is important to remember that Slovakia's invocation of the adverse impact of bed degradation (SC-M, paras. 1.57-1.60) focused only on the river stretch upstream of Palkovičovo (Sap) - rkm 1811. Downstream, the river gradient changes, as does the terrain, and bed degradation is not so problematic: not degradation but aggradation is the real problem here. Nonetheless, Hungary focuses on the downstream (common) section, where there was considerable commercial dredging, in order to give the confused impression that commercial dredging created the problems in the upstream sector. <u>See</u>, Comments to Chapter 2 below.

"To develop an appropriate solution": This purpose does not accord with the stated aim of the "Scientific Evaluation", which is to explain "the potential impacts of the Original Project", and is not relevant to the questions put to the Court under the Special Agreement.

(9) *The evolution of groundwater aquifers is related to the history of river morphology and the groundwater system (and groundwater resources) of the region are primarily controlled by Danube flows.*

The reference to "the region" is misleading. The groundwater system of <u>Szigetköz</u> is interconnected with Danube flows. (Although, <u>see</u>, Comment 1 to "Scientific Evaluation" p. 45, below.) But the "250 km stretch" which is the environmental impact area according

to Hungary comprises Szigetköz, the Danube Valley and the Danube Bend (see, HM, Ch. 5A). Downstream of Szigetköz the river flows at the foot of hills in relation to the Hungarian terrain, and later in a valley, and therefore does not control the groundwater of the surrounding terrain.

(10) The anticipated impacts, in addition to changes observed after the diversion of the river in October 1992, are described in Chapter 4, with special regard to the effect of the Original Project's peak power operation.

In its attempt to establish the uniquely damaging nature of the G/N Project, Hungary focuses on peak power operation. But at HC-M, para. 1.211, Hungary accepts that: "Peak operation of barrage systems is a frequent practice, even on lowland rivers used for navigation such as the Danube and the Upper Rhone." For Hungary, it is therefore not the peak operation mode itself that is insupportable but its extent, for it is alleged that the "Original Project" was "planned to operate on large scale peaking modes".

Against this, Slovakia points out that no mode of peak operation was fixed in 1989 when Hungary abandoned the Nagymaros section of the Project (and, therefore, peak operation). It was originally "planned" that the mode of peak operation would be tested and agreed upon by the Treaty parties within the framework of the Joint Operating Group, leading to a specific operating modes agreement. But this procedure was never followed - because Nagymaros was never built as a result of Hungary's abandonment.

As to the likely contents of such a peak operating mode agreement, it may be that Hungary would have insisted on "large scale peaking modes". But Czechoslovakia, at least, was sensitive to environmental requirements, agreeing in October 1989 to limit or even exclude peak operation if such was justified. See, SR, para. 7.33. Slovakia does not now concede that peak operation is necessarily harmful - even Hungary accepts that it is not and that it is a "frequent practice" on the Danube and the Upper Rhine. But, at least insofar as Czechoslovakia was concerned, peak operation, was to be subordinated to environmental objectives, not vice versa.

(11) Assessments are included of the remedial measures which were considered after the signing of the Treaty in 1977, including weirs in the Danube section alongside the power canal and impoundments of side branch systems as carried out on the Slovak side.

Hungary chooses the "remedial measures" that fit its theories - not those modifications that actually evolved. Its evaluation of underwater weirs is particularly unbalanced scientifically. See, Comments 3 and 1 to "Scientific Evaluation" pp. 35-36, below.

"Impoundments of side branch systems": It is important to note that the remedial measures proposed by Slovakia (and by the EC Experts) go far beyond the existing impoundments in its side arms. Slovakia aims to ensure the reconnection of the side arms with the main channel. Note also, that "impoundments" also exist on the Hungarian side - see, the transverse dykes at Plate 11 of HCM (opposite p. 166). A fairer picture of the success of the "impoundments" is given at Vol. III, Ch. 6.

(12) Chapter 5 concentrates on the consequences for agriculture, forestry and fishery.

As pointed out at SR, para. 1.48, the Project's impacts on agriculture, forestry and fishery, covered by Chapter 5 of the "Scientific Evaluation" are not relevant to Hungary's legal claim based on a "state of environmental necessity". The contentions of Chapter 5 are nonetheless considered below and are shown to be unsubstantiated. See, also, Vol. III, Chs. 3, 4 and 6.

(13) Many of the wetland forests are situated on the active part of the floodplain and were exposed to a large drop of groundwater levels after the diversion of the Danube.

"Wetland forests": It is important to remember that these do not represent an original ecosystem. According to the "Scientific Evaluation" (p. 183), 64% of these forests are made up of just one tree type - a hybrid poplar - planted in the region by Hungary for commercial harvesting.

The exposure to the "large drop" in groundwater levels was caused by Hungary's failure to implement the recharge system, not the diversion per se. Where the recharge system has been implemented, as in the Slovak sidearms, favourable results have been recorded on the floodplain forests. See, Vol. III, Chs. 3 and 4.

(14) Considerable detrimental effects on fishery are predicted in the case of peak operation. Due to the dissection of the river by the barrage system the fish fauna is affected in large reaches both upstream and downstream of the Project.

"As to peak operation", see, Comment 10, above. As to the "dissection of the river" Hungary ignores the existence of other barrages on the Danube: 9 in Austria, 26 in Germany as well as barrages downstream in Romania. Current monitoring of the actual impacts of Variant "C" on fisheries supports the predictions that the Project will mostly have a beneficial impact on fish fauna. See, Vol. III, Ch. 6.

(15) It is concluded that there were substantial grounds for concern over design standards and other unresolved issues when Hungary suspended construction in 1989.

There was no evidence for this in 1989 (nor is there today). Hungary's allegations concerning seismology and earthquake engineering are not possible to respond to in summary form, save to say that they present a scientifically invalid picture of risk. See, Comment to Ch. 7, below, and Vol. III, Chs. 9, 10 and 11.

(16) Particular attention has been paid to EIA for dams and reservoirs.

To compensate for the incorrect allegations contained in its 1992 Declaration as to an absence of environmental research, Hungary now focuses on the specific need for an EIA, which is presented not only as having been an international requirement by 1989-1992 but also as something quite different from - and necessary in spite of - the comprehensive research actually carried out by the Treaty parties. In particular, Hungary focuses on the need for EIAs in the case of large dams. Yet Chapter 7 of the "Scientific Evaluation" which is a shortened version of a paper annexed at HC-M, Vol. 4, Annex 23, fails to explain the relevance of this discussion of EIAs for large dams when the paper itself recognises that the G/N Project is not a large dam project (at p. 895). For a brief resumé, see, SR, paras. 1.24 to 1.30.

(17) The abundance of issues and data on the one hand and the lack of knowledge and information in certain fields on the other leaves a great deal of uncertainty over the extent to which the environment will be affected in the short and long term by the Project, and whether or not these changes can be considered acceptable.

"Uncertainty": this is Hungary's dominant theme. But there is no correlation whatsoever between an "abundance" of data and "uncertainty". As is discussed above in the Introduction to this Vol. II, Hungary's thesis of "uncertainty" is scientifically unsound as to environmental and drinking water effects, which can be forecast by microanalysis and constant monitoring. As the following pages show - in conjunction with Vol. III to this Reply - these allegations are no less exaggerated than the horrifying prospects of

environmental damage that Hungary originally depicted in its 1992 Declaration, but has now sought to abandon. <u>See</u>, SR, paras. 1.12 to 1.18 and paras. 11.03 to 11.08.

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CHAPTER 2

RIVER MORPHOLOGY AND RIVER HYDRAULICS

by Klaus Kern

SUMMARY

BED DEGRADATION

1 River regulation since the 19th century has confined the Danube to a single thread channel but has nevertheless retained a system of active side branches in the Szigetköz and Žitný Ostrov of high value with respect to nature conservancy. Excessive industrial gravel mining since the 1960s together with ford dredging has led to a reduction of low-flow water levels with subsequent lowering of groundwater levels in the vicinity of the channel. 2 Surveys of the riverbed provide evidence that the bed morphology is still governed by accumulation of sediment, and that dredging overwhelms possible impacts of river training and upstream dams.

3 If riverbed degradation due to reduced sediment supply from upstream were to pose a problem, e.g. near Bratislava, alternative solutions for stabilisation would be feasible as shown at the Upper Rhine and tested at the Austrian Danube.

IMPACTS OF THE G/N PROJECT

(a) Original project

4 With the construction of the Dunakiliti-Hrušov Reservoir a large part of the Slovak side branch system would be and was actually destroyed. The completion of the Nagymaros Dam would drown almost all islands between Győr and Nagymaros, destroying valuable riparian habitats along their mostly unprotected banks. With a remaining discharge of 50 m^3/s in the Old Danube, even with an unspecified possible increase to 200 m^3/s during the growing season and with an occasional flood release during a few days only per year, the fluvial habitats of the Old Danube and the adjacent wetlands would be severely endangered. The missing bedload and the impact of peak power operation at Gabčíkovo with daily flow reversal in the lower third of the Old Danube would result in severe bed degradation reaching in some locations up to 3 m after 50 years of operation.

5 Peak energy production at Gabčíkovo, as it was originally considered, would result in daily water level fluctuations of up to 4.5 m at the upper end of the Nagymaros Reservoir resulting in a devastated strip of land along the banks. The daily change

of flows would also damage the aquatic habitats. 6 Scouring and sediment accumulation could be expected to a certain extent, probably affecting bank filtered water wells in the Nagymaros Reservoir, as well as those downstream of Nagymaros.

(b) Variant C

7 Almost the same effects can be expected with the operation of Variant C. The prevailing discharge in the Old Danube amounts to about 200-250 m^3/s while flood discharges exceeding 3,000 m^3/s are released in the old riverbed. On such occasions the flow is suddenly released into the Old Danube and the side branches causing above normal degree morphological changes both in the main channel and in the floodplain.

REMEDIAL MEASURES

8 The impoundment of the remaining flow in the Old Danube with eight "underwater weirs", as was suggested, would prevent the degradation of the riverbed, but not necessarily sustain groundwater to the desired level, as is shown by German experience at the Upper Rhine barrage of Rhinau. In addition, the "underwater weirs" would create a sequence of small reservoirs with the well known detrimental effects on the aquatic habitats due to siltation, reduced flow velocities, etc.

FLOOD PROTECTION

9 As far as flood protection is concerned there was and is no need for the G/N Project. The Szigetköz problems were solved by reinforcement of the dyke systems in the 1960s and 1970s, providing a 100-year flood protection which complies with international standards. Downstream of Győr some works have to be completed to reach the same level of security. In this reach the Slovak levees were raised to a higher level according to the Original Project plans *after* Hungary had suspended works at Nagymaros.

The incomplete state of construction of Variant C called "Phase I" falls below the mutually agreed safety standards of the Original Project. Neither the 100-year flood nor the 1,000-year flood can be discharged by the structures at the same level of safety which was previously adopted. Immediately after closure of the Danube, the Čunovo weir could not even safety handle the flood discharge for which it was designed. The high November flood in 1992 (which was still less than half of the 100-year design flood to be released at Čunovo at Phase I) caused considerable damage in the downstream channel, on the floodplain, in the side arms and at the structure itself. The danger of uncontrolled flood – possibly overtopping the reservoir dyke – imposes an additional flooding risk on Hungary.

In the past many floods in this region were caused by so-called ice jams, i.e., a barrier of accumulated ice floes blocking the channel. Due to river regulation the danger of ice floods was considerably reduced. With the construction of a large reservoir – only necessary for peak energy production – a solid ice cover is likely to develop every winter increasing the risk of ice jams at its upper end or at the weir gates. The safe release of broken ice is possibly the most difficult task in reservoir operation. Therefore certain operational procedures were established in the Original Project. The state of construction of Variant C, Phase I, does not allow the same procedures of ice release, as was indicated by ice problems in January 1993; a significantly higher risk of uncontrolled flood discharge was accepted by the Slovak side.

NAVIGATION

Plans for river training to facilitate navigation were worked out in the 1960s, but were only partially fulfilled due to the anticipated installation of the G/N System. In the Danube stretch in the region of the power canal, where the regulation was completed, only minor problems concerning a sharp bend remain, not presenting significant restrictions to navigation. Between Sap and Gönyü additional fords appeared after the opening of the power canal. 10 Recent preliminary investigations by VITUKI and a Dutch-Hungarian consortium indicate that traditional regulation methods including some maintenance would be sufficient to meet the requirements established by the Danube Commission. It is quite common for there to be permanent dredging in international fairways, as is shown on the Rhine.

2.1 THE NATURAL SYSTEM

Downstream of the fault gap through the Alps-Carpathians at Bratislava the Danube flows through the Little Danube Plain, where the majority of its sediment deposits. Together with the river Váh the Danube has eventually formed a long alluvial cone, stretching from Bratislava to Komárom. At its upper edge the Danube separates into three branches forming an inland delta which is unique for European river systems. Period maps show that the river repeatedly switched its main course since Roman times.

In the middle of the 19th century the main channel was flowing south forming an anabranched meandering river. Continuous aggradation was prevailing, and the river was forced to erode new branches with each major flood depositing large amounts of sediment in its previous bed. Thus a confusing system of more or less flushing side branches existed at that time, embracing numerous islands. The prevailing accumulation of alpine sediment 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.

11 The ever changing system of side branches with the deposition, scouring and transportation of sediment 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. *The fluctuation of discharges and water levels was and still is a vital prerequisite for the existence of all types of habitats in the wetlands in this Danube section.*

2.2 HISTORICAL DEVELOPMENT

2.2.1 RIVER REGULATION

Large scale river regulation started in the middle of the 19th century with the construction of floodplain levees confining the inundated area to a width of about 2-6 kilometres in the reach between Bratislava and Gönyü. Between 1886 and 1914 a mean-flow channel of 300-380 m width was created for flood protection, especially related to ice problems, and for the improvement of navigation. The meandering of the low flow within the then created channel was intolerable for navigation and required a low-flow regulation by fixing the thalweg with spur-dykes (groynes), eventually resulting in a navigation channel of 80-120 m width and 2 m depth (Stančík *et al.*, 1988).

Although the river regulation carried out at the Danube between Bratislava and Gönyü was similar to the Upper Rhine training, *aggradation* was still prevailing instead of incision. Measured rates of aggradation between rkm 1800 and rkm 1841 amounted to 2.4-2.7 cm annually before excessive gravel exploitation was started (Bačik *et al.*, 1992).

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). At a discharge of 1958 m^3/s, which is exceeded on 168 days of the year, the side branches carried up to 500 m^3/s (data from 1960) (Mucha, 1993). 12 *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 water levels which are vital to the wetland ecosystem.*

2.2.2 RIVERBED DEGRADATION

From an engineering point of view there should be an equilibrium between the amount of sediment entering a certain river section and leaving it at its downstream end, in order to maintain a constant bed and water level. Since river training works, including the construction of groynes, did not succeed in balancing

2. COMMENTS TO HUNGARY'S "SCIENTIFIC EVALUATION", CHAPTER 2: RIVER MORPHOLOGY AND RIVER HYDRAULICS

(1) *River regulation since the 19th century has confined the Danube to a single thread channel but has nevertheless retained a system of active side branches in the Szigetköz and Žitný Ostrov of high value with respect to nature conservancy.*

"Active side branches": The "high value" of the side arms is accepted by both Parties. But it is important to recall that the active floodplain area had been reduced last Century to a strip 1-5 km wide along the Rajka-Sap stretch. This is shown in Illus. No. CM-8 to Slovakia's Counter-Memorial; see, also, Illus. No. R 4 (appearing at the start of SR, Part III). But even within the active floodplain, prior to 1992, the major part of the side arm system of the Danube in Žitný Ostrov and Szigetköz was not "active"; many of the side arms were virtually dry except at times of flooding. See, Vol. III, p. 3. Hungary admits that by the end of the 1960s the side branch system had ceased to be fully integrated with the Danube - see, "Scientific Evaluation" at p. 7.

With the putting into operation of the Gabčíkovo section of the Project through Variant "C", the branches and side arms on the Slovak side have now been rejuvenated - as a result of measures taken to feed water back into the side arm system from the bypass canal. See, Vol. III, pp. 83-86.

The Hungarian side arms have continued to dry up for lack of water - as a direct result of Hungary's failure to adopt the remedial measures agreed upon by the Treaty parties and, in particular, its failure to use the Dunakiliti offtake with its capacity of up to 250 m^3/s. Hungary's change of heart in the Agreement of 19 April 1995 has been noted in SR, para. 1.03.

(2) *Surveys of the riverbed provide evidence that the bed morphology is still governed by accumulation of sediment, and that dredging overwhelms possible impacts of river training and upstream dams.*

The effects of dredging are relevant only as to limited stretches of the Danube. It is essential to remember that the "riverbed" in question stretches from Bratislava to Budapest and its morphology is governed by different factors in different stretches. The sinking of the riverbed, to which particular attention was paid in the SM, has been a serious environmental problem in the Bratislava-Palkovičovo (Sap) stretch. Sediment accumulation does not govern the riverbed morphology in this stretch of the Danube where the river gradient is still fairly steep (0.043%-0.03%) and water velocities high, leading to riverbed erosion. At Palkovičovo (Sap), the gradient changes to that of a lowland river (0.018%-0.01%) and sediment accumulation does indeed govern downstream from there.

Regrettably, Chapter 2 of the "Scientific Evaluation" broadens the discussion of riverbed morphology and applies conclusions valid for certain stretches of river to stretches where different factors apply. It focuses on dredging but neglects three important points. First, dredging downstream of Palkovičovo (Sap) is not relevant to the problem of the sinking water table in Žitný Ostrov and Szigetköz and is of lesser environmental impact at least to Hungary, due to the different configuration of its terrain. And implementation of the Nagymaros section of the Project would remedy such environmental impacts by raising the surface water level in the riverbed. Second, dredging by Czechoslovakia and Hungary has been dramatically scaled down since the 1980s, and was anyway to jointly agreed quotas. Third, the stretch downstream of Nagymaros has been seriously overdredged by

Hungary (alone), for commercial purposes, although this fact is all but ignored by the "Scientific Evaluation".

(3) *If riverbed degradation due to reduced sediment supply from upstream were to pose a problem, e.g. near Bratislava, alternative solutions for stabilisation would be feasible as shown at the Upper Rhine and tested at the Austrian Danube.*

Reduced sediment supply has - alongside the other factors mentioned at SM, para. 1.57 (which include gravel excavation) - certainly led to a severe riverbed degradation near to Bratislava, where a groundwater level drop of up to 2 m was recorded in the last 30 years. But alternative solutions are not required, for the water impounded in the Variant "C" reservoir has solved the problem of the progressive erosion downstream of Bratislava. Insofar as a problem of riverbed degradation remains downstream of the Variant "C" reservoir along the old Danube stretch (rkm 1851-1811), underwater weirs would, as Hungary accepts, provide a solution. See, "Scientific Evaluation", p. 5. See, also, Vol. III, Chs. 1 and 12.

As to the "alternative solutions" that Hungary is so anxious to propose, these are not only without relevance to this dispute but are also wholly unsuited to the problem in question. The cost of trying to replace millions of cubic metres of gravel would be utterly prohibitive, aside from the problems of where the gravel would come from and the environmental damage occasioned by its extraction elsewhere.

No doubt - as noted at HC-M, Vol. 4, Annex 11 (at p. 495) for example - riverbed degradation has been a problem on other rivers such as the Rhine or upstream on the Danube. But it is not apparent that gravel replacement there has gone beyond the experimental stage.

(4) *With the construction of the Dunakiliti-Hrušov Reservoir a large part of the Slovak side branch system would be and was actually destroyed. The completion of the Nagymaros Dam would drown almost all islands between Györ and Nagymaros, destroying valuable riparian habitats along their mostly unprotected banks. With a remaining discharge of 50 m^3/s in the Old Danube, even with an unspecified possible increase in 200 m^3/s during the growing season and with an occasional flood release during a few days only per year, the fluvial habitats of the Old Danube and the adjacent wetlands would be severely endangered. The missing bedload and the impact of peak power operation at Gabčíkovo with daily flow reversal in the lower third of the Old Danube would result in severe bed degradation reaching in some locations up to 3 m after 50 years of operation.*

When the Treaty parties entered into the 1977 Treaty, they accepted the fact that Project construction would require the clearing of certain areas of forest and natural habitat in order to construct the reservoir. This activity had been completed before 1989. The Treaty parties also accepted the fact that islands in the Danube and habitats close to the Danube would be affected in the Nagymaros section. But it is misleading to describe these small areas as "valuable riparian habitats" having nowhere near the environmental importance of the side arm system and active floodplain of Upper Žitný Ostrov and Szigetköz.

In addition, Hungary bases its allegations of possible adverse environmental effects on its concept of the "Original Project", i.e., the Project as it was conceived in 1977 and ignoring major developments that took place subsequently. Hungary's predictions here are based on a reduced discharge rate into the old Danube and ignore other agreed measures to provide for restoration of the side arms. They also assume that the Gabčíkovo plant would have operated at a level of maximum peak mode operation that was never agreed

between the Treaty parties, and as to which Czechoslovakia offered its pledge to limit or exclude in October 1989 if justified by subsequent studies.

It is incorrect that there would be bed degradation of up to 3m in some locations on the old Danube. See, Comment 1 to "Scientific Evaluation" p. 21, below. Furthermore, Hungary concedes that there would be no "severe bed degradation" if underwater weirs were constructed in the old Danube. See, Comment 8 below.

(5) *Peak energy production at Gabčikovo, as it was originally considered, would result in daily water level fluctuations of up to 4.5m at the upper end of the Nagymaros Reservoir resulting in a devastated strip of land along the banks.*

"Peak energy production": No agreed method or level of peak mode operation had been reached prior to 1989; a fluctuation of 4.5 m would only have occurred at maximum peak mode operation and mainly in the tailwater section of the bypass canal, an artificial structure which was designed to handle large fluctuations. In October 1989, Czechoslovakia offered its pledge to limit or even exclude peak operation if adverse environmental effects were identified that called for such steps to be taken. The focus on peak operation here is therefore misplaced, for it assumes a mode of operation that was neither agreed nor certain to be adopted in any form.

(6) *Scouring and sediment accumulation could be expected to a certain extent, probably affecting bank filtered water wells in the Nagymaros Reservoir, as well as those downstream of Nagymaros.*

Hungary states that a certain impact "could be expected" and implies that this would inevitably be negative. But there is no evidence at all of such an impact, nor that it would be negative. For, at "Scientific Evaluation", p. 7, Hungary writes of the importance of having the variety of "deposition, scouring and transportation of sediment" so as to offer a variety of aquatic habitats. Moreover, Hungary cannot argue that all sediment would be trapped in the reservoir and the old Danube (due to the underwater weirs) and yet that, at the same time, there would be high sedimentation downstream.

Insofar as Hungary's claim is premised on maximum peak mode operation, this statement has no importance for the reasons set out in Comment 5 above.

(7) *Almost the same effects can be expected with the operation of Variant C.*

This is patently incorrect. Quite aside from the errors in Hungary's dire predictions of the adverse effects of the "Original Project", Variant "C" is a variant allowing for the implementation of the Gabčíkovo section of the Project alone. There is therefore no Nagymaros reservoir and not even the capacity for peak mode operation. Impacts allegedly connected with peak operation could not therefore even theoretically occur. Further, a substantially higher rate of discharge into the Danube occurs - currently 400 m^3/s on average - than the rate on which Hungary's predictions are based.

Measures to recharge the side arms on the Slovak side are operating. The impact of these on the side arms riverbed morphology is considered at Vol. III, Ch. 12 where, in particular it is confirmed that there is no colmatation problem. Finally, after two years of operation no adverse effects on river morphology in the old Danube have appeared. See, also, Vol. III, Ch. 12. In fact, the river in the old Danube may now resume its natural tendency to meander, which is clearly a positive effect.

(8) *The impoundment of the remaining flow in the Old Danube with eight "underwater weirs", as was suggested, would prevent the degradation of the riverbed, but not necessarily sustain*

groundwater to the desired level, as is shown by German experience at the Upper Rhine barrage of Rhinau.

"Would prevent the degradation": Hungary concedes that underwater weirs in the old Danube would be effective to prevent degradation. The German experience has been with ordinary transverse barrages operating under low (5-15 m^3/s) flow - an entirely different system - and has no relevance here. See, SC-M, Annex 24 (at pp. 332-334, and Figs. 3.1 and 3.2, at pp. 344-345). The EC Working Group of Experts also specifically indicated their approval of the use of underwater weirs. See, SM, para. 5.41.

(9) As far as flood protection is concerned there was and is no need for the G/N Project. The Szigetköz problems were solved by reinforcement of the dyke systems in the 1960s and 1970s, providing a 100-year flood protection which complies with international standards. Downstream of Györ some works have to be completed to reach the same level of security.

The 100 year flood protection accorded by the inundation dykes in Szigetköz is only adequate because the Project provides for the division of flood waters between the old Danube and the bypass canal. See, SR, paras. 13.40-13.57. The devastating floods in Holland and Germany in early 1995 demonstrate the dangers of underestimating potential flood damage. Where it is possible to divide the flood waters, as under the G/N project, this is to be recommended as it provides much greater protection; this division was considered by the Hungarian scientist, Dr. Vagas, to be vital to preventing a severe flooding of Szigetköz. See, SM para. 5.06.

The G/N Project allows for good flood protection to be achieved in a way that is economically feasible, i.e., as part of a scheme that also produces navigation improvement and valuable hydroelectricity. This multi-purpose project was the Treaty parties' agreed method of ensuring flood control. But as a result of Hungary's failure to carry out the flood control measures required of it under the G/N Project, a serious risk of flooding exists in certain sectors of the Danube downstream of Palkovičovo (Sap), particularly on the Slovak side.

(10) Recent preliminary investigations by VITUKI and a Dutch-Hungarian consortium indicate that traditional regulation methods including some maintenance would be sufficient to meet the requirements established by the Danube Commission.

Hungary has made no document supporting this contention available. The contention is counter to decades of experience of navigational training on this stretch.

The contention is anyway entirely irrelevant (as well as untenable): the Treaty parties agreed on the method of solving the serious navigation problems existing in the stretch of the Danube between Bratislava and Budapest. These problems continue to exist downstream of the bypass canal as a result of Hungary's refusal to perform its obligations under the Treaty and, as the Danube Commission has noted, the G/N Project is the means of addressing these problems. See, SC-M, para. 7.116. The Court has not been asked by the Parties to determine whether some alternative to the methods agreed between the Treaty parties might be adequate to meet the Danube Commission's requirements.

In any event, the "traditional regulation methods" relied on by Hungary appear to be "the application of river construction works" - see, HC-M, Vol. 4, Annex 8 (at p. 442). This means the constricting of the Danube's waters into a narrow section of the main channel, which inevitably means the continued isolation of the side arms. Without interaction between the main channel and the side arms, the environment of the region will inevitably degrade. See, e.g., HC-M, Vol. 4, Annex 10 at p. 485.

Furthermore, the "traditional regulation methods" do not meet the Danube Commission's recommendations, providing for widths of 80m/120m not 150m/180m.

(11) *The ever changing system of side branches with the deposition, scouring and transportation of sediment 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. The fluctuation of discharges and water levels was and still is a valid prerequisite for the existence of all types of habitats in the wetlands in this Danube section.*

"A frequently inundated floodplain": The interconnection between the Danube and the side arms had largely ceased to exist by 1989. In fact, the inundation of the floodplain was not even an annual event, as shown by Illus. No. R-12 (appearing at SR, para. 13.15).

The G/N Project, as it evolved, enabled the restoration of the side arm system on both sides of the Danube and the raising of ground water levels while maintaining the capacity for water level fluctuation. As the EC working Group of Experts explained in their last report, sufficient fluctuation for natural ecological requirements can be achieved through the direct recharge system, even if this does not allow the imitation of the extreme and unnatural fluctuations in the pre-dam state (caused by the creation of the Danube main channel and the construction of flood dykes and aggravated by the isolation of the Danube side arms and higher velocities in the main channel). See, EC Working Group Report of 1 December 1993, HM, Vol. 5 (Part II), Annex 19 (at p. 790): "Reestablishing the dynamics of ground water level fluctuations will to [a] large extent be possible downstream the reservoir." This confirms their previous finding that the implementation of Variant "C" allows the floodplain to "develop more naturally" See, EC Working Group Report of 23 November 1992, ibid., Annex 14 (at p. 418). Indeed, without the G/N Project, it is considered that the floodplain forest would have disappeared altogether- see, Vol. III, p. 87.

"Our experience since the end of the 1950s leads us to conclude that due to the decrease of water flows in the side arm system following the regulation of the Danube riverbed, the retention of sediments in the Austrian and German stretch of the Danube and the continuing trend of the Danube riverbed towards erosion, the floodplain forests would eventually have disappeared on the Slovak side of the Danube river. The Gabčíkovo Project and Variant "C" have prevented this regression."

(12) *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 water levels which are vital to the wetland ecosystem.*

See, Comment 11 above. It is not clear what is the relevance to the 1977 Treaty Project of the pre-1960s conditions. From the 1960s, the branches of the side arm system were no longer integrated with the Danube, partly as a result of the deliberate isolation of the side arms to improve navigation conditions, partly due to the riverbed degradation in the main channel, which meant that the surface water levels no longer reached the thresholds into the side arms. The G/N Project enabled this situation to be addressed because it allowed for the transfer of navigation into a new channel. The re-connection of the side branch system and the main channel is now possible because the G/N Project has been put into operation under Variant "C". The fluctuations can now be achieved.

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. 1

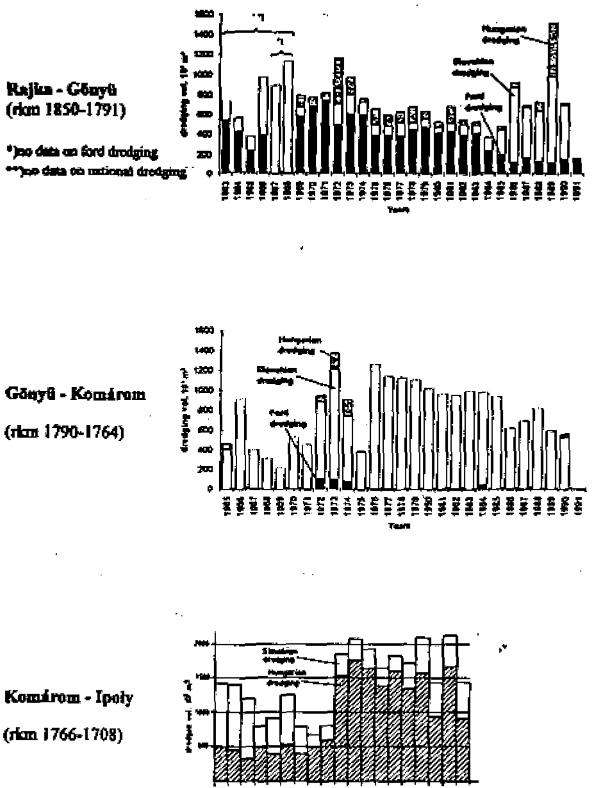
2 Downstream of Sap/Palkovičovo (rkm 1810) the gradient of the river drops from 0.35 to 0.17‰, at the mouth of Mosoni Duna (rkm 1793) to 0.10‰ and at Komárno (rkm 1768) to only 0.07‰ (Stančík *et al.*, 1988). In this reach excessive dredging was carried out by both countries (*Figure 2.1*).

Table 2.1 gives dredging data of different Danube reaches in Hungary covering different time spans. No specific information about dredging in the Slovak Danube stretch between rkm 1880 and rkm 1850 is available to the authors. But the total dredging volumes of the reach Rajka-Gönyű indicate that considerable dredging was carried out in the 1960s and the early 1970s (*Table 2.1*, *Figure 2.1*). Half of the dredging was done for the removal of fords to facilitate navigation. 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 m³ per year. In some years dredging in this river stretch exceeded 1 million m³ with a maximum value of 1.526 million m³ in 1989 (VITUKI 1993b). Dredging of fords was necessary at all times independently of the arriving bedload, because the fluvial rearrangement of sediment in the riverbed was unfavourable to navigational requirements.

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. In both reaches navigational dredging was insignificant.

Table 2.1: Gravel dredging in different reaches and periods along the Danube (mio=million) (Kern, 1994a).

Reach	rkm 1849 to rkm 1791 (Rajka - Gönyű)	rkm 1850 to rkm 1790 (Rajka - Gönyű)	rkm 1849 to rkm 1791 (Rajka - Gönyű)	rkm 1791 to rkm 1664 (Gönyű - 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 (m³)	no data	12.9 mio	16.4 mio	20.7 mio	27.5 mio	16.1 mio
Ford dredging & river training (m³)	6.4 mio	ca. 7 mio	8.9 mio	372,000	200,000	no data
National dredging (industr.)	no data	ca. 6 mio				no data
-Slov. (m³)			4.8 mio	19.8 mio	9.0 mio	
-Hung. (m³)			2.7 mio	535,000	18.5 mio	
Annual dredging (m³/yr)	350,000 (only navigational)	760,000	715,000	768,000	1.447 mio	1,610,000
Specific annual dredging (m³/rkm·yr)	6,000 (only navigational)	12,600	12,300	28,000	25,000	46,000


Rajka - Gönyű
(rkm 1850-1791)

*)no data on ford dredging
**)no data on national dredging

Gönyű - Komárom

(rkm 1790-1764)

Komárom - Ipoly

(rkm 1766-1708)

Figure 2.1: Volumes of dredged sediment from the Danube between Rajka and Ipoly mouth (Kern, 1994a)

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 and on navigation. After 1979 only minor dredging of fords was done. On the 32 km-reach of the Szentendre Duna 4.0 million m³ of gravel was excavated between 1970 and 1980 and about 100,000 m³ in 1987 (Laczay, 1988).

The bedload transport capacity drops along the river with the reduction in slope. Before the construction of dams in Austria the arriving bedload at Bratislava was estimated to 600,000 m³ per year, in the Szigetköz to about 100,000 m³, around Komárom to about 50,000 m³ and at Nagymaros to only 10,000 m³ per year. *Comparing these figures to the annually dredged volumes of gravel* (*Table 2.1*, second line from the bottom) *it is obvious that all Danube reaches were heavily overdredged, especially when considering reduced levels of bedload arriving at Bratislava after dam construction in Austria.*

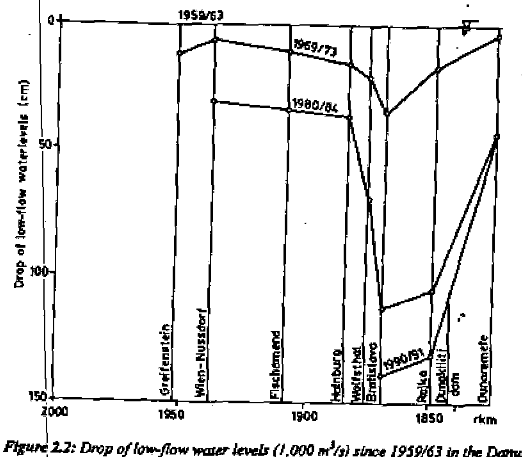


Figure 2.2: Drop of low-flow water levels (1,000 m³/s) since 1959/63 in the Danube between Vienna and Dunaremete (VITUKI, 1993d)

(1) *In addition, growing amounts of gravel have been extracted from the entire river reach between Bratislava and Budapest for industrial purposes.*

"Growing amounts of gravel": This is untrue. The amounts of gravel extracted have been decreasing. The very large decrease in dredging since 1991 is shown at Vol. III, Ch. 12, Fig. 1.2. Upstream of Čunovo, gravel extraction was radically reduced after 1984 and was practically halted save for the excavation of fords for navigation purposes. The area downstream from Čunovo to Sap (the old Danube) is no longer exploited.

(2) *Downstream of Sap/Palkovičovo (rkm 1810) the gradient of the river drops from 0.35 to 0.17%, at the mouth of Mosoni Duna (rkm 1793) to 0.10%0 and at Komárno (rkm 1768) to only 0.07%0 (Stančík et al., 1988). In this reach excessive dredging was carried out by both countries.*

The dredging has been carried out downstream of Sap precisely because of the change in gradient, which means that this is an area of aggradation. See, Comment 1 to "Scientific Evaluation" p. 13, below.

There is anyway little relevance to the fact that substantial dredging may have occurred in the past downstream of Sap, where the bypass canal now ends. Dredging is relevant to the problem of sinking riverbed levels and, therefore, sinking groundwater levels. Sinking groundwater levels have been severely problematic in Upper Žitný Ostrov and Szigetköz, not downstream of Sap. It was this upstream section that was the focus of attention in SM, paras. 1.57-1.60. In this upstream section, the dredging for industrial purposes has been minor, as is clear from Figs. 2.1 and 2.3 (at pp. 10 and 12 respectively) of the "Scientific Evaluation". The major dredging, as Fig. 2.3 (reproduced at SR para. 13.22 as Illus. No. R 13) shows, is downstream of rkm 1811, i.e., downstream of Sap, which is an area of aggradation. See, Vol. III, Ch. 12.

(3) *The exploitation of gravel was not shared equally on all river reaches; the stretch between Gönyü and Komárom was almost exclusively exploited by Slovakia while the lower common Danube reach was intensively excavated by both countries.*

The localities of dredging and the amounts of exploited gravel and sand were annually discussed and agreed between the Treaty parties. The exploitation of the stretch between Gönyü and Komárom is anyway not of importance to the case.

Note: in Hungary's Table 2.1 the annual dredging in rkm 1766-1708 (which was largely exploited by Hungary) and in rkm 1694-1659 (which was solely exploited by Hungary) is double the amounts for stretches principally exploited by Czechoslovakia.

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 Gönyű (rkm 1791) the low flow water levels dropped by more than 1.50 m (*Figure 2.3*). *Figure 2.2* shows the drop of low-flow water levels between Hainburg/Austria and Dunaremete (rkm 1826) with its maximum between Bratislava and Rajka. Obviously riverbed degradation increased significantly entering the Slovak reach at rkm 1880.

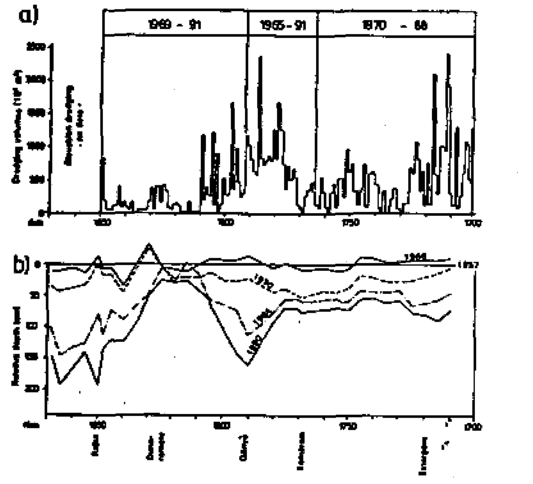


Figure 2.3: a) Dredged volumes of sediment in the Danube along the Slovak-Hungarian border at different periods of time. b) Lowering of the low-flow water levels (ca. 1,000 m³/s) since 1957 (Kern, 1994a)

The lower part of *Figure 2.3* shows the drop of the navigational low-flow water levels. The horizontal line represents the 1957 navigational low-flow water level. The water levels of 1966 reveal that the riverbed remained rather stable until the

mid 1960s. Between 1966 and 1970 a considerable drop was registered between Bratislava and Rajka and especially downstream of Dunaremete. Dramatic changes occurred in the period after 1970. Apparently the drop of water levels was not uniform; former aggrading or rather stable sections degraded severely, e.g. upstream of Rajka and in the vicinity of Gönyű. Comparing the lowering of the water levels and the amount of dredging a close relationship is obvious.

Both graphs reveal a considerable drop of low-flow water levels 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 (Kern, 1994a).

Figure 2.4 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 water level, respectively, in the year 1969. 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. The low water levels are obviously governed by dredging and prevailing accumulation of sediment 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 surpassing accumulation of sediment, while in the centre of the reach aggradation is still prevailing and leads to an almost stable water level.

1

The morphology of the river is governed by the accumulation of sediment and the excavation of gravel. Overdredging in many reaches resulted in a significant drop of water levels. In some reaches (e.g. around Palkovičovo) aggradation is overruling excessive dredging. 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 sediment even today. Due to the lack of data no certain conclusion can be made for the Slovak reach. But the sudden drop of water levels at Bratislava after the year 1967 indicate excessive (industrial) gravel dredging rather than the influence of upstream dams.

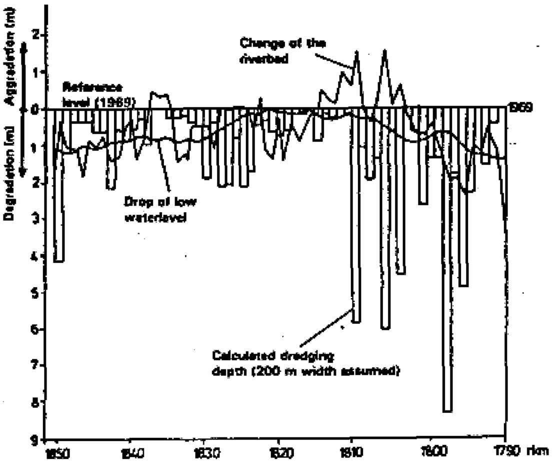


Figure 2.4: Relative changes of the riverbed, drop of low-flow water levels and average depth of dredging between 1969 and 1991 in the Danube between Rajka (rkm 1850) and Gönyű (rkm 1791) (after VITUKI, 1993b; see also Plate 2.1*).*

This contrasts with the situation on the Upper Rhine, where early regulation works caused severe incision of the riverbed, and where the missing bedload downstream of the last barrage of Iffezheim would lead to bed degradation without the continuous addition of sediment by man (Kern, 1994b).

2

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. After degradation the threshold for the branch system inflow increased to 2,500-2,700 m³/s which occurs for 75-100 days of the year. In addition, entrance sections of side branches were closed in the last 30 years in order to maintain minimum water depths required for navigation.

3

It can be assumed that the over-excavation of gravel has been done on the expectation of the construction of the Gabčíkovo-Nagymaros Barrage System, at least in certain river reaches like in the Dunakiliti/Čunovo Reservoir, where the rise of water levels has compensated for the drop around Bratislava. In this regard riverbed degradation is closely related to the project plans.

2.2.3 NAVIGATION

4

(based on Laczay, 1994a)

All river training activities in the Szigetköz reach of the Danube including the low-flow regulation until 1940 did not result in a permanent and sufficient fairway for international shipping. In 1963, the Hungarian-Czechoslovak Joint Engineering Committee outlined and approved principles for further improvement of the navigation channel by traditional methods, i.e., closure of side arms and rearranging banklines to convey up to 3,000 m³/s in the main channel, confining the channel in width to increase sediment transport capacity. A general river training plan was prepared for the stretch from rkm 1842-1816 only, because all other reaches would be affected by planned impoundments of the G/N Project. The construction was performed in the 1960s and 1970s. Additional work of minor extent was done upstream of Dunakiliti and downstream of Ásványráró.

It was confirmed in the late 1970s that, until the G/N Project comes into operation, no further comprehensive river training activities were justified. Navigation was to be maintained by occasional dredging.

The most severe navigational obstacle in the last years before the closure of the Danube was caused by the excavation of the inlet and outlet canal of the Dunakiliti weir. Middle bars developed in the overwidened main channel decreasing navigational low flow depth to 1.6 m around Dunakiliti.

An old navigational problem is the sharp bend at Bagomer (rkm 1814). No river training solution is available to solve the problem, but vessels can negotiate it, since there are no depth restrictions here. No other main obstacles for navigation are known in this reach, so the bypass canal only solves these two problems, one of which was caused by the project itself.

Between Sap and Gönyű sedimentation prevails, and some locations are restricted in width and depth. Additional shallow sections have developed since the opening of the power canal in the stretch between rkm 1808-1800.

2.2.4 FLOOD PROTECTION

(based on Laczay, 1994b)

The first continuous dyke system was built after the 1883 flood. The levees were damaged by the 1887 and 1899 floods, the reconstruction was finished in 1906 with a crest level of 1 m above the 1899 flood level. In 1954, a large flood caused four levee breaks along the Danube (see *Plate 2.2*). Two thirds of the Szigetköz area was inundated causing damage of 383 million HUF (in paragraph 1.31 of the Slovak Memorial the damage were seriously overestimated at 1.5 billion U.S.$).

(1) The morphology of the river is governed by the accumulation of sediment and the excavation of gravel. Overdredging in many reaches resulted in a significant drop of water levels. In some reaches (e.g. around Palkovičovo) aggradation is overruling excessive dredging. 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 sediment even today. Due to the lack of data no certain conclusion can be made for the Slovak reach. But the sudden drop of water levels at Bratislava after the year 1967 indicate excessive (industrial) gravel dredging rather than the influence of upstream dams.

It is not understood how dredging can be "excessive" in an area where aggradation is "overruling". The two statements are mutually exclusive. The accumulation of gravel sediment around Palkovičovo creates a serious flood risk and its dredging is desirable on this ground alone.

The conclusions in this paragraph are inconsistent with Hungary's earlier statements; and they are oversimplified. The reduced bedload effect after the upstream dams in Austria were constructed is expressly recognised by Hungary just above (at p. 11); and there have also been ground water level drops upstream, <u>e.g.</u>, in the Vienna area, during the last 30 years following construction of the Austrian dams - <u>see</u>, HC-M, Vol. 4 (Part 2), Annex 11 (at p. 495).

Riverbed morphology is affected by a number of factors. The <u>primary</u> factor is gradient and the resulting velocity of water flows. Dredging is a factor, but only alongside river regulation works and, in particular: (i) natural erosion due to increased velocities in the straightened and narrowed navigation channel; (ii) the prevention of bank erosion due to fortification of river banks; and (iii) the reduced bedload effect of upstream dams (just noted above) - changes that started to appear long before the industrial dredging in the 1970s and early 1980s. As Hungary concedes, the installation of underwater weirs in the old Danube would prevent riverbed degradation - <u>see</u>, Comment 8, p. 5, above.

(2) 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. After degradation the threshold for the branch system inflow increased to 2,500-2,700 m3/s which occurs for 75-100 days of the year. In addition, entrance sections of side branches were closed in the last 30 years in order to maintain minimum water depths required for navigation.

Hungary's statement is correct as far as it goes (especially in relation to the isolation of the side arms to ensure navigational depths), but it does not fully describe the extent to which the side arm system had deteriorated. Hungary's 1985 EIA indicated that for nearly 300 days a year the water discharge rate was below the level required to allow water to flow into the side arms - <u>see</u>, SC-M, para. 7.39. And at "Scientific Evaluation" p. 52, the Hungarian statistics (appearing in table 3.1) indicate that there was flow from the Danube in almost all river arms annually for a duration of only 17 days and complete inundation of the floodplain for only 4 days. Furthermore, these are <u>average</u> values. In other words, in certain years there would be no floods and no complete inundation, whilst in other years the period would be longer. <u>See</u>, <u>Illus. No. R-12</u> appearing at SR, para. 13.15). The installation of underwater weirs together with utilisation of the Dunakiliti offtake would have solved this problem, allowing Hungary's side arm system to be supplied with water at low conditions, as noted by the EC in its report of 1 December 1993 - <u>see</u>, SC-M, para. 8.11.

(3) *It can be assumed that the over-excavation of gravel has been done on the expectation of the construction of the Gabčíkovo-Nagymaros Barrage System, at least in certain river reaches like in the Dunakiliti/Čunovo Reservoir, where the rise of water levels has compensated for the drop around Bratislava. In this regard riverbed degradation is closely related to the project plans.*

This assumption is wrong. A Slovak 1991 study reveals that, between 1976 and 1989, 48.3 mil. m^3 of gravel was excavated along a reach of 171 km (between rkm 1880, at Bratislava and rkm 1709.024, downstream of Štúrovo). On the other hand, between Čunovo and Sáp (the area of the Gabčíkovo sector), only 3.5 mil. m^3 of gravel was excavated - see, SC-M, Annex 24 (at p. 309). There was no over-excavation of gravel in this stretch of the river at all, let alone in anticipation of the G/N Project.

(4) *Navigation*

The key point is omitted in this discussion of navigation: that the opening of the bypass canal has undoubtedly improved navigation whilst, at a number of reaches of the Danube below the bypass canal, the navigation requirements of the Danube Commission are not met as a result of Hungary's abandonment of the Nagymaros section of the Project - see, Vol. III, Ch. 12, Figs. 1.5-1.9. As pointed out in SC-M para. 7.117, in the sector of the Danube downstream of the bypass canal, the Danube Commission's depth specification of 2.5 m was met in 1992 along only 40% of this stretch. See, also, Vol. III, Ch. 12, showing that much of this stretch fails to meet the Danube Commission's width standard.

please turn to next page

After the 1954 flood, improvement of the dyke system was planned on a statistical basis fixing the 100-year flood levels as a design standard. Reconstruction of the levees according to the new standard was performed in 1955-1961. Revisions of the design flood levels due to morphological changes of the channel and the floodplain were carried out in 1957, 1964 and 1976. All design levels were agreed in the Danube Subcommittee of the Hungarian/Czech/Slovak Border Water Committee and approved by the Plenipotentiaries.

Owing to the reinforced dyke system, the historical flood of 1965 caused no major failure in the Szigetköz reach of the Danube. The entire damage on the Hungarian side between Rajka and Nagymaros amounted to about 1,000 million HUF and not to 1,500 million HUF as stated in paragraph 1.33 of the Slovak Memorial.

In 1965, 94% of the levees did not meet the safety requirements of the 100-year flood. Reinforcement of the dyke system in the Szigetköz reach was finished in 1977 incorporating a freeboard allowance of 1.2 m above the 100-year flood levels. Sufficient cross dimensions and the necessary structures to prevent seepage had been built. The exception was along the stretch Rajka-Dunakiliti, where the Dunakiliti-Hrušov Reservoir dyke was planned. On the left bank of the Mosoni Danube the flood protection system also did not meet the requirements in 1977.

Between Győr and Nagymaros only 18 km of Danube banks need flood protection on the Hungarian side because of the altitude of the adjacent area. The flood protection system consists of dykes, walls, elevated public roads and a railway line. Despite repeated reinforcements only a short length of the levees met the design requirements in 1977, e.g. the elevation of the railway line equalled the 100-year flood level without freeboard allowance.

1

Conclusion. By 1977, the major part of the Hungarian flood protection system met the safety level on which both sides had agreed, i.e., 100-year design flood plus 1.2 m freeboard allowance and sufficient cross dimensions of levees with seepage control.

2.3 IMPACTS OF THE ORIGINAL PROJECT

2.3.1 CONSTRUCTION

Dunakiliti-Hrušov Reservoir

2

The construction of the Dunakiliti-Hrušov Reservoir would destroy and actually has destroyed about one third of the Žitný Ostrov floodplain. 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 have been reduced from 2.0 m/s to about 0.3 m/s. The water level at Bratislava has actually risen by 1-2 m since the closure of the Danube, reaching its original level before degradation of the bed.

Old Danube

Dredging between rkm 1811 and rkm 1817 should level out the step created by the deepening of the tailwater canal of Gabčíkovo.

Nagymaros Reservoir

The Nagymaros Reservoir would have extended from the Gabčíkovo power station (rkm 1811+8) to Nagymaros (rkm 1696). Its backwater would reach up to rkm 1823 in the Old Danube, more than 20 km upstream of the Malý Dunaj (= Váh) mouth and several kilometres upstream of the confluence of the rivers Hron and Ipoly. According to the Joint Contractual Plan, channel dredging should lower the water level at a discharge of 2,300 m^3/s from Ásványráró (rkm 1816) to Gönyű (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). 3 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 and carry softwood vegetation. 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 substantially alter their physical properties.

Downstream section of Nagymaros

According to the Original Project channel dredging along Szentendre island from Nagymaros to rkm 1656 should lower the low-flow water levels by 0.60-1.20 m in order to increase the head of the power plant. Dredging, which was carried out mainly for industrial purposes, was stopped in 1980 because of problems with the bank filtered wells of the waterworks of the city of Budapest.

2.3.2 OPERATION

Dunakiliti-Hrušov Reservoir

Depending on the actual flow into the reservoir, certain peaking modes were established as operation rules for Gabčíkovo. *Figure 2.5a* shows the fluctuations in the Dunakiliti-Hrušov Reservoir resulting from mode 1500/700, which means 1,500m^3/s inflow produce 700 MW. In this case there would be two daily peaks in the reservoir water level with fluctuations of about one metre. The backwater reach was expected to vary between rkm 1858/60 and rkm 1870/72. 90% of the bedload was expected to deposit at this place and should be dredged continuously; 77% of the suspended load was expected to deposit, hence the reservoir's life time was calculated to be about 60 years.

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 in fact with the operation of Variant C; see *Chapter 2.4*).

4

Table 2.2 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, 50-200 m^3/s would be released from the reservoir – 200 m^3/s only in case of the need for vegetation. Any water level 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 nearly all fluvial and riparian habitats that had developed and the cycle of restructuring would start again. Regular maintenance would be required to ensure the flood discharge capacity of the channel, but this would have similar destructive effects as the larger floods themselves in disrupting the fluvial habitats.

5

According to the Joint Contractual Plan the low-flow water level – that had been lowered since 1967/68 through excessive channel dredging – would drop by 2.50-3.00 m below the regulation water level. Flow velocities would be reduced to less than one metre per second (CEC, 1993b). 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 2.5*) there would be a backwater reach up to rkm 1823 in the Old Danube.

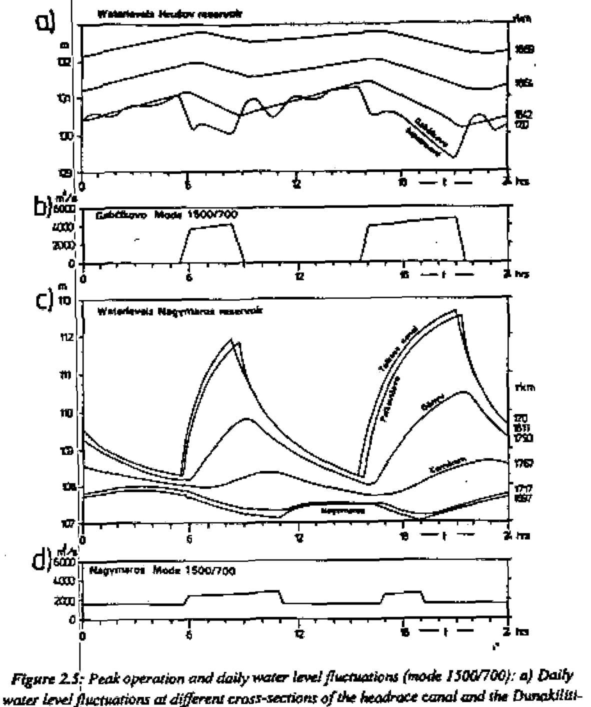


Figure 2.5: Peak operation and daily water level fluctuations (mode 1500/700): a) Daily water level fluctuations at different cross-sections of the headrace canal and the Dunakiliti-Hrušov Reservoir b) Discharge release at Gabčíkovo c) Daily water level fluctuations at different cross-sections of the tailrace canal and the Nagymaros Reservoir d) Discharge release at Nagymaros

(1) *Conclusion. By 1977, the major part of the Hungarian flood protection system met the safety level on which both sides had agreed, i.e., 100-year design flood plus 1.2 m freeboard allowance and sufficient cross dimensions of levees with seepage control.*

This is a deceptive statement. The starting point adopted by the Treaty parties in assessing flood risk was not the 100 year flood but the 1,000 year flood (a discharge of 13,000 m^3/s). The agreed operating regulations provided for this flood water discharge, to be divided between the bypass canal and the old Danube, in such a way as to ensure that the dykes along the old Danube, built to the 100 year standard, were adequate. (See, SR, para. 13.48, et seq.) The only way in which the dykes on the Hungraian side, designed under the Project to reach the safety standard of the 100 year flood, would be safe against the agreed safety standard of the 1,000 year flood was by putting the Gabčíkovo section into operation, thereby dividing the flood waters. This is one of the great (but unacknowledged) benefits Hungary now enjoys from the putting into operation of the Gabčíkovo section under Variant "C".

The discussion of flood control in the "Scientific Evaluation" of Hungary is addressed only to Hungary's protection, ignoring the obvious fact that flood protection along a stretch of river shared by two States is a joint problem and that it was a problem jointly resolved under the G/N Project.

In this respect, it is informative to read the summary of the Joint Contractual Plan contained in Hungary's own annexes (HM, Vol. 3, annex 24):

"3.3.1 Flood control

Levees were constructed along the Danube and its tributaries which needed a very high investment budget and still do so. Though the levees were constructed with a high security factor, they do not ensure the flood protection of the extensive areas located on both sides of the river. The protected area on the Czechoslovak side is more than 200 000 ha and on the Hungarian side is about 40 000 ha.

The basic soil of the dams consists of varying geological alluvium. During floods or lengthy high water periods the fine particles of the dams can be washed out, resulting in levee failures. The Danube levee on the Hungarian side failed three times in 1954 and twice on the Czechoslovak side in 1965. The latest direct inundation devastated 60 000 ha in Czechoslovakia.

The present conditions of flood control are getting worse year by year, because owing to the sudden slope change at Palkovičovo gravel settles in the bed, and consequently the bottom of the bed and the water levels keep on rising. The flood levels increased 150 cm between 1901 and 1950 which caused a higher groundwater level over the surrounding area, and less security of the levees during floods and ice gorges. The planned solution is advantageous from the flood control point of view, because the most difficult and most dangerous Hrušov-Palkovičovo stretch is by-passed by a diversion canal.

The discharge capacity of the bed will be increased along the Nagymaros-Budapest stretch owing to the dredging of the bed. An improvement can be expected during the flood period when the water flows through the reservoir, because the forests hampering the free flow will be removed.

The discharge capacity of the diversion canal and the abandoned riverbed after the construction of the barrage along the stretch above Palkovičovo jointly provide the

<u>necessary security even against the occurrence of a 10 000 year flood</u>. The levees along the downstream stretch ensure the required security against the occurrence of a 1000 year flood.

With respects to all these facts the conclusion can be drawn, that <u>with the construction of the planned Gabčíkovo-Nagymaros Barrage system the requested level of flood protection of the entire surrounding area will be provided</u>, therefore the value of the watershed area, considering the continual development of the agricultural production, industry and municipalities, will be constantly rising." Emphasis added.

(2) The construction of the Dunakiliti-Hrušov Reservoir would destroy and actually has destroyed about one third of the Žitný Ostrov floodplain. Through the impoundment of 200 million m^3 of water the previous river ecosystem characterised by numerous islands, side branches and wetland would have been lost.

The area of floodplain replaced by the reservoir under the Treaty Project was largely within Slovak territory. The entire area was cleared before 1989 and ready to be filled with water. Thus the "previous river ecosystem" of this area was already lost by 1989. The environmental impact of this aspect of the Project was understood and accepted by the Treaty parties. The G/N Project did not however require any further loss of floodplain - unlike upstream projects on the Danube and projects on the Rhine - because it located the bypass canal outside the floodplain (in agricultural land on Slovak territory).

(3) The construction of the barrage would cause the inundation of about two dozen islands situated between Gönyü (rkm 1791) and Nagymaros. Most of the riparian zones of these islands rendering valuable ecotones were left unprotected and carry softwood vegetation. In addition, established riparian zones of 300-350 km length of several tributaries and of the Danube itself would be inundated.

Just as to Comment 2 above, the described environmental impacts on the Nagymaros section were also understood and accepted by the Treaty parties. Moreover, Hungary greatly exaggerates the environmental importance of the riparian zones concerned. (<u>See</u>, Comment 4 to "Scientific Evaluation" p. 4, above). However, by not proceeding with its obligations under the Treaty as to Nagymaros, Hungary has not felt these impacts, leaving almost all of the accepted environmental impacts of proceeding with the G/N Project in accordance with the Treaty to fall on Czechoslovakia (and now Slovakia).

(4) Table 2.2 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, 50-200 m^3/s would be released from the reservoir - 200 m^3/s only in case of the need for vegetation. Any water level fluctuations would be limited to 12 days of the year on average, when the inflow into the reservoir exceeds 4,000 m^3/s.

The discharge rate described here was that foreseen under the Treaty Project in 1977. By 1989, these rates were to be increased and other measures to deal with the water level and the effect on the side arms had been adopted. Nevertheless, Hungary's predictions are based on the "Original Project", <u>i.e.</u>, without taking account of Project developments and thus vitiating this "evaluation". The predictions of severe scouring problems contained in Table 2.2 are also unfounded. <u>See</u>, Comment 1 to "Scientific Evaluation" p. 21, below.

It is also worth noting that Hungary gives the impression that all changes are negative. For instance, Table 2.2 predicts a drop in water velocity from 1.2-2.0 m^3/s to 1.0 m^3/s. Such a decrease is <u>beneficial</u> - in terms of reducing bed erosion and creating better aquatic habitats. <u>See</u>, Comment 1 to "Scientific Evaluation" p. 24, below. Similarly, the spread of

vegetation in the channel outside the new low flow bed would mark a return to a more natural riverine ecosystem.

(5) *According to the Joint Contractual Plan the low-flow water level - that had been lowered since 1967/68 through excessive channel dredging - would drop by 2.50-3.00m below the regulation water level.*

Again, the low-flow level in the 1977 Joint Contractual Plan was not fixed at 50-200 m^3/s in 1989 as Hungary suggests; by this date, other measures such as underwater weirs had been agreed. Even under the earliest plans, only one very short stretch of the old Danube would have experienced a drop of 2.5-3.0 m - see, Comment 1 to "Scientific Evaluation" p. 21, below. Hungary deliberately ignores major changes made in the Project before 1989, when Hungary started to breach the Treaty, as well as changes that Czechoslovakia showed itself willing to accept after that date.

Table 2.2: Hydro-morphological impacts of the Original Project on the Old Danube

OLD DANUBE			
	short term (5-10 yrs.)	medium term (10-20 yrs.)	long term (20-50 yrs.)
Discharges	• 50/200 m³/s should be released from the reservoir into the Old Danube higher releases only at discharges exceeding 4,000 m³/s (ca. 12 d/yr.) • daily flow reversal for a few kilometres upstream of the conjunction with the power canal caused by peaking operation		
Water levels	• sudden drop of water levels by several metres	• gradual lowering of the water levels 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 m³/s; • 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 & water levels	• exclusion of all discharge and water level fluctuations for ca. 350 d/yr. except for the reach influenced by backwater where daily fluctuations of 4 metres would occur (*Figure 2.5*) • sudden rise and fall of discharges and flow velocities in case of flood discharge release		
Riverbed stability	• during a flow of 50/200 m³/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 Dunakiliti-Hrušov Reservoir (Bačik *et al.*, 1992)	• after 50 yrs. operation scouring was predicted to reach 3 m in some sections leading to a severe drop of the prevailing water levels at 50/200 m³/s (*Figure 2.6*) (Bačik *et al.*, 1992)
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 presumedly 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 water level 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	

The sharp rise of discharges at the begin of peak energy production would result in a rise of water levels at the sill of Palkovičovo (rkm 1811) of about 4 metres

depending on the peaking mode (*Figure 2.5*; refer also to Karadi and Nagy, 1993). 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 water level fluctuations at all except for a few days per year, and a lower part with large fluctuations every day damaging fluvial and riparian habitats.

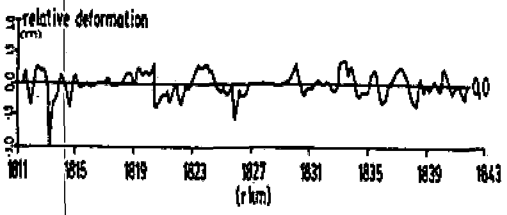


Figure 2.6: Anticipated relative change of the riverbed after 50 years of operation (after Kališ and Bačik, 1992)

Since all bedload will be trapped in the Hrušov Reservoir, eventual degradation of the bed should be expected even with few flood discharges per year. Kališ and Bačik (1992) predicted up to 3 m scouring in some sections after 50 years of operation entailing a further drop of the prevailing 50/200 m³/s water levels. *Figure 2.6* shows the deformation of the riverbed simulated for a 50-year period of operation. 1

Altogether fluvial and riparian habitats would either be destroyed or would suffer from instability caused by the imposed discharge regime. Large daily water level fluctuations in the lower part of the Old Danube contrast a rather steady water level 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. 2

The Szigetköz floodplain

Table 2.3 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. 3

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 m³/s. There would be flow in some side branches at 6,500-7,500 m³/s and in almost all during inundation of the floodplain at 7,500 and 8,500 m³/s corresponding to a 5- to 10-year flood and a 10- to 25-year flood, respectively (CEC, 1992).

Table 2.3: Hydrological impacts of the Original Project on the Szigetköz floodplain

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 m³/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 m³/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 discharges	• 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 Dunakiliti-Hrušov 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		

Table 2.4: Hydro-morphological impacts of the Original Project on the Nagymaros Reservoir

NAGYMAROS RESERVOIR			
	short term (5-10 yrs.)	medium term (10-20 yrs.)	long term (20-50 yrs.)
Discharges	• daily fluctuations from 1,000 m³/s to more than 5,000 m³/s depending on the mode of peak operation (*Figures 2.5*) • with mode 900/700 no release of water at Gabčíkovo for 18.5 hrs.		
Water levels	• at 2,300 m³/s compared to pre-dam conditions (without peaking): +6 m at Nagymaros, ±0 at Vének, -2 m at Palkovičovo (dredging)		
Flow velocities	• v_{min}/v_{max} flow velocities through peak operation (mode 2000/700): 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) (Karadi and Nagy, 1993)		
Fluctuations of discharges & water levels	• about 4,000 m³/s daily fluctuations of discharges • daily water level fluctuations through peak operation (mode 2000/700): 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) (Karadi and Nagy, 1993)		
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 (Bognár and Rákóczi, 1988)	• according to (Bognár and Rákóczi, 1988) 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 water level • 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 water levels 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 water level 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	

(1) *Since all bedload will be trapped in the Hrušov Reservoir, eventual degradation of the bed should be expected even with few flood discharges per year. Kališ and Bačík (1992) predicted up to 3 m scouring in some sections after 50 years of operation entailing a further drop of the prevailing 50/200 m^3/s water levels. Figure 2.6 shows the deformation of the riverbed simulated for a 50-year period of operation.*

Kališ and Bačík in fact predicted: "Sedimentation by the bedload transport in the reservoir of Hrušov-Dunakiliti isn't expected to cause serious problems ..." - see, HC-M, Vol. 4, Annex 5 (at p. 359). Hungary also omits the conclusion of these two Slovak scientists as to riverbed deformation: "The obtained results showed that the Old Danube channel deformations will be relatively small." Indeed, Fig. 2.6 of the "Scientific Evaluation" shows this to be so, with both increases and decreases in the level of the riverbed and a decrease of 3m in only one specific location. And, as Hungary admits, riverbed deformation can be cured by constructing underwater weirs - see, "Scientific Evaluation", at p. 5.

(2) *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.*

The conclusion reached by the Slovak scientists relied on by Hungary (as just discussed at Comment 1 above) was that the deformation of the old Danube riverbed would be "relatively small" even after 50 years of operation. Fig. 2.6 shows a rough balance between aggradation and degradation.

(3) *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.*

This marks a change of view on Hungary's part, for Hungary noted in its 1985 EIA that the direct recharge into the side arms allowed by the Project allowed a flow of water "far exceeding their present discharge throughout the entire year". HM, Vol. 5, Annex 4. This 1985 assessment is confirmed by the 1993 reports of the EC Working Group of Experts, as well as by Volume III hereto, which conclusively proves the beneficial impact of the direct recharge into the Slovak side arms at Dobrohošť.

The problem exists on the Hungarian side because of its past refusal to proceed with the Project. According to the EC Experts, if direct recharge into the Szigetköz side arms is increased to the same levels as on the Slovak side: "Ground water levels on the Hungarian territory are expected to be not lower than in the pre-dam conditions." HM, Vol. 5, Annex 19 (at p. 790). Needless to say, Hungary can point to the actual impact on its territory of the damming of the Danube in October 1992, which has (apparently) been followed by a decrease in ground water levels on an area covering 297 km^2. But this proves only that the direct recharge system was well-conceived and that it is wholly illogical not to allow for its implementation. And, once again, on Slovak territory, the effectiveness of direct recharge has been confirmed by EC experts and by over two years of monitoring of actual impact:

> **"The Gabčíkovo hydropower structures, after two years of operation, show on the prevailing part of the territory the recovery of water-related conditions to those known in the region a few decades ago. The measured changes in ground water levels in the floodplain area and in the whole region confirm the positive impact on the upper part of the area and the important positive role of water supply for the Danube left side floodplain." Vol. III, p. 18.**

As to "flushing and inundation", the actual inundation of the side arms area is indeed possible. Even to date the flow rate achieved in the Slovak side arms since May 1993 has been neither small nor constant. It has varied between 10 and 90 m^3/s as ecological considerations have dictated and there is no sense in which the flow has been insufficient. And it will be remembered that both intakes into the side arms (Dunakiliti on the Hungarian side - Dobrohošť on the Slovak side) have capacities of around 250 m^3/s, allowing precisely for inundation.

please turn to next page

Water level fluctuations influencing groundwater recharge and quality would be limited to an average of 10-12 days per year but not necessarily in a consecutive row. Thus the significant contribution to groundwater recharge by rare but long lasting floods would not longer occur.

Floodplain habitats depending on the height and fluctuation of the groundwater-table as well as on the frequency, height and duration of inundations would be governed by the prevailing low-flow and low groundwater table conditions. The desiccation of the Szigetköz floodplain would eventually alter the previous riverine wetlands into dry habitats similar to large floodplain areas of the Upper Rhine near Breisach. In the case of impounding the side branch system with artificial supply a completely different wetland ecosystem would develop adapted to nearly stagnant surface and groundwater levels.

1

Nagymaros Reservoir

Several peaking modes were envisaged in the Original Project. Depending on the average flow, certain peaking modes were considered as operation rules for the Gabčíkovo power plant. For instance, at mode 900/700, 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. 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 (Karadi and Nagy, 1983). Higher discharges would allow for the release of two peaks per day. *Figure 2.5* shows daily water level fluctuations in the Dunakiliti-Hrušov Reservoir (a) and the Nagymaros Reservoir (c). 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 water levels as documented in *Table 2.4* are detrimental to the whole ecosystem in many respects: The riverbed would be endangered by erosion in certain reaches as was concluded by Bognár and Rákóczi (1988). This process would only be stopped in case of eventual armouring. Near the banks and in the vicinity of the Nagymaros barrage accumulation of fine sediment can be expected.

The ever changing flow conditions and water levels are very unfavourable to all aquatic and riparian habitats. 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 water level fluctuations would stay without vegetation and lose its high ranking ecological value. The former valuable wetland vegetation of the islands would be impounded anyway.

The aquatic habitats would also suffer from the ever changing flow conditions. The substrates would never be stable; suspended sediment 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 (see *Chapter 4.4.2.4*).

Altogether the construction and operation of the Nagymaros Barrage would destroy valuable habitats and generate very unfavourable living conditions for the aquatic fauna in the reservoir. The daily fluctuations of water levels by several metres would yield a devastated strip of riverbank instead of valuable riparian habitats.

Downstream section of Nagymaros

2

The Nagymaros power plant was also supposed to operate on a peaking mode (*Figure 2.5*). Unlike at Gabčíkovo, there would always be a minimum discharge of at least 1,000 m^3/s. At mode 2000/700 the maximum difference in discharge would still be 1,300 m^3/s with a maximum descent rate of minus 102 m^3/s per minute (Karadi and Nagy, 1993). The maximum decrease of discharge would then correspond to a water level difference of 2 m at the gauge station of Budapest.

Although the daily discharge and water level 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 (Électricitée de France) operates the 10 water power stations from Kembs to Iffezheim at a moderate peaking mode (maximum discharge exceeding natural flow Q = 300 m^3/s). Although the peaking of the discharge is considerably 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.

The construction and operation of the Nagymaros power plant including peak energy production would probably entail the construction of another barrage at Adony (rkm 1601).

2.3.3 FLOOD PROTECTION IN THE ORIGINAL PROJECT DESIGN

(based on Laczay, 1994b)

The generally accepted level of flood protection for rivers ranges from the 50 to the 200-year flood depending on the value of the endangered area (DVWK, 1983). Higher protection levels are only applied for large cities, important industrial compounds and nuclear power plants.

With the installation of reservoirs in river systems an additional risk of flooding has to be accounted for. The rupture of a dyke or dam impounding a large body of water may result in higher flood waves than any natural flood event. Therefore the design flood for the safety structures (levees, spillways, flood gates) is generally higher than the design flood for the "normal" dyke system and may go up to the 1,000- or 10,000-year event or to the so-called "Probable Maximum Flood".

Closely associated with the design flood level is the freeboard allowance, which is the safety margin above the calculated water level accounting for wave action, softening of the crest, settling of the dam, etc. Large reservoirs necessitate a higher freeboard, e.g. 2.5 m, as opposed to traditional levees (0.5-1.5 m).

For operational safety it is common usage not to include all available structures for flood release in the calculation but to reserve one or two openings to account for a potential failure of release structures.

In the case of the G/N System the Joint Contractual Plan specified the flood release under various operational conditions, using the Gabčíkovo complex consisting of 8 turbines and 2 ship locks and/or the Dunakiliti weir with 6 gates and 1 ship lock (*Table 2.5*). Several alternative plans for flood operation were considered, the last one, in 1989, stipulated a "Temporary Order of Operation" as follows:

Table 2.5: Safety procedure for flood release as stipulated for the Original Project

Design flood	Gabčíkovo	Dunakiliti	Free-board	Discharge capacity
100-year 10,600 m^3/s	release through 4 turbines (50%) and 1 ship lock including the filling system (50%) capacity: 3,920 m^3/s	release through 5 openings (77.4%) capacity: 6,680 m^3/s	1.5 m	10,600 m^3/s (100% of the design flood)
1,000-year 13,000 m^3/s	release through 4 turbines (50%) and 2 ship locks including the filling systems (100%) capacity: 5,170 m^3/s	release through 6 openings (85.7%) capacity: 7,830 m^3/s	0.5 m	13,000 m^3/s (100% of the design flood)

For the release of the 10,000-year flood all openings at Dunakiliti should be used. In case of emergency the 100-year flood could be released through Dunakiliti alone with sufficient freeboard.

According to the calculations and model investigations the G/N System provided a suitable release of the design floods with proper safety in case of coinciding structural failures and with sufficient freeboard allowance. The adopted design philosophy complies with international standards.

3

Ice release

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 leading to rising water levels. If the ice jam does not start moving, the flow levels may exceed the top of the protecting levees.

Due to the effects of river training the frequency of icy floods has considerably decreased. The last big icy flood occurred in 1956, the last solid ice cover in the Szigetköz reach developed in 1963/64 causing smaller ice jams with no major consequences. Meanwhile only ice drifts occurred, and there was no solid ice cover on the Danube in the last seven winters.

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.

During almost every winter a solid ice cover up to 30 cm thick would develop. This could lead to an ice jam at the upstream end endangering the city of Bratislava. The following measures were decided on in the Order of Operation in 1978:

- A solid ice cover should be kept undisturbed as long as possible; the water level should be raised by 0.5 m above the operational level of 131.1 m asl.; no peak power operation; if possible the ice cover should be left to thaw on the spot.
- In case of strong ice drifts from upstream and/or considerable increase of discharge, an ice free corridor must be provided by ice breakers.
- The broken ice must gradually be let down through the open Dunakiliti weir; this procedure requires a flow velocity of about 1 m/s which can be generated by lowering the water level to 128.0-128.5 m asl. to provide the appropriate rate of flow. A releasing cycle was planned to last 8-12 hours at 800-1,500 m^3/s arriving flows.

(1) *In the case of impounding the side branch system with artificial supply a completely different wetland ecosystem would develop adapted to nearly stagnant surface and groundwater levels.*

The Treaty parties agreed in the Joint Contractual Plan, as it evolved, to supply water from the Danube to the side arms on both sides of the river by means of intake structures on the bypass canal (at Dobrohošť) and at the Dunakiliti weir. These measures coupled with the construction of underwater weirs in the old riverbed may now also restore the interconnection between the Danube and the floodplain, including periodic flooding and inundation (which had started to be lost in the 1960s and had all but vanished by 1989).

The great progress made in rejuvenating the Slovak side of the river in the last two years proves the effectiveness of these remedial measures in compensating for the adverse effects of human activity in the past. The "wetland ecosystem" being restored there is closer to what existed before the 1960s. Where direct recharge has been implemented, there are signs of a positive increase in biodiversity and of a return to the more natural biodiversity of a century ago due to the multiple succession of new ecotypes. Already, species that had been considered locally extinct have been recorded again - particularly in the shallow areas of the reservoir, the Čunovo and Rusovce side arms, the Biskupcé side arms and in the reservoir seepage canals. See, Vol. III, pp. 93-104. For it is not only in the side arm areas that more natural conditions can be restored. The fast flowing main channel of the Danube in the pre-dam state was not a natural environment and had resulted in the destruction of the main benthic and littoral communities. The typical flora and fauna of the Danube river delta had been preserved to an extent in the side arms, but the communities there were being harmed by lack of water flow. The Project increases flow into the side arms and reduces flow velocity in the main channel by around 30%. This allows the regeneration of the typical inland delta species. The creation of the reservoir both allows the revitalisation of the upstream river branches (at Kopáč, Rusovce and Čunovo - where there has been a rapid regeneration of water organisms) and provides a vast new habitat, of particular importance for fish and birds.

(2) *The Nagymaros power plant was also supposed to operate on a peaking mode (Figure 2.5).*

This is completely incorrect; only Gabčíkovo was to operate at peak mode - but to do so, the Nagymaros step was essential. In any event, as discussed earlier (see, Comment 5 to "Scientific Evaluation" p. 4, above), no agreement between the Treaty parties covering peak mode operation had been reached as to Gabčíkovo in 1989; and in October 1989, Czechoslovakia offered its pledge to limit or abandon peak mode operation entirely.

(3) *Ice release*

This discussion of ice release is not critical of the Project. As is shown in Vol. III, Ch. 12, Sec. 3, the ice phenomenon had been carefully studied, benefitting from 50 years' experience at Austrian and German river power projects.

In order to direct the broken ice towards the Dunakiliti weir a guiding "ridge" had been built along the left bank of the Danube up to rkm 1847.5. In front of the weir so-called ice catching islands were built to break up large floes of ice in order to avoid possible failure of the gates by blocking. The sill level of the Dunakiliti weir is at 120.7 m asl., yielding sufficient water depth for the safe discharge of broken ice. The entire structure was optimised for ice release. On top of the sector gates tilting gates have been mounted for precise handling of flows. Depending on the actual flow 2, 4 or 6 gates were planned to be raised above the water and the ice. In case of emergency, ice from the headrace canal was planned to be let downstream through the ship locks at Gabčíkovo. It is clear that this procedure of ice release requires a precise and faultless operation of the weir gates.

2.4 IMPACTS OF VARIANT C

2.4.1 CONSTRUCTION

Čunovo Reservoir

The Hungarian part of the projected Dunakiliti-Hrušov Reservoir is not impounded, but the floodplain vegetation and the side branch system were already devastated in 1989, when Hungary suspended work at the Dunakiliti weir structures. The Slovak part of the reservoir was constructed more-or-less according to the Original Project design with a connecting levee to the dyke of the power canal. The detrimental effects of the Čunovo Reservoir are the same as of the original Dunakiliti-Hrušov Reservoir.

The present operation of Gabčíkovo without peaking would not require an operational reservoir volume. If Gabčíkovo was just used as a run-of-river power plant the Čunovo Reservoir could be much smaller, constricted to the main channel without impounding the former floodplain.

2.4.2 OPERATION

Čunovo Reservoir

1

There is no information on the daily operation mode of Gabčíkovo. Presumably the system is working at constant discharges without peaking although a sudden increase in the discharge was reported in July 1994 causing fish mortalities in the old riverbed (see *Chapter 5.4*). Thus, there are only minor water level changes in the reservoir on a daily basis.

2

During the first flood after the closure of the river in November 1992 the downstream channel and floodplain were severely eroded due to unfinished protection measures and some tainter gates were washed away (cf. *Chapter 2.4.4*, below).

The high amount of eroded material is intermittently transported along the Old Danube during the flood discharge releases and finally contributes to the riverbed aggradation between rkm 1808-1800 (see *Chapter 2.4.3*). This process can still last for several years.

Table 2.6: Hydro-morphological Impacts of Variant C on the Old Danube

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.
Water levels	• sudden drop of water levels by 2-3 m (CEC, 1993a)
Flow velocities	• reduction of flow velocities from the former 1.2-2.0 m/s to about 1.0 m/s (CEC, 1993b); • reduced flow velocities in the tailwater of the power canal conjunction
Fluctuations of discharges & water levels	• 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 water levels) during flood release
Riverbed stability	• bank failures caused by the sudden drop of water levels after damming the Danube; • gradual degradation of the riverbed can be expected as predicted for the Original Plan (Bačík *et al.*; 1992)
Riverbed structures	• gradual formation of a riverbed adapted to flows of about 200 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

Old Danube

There is not much difference in hydro-morphological impacts between the Original Project design and Variant C. The discharges released to the Old Danube since the damming of the river, were kept on a base level of 200-250 m^3/s with an increase to about 350 m^3/s in the vegetation period of the first year of operation. In 1994 the discharges were kept to a base level of about 200 m^3/s and were not increased in the summer. Consistent with the discharge capacity of the 6 turbines at Gabčíkovo, flood discharges exceeding 3,000 m^3/s were released in the Old Danube.

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 flow and to a certain range of flood flows. Major changes in bed morphology could be expected during rare flood events. Vegetation grows and spreads between flood events on the formerly inundated part of the riverbed, decreasing its discharge capacity.

Although one-tenth to one-fifth of the discharge of the river is directed to the Old Danube, the actual increases of the every day water levels produced by the operation of Variant C are insufficient for the existence of floodplain habitats. In addition, similar degradation of the riverbed in the medium and long term has to be expected due to the total retention of the bedload in the reservoir.

The effect of "underwater weirs" is discussed in *Chapter 2.5* below.

The 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 200-250 m^3/s resulted in a considerable drop of the groundwater-table adjacent to the river (see *Plate 3.14*). In addition, the flood stages do not last long enough for efficient groundwater recharge.

3

On the Hungarian side, the desiccation that started in the mid-1960's 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 comprehensively (Chapter 4).

Table 2.7: Hydrological impacts of Variant C on the Szigetköz floodplain

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 (CEC, 1992)
Groundwater-table	• drop of the groundwater-table near the Danube corresponding to the 250 m^3/s water level • insufficient recharge of the groundwater by the side arm system at least on the Hungarian side; pumping of Danube water into the Szigetköz since July 1994 • 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 water level in the impounded side branch system • stagnancy in the evolution of all habitats due to missing dynamics of waterflow, water levels and sediment input

(1) *There is no information on the daily operation mode of Gabčíkovo.*

A comprehensive daily record is kept of the operations at Gabčíkovo - as required by law.

(2) *During the first flood after the closure of the river in November 1992 the downstream channel and floodplain were severely eroded due to unfinished protection measures and some tainter gates were washed away (cf. Chapter 2.4.4, below).*

The results of the flood that reached its peak on 24 November 1992 is discussed in detail in Vol. III, Ch. 12, Sec. 3 and has been set out in the SC-M para. 8.58. As shown there (and as admitted in the Hungarian annexes at HCM, Vol. 4, Annex 9 at p. 455), this was an extraordinary phenomenon. The structures washed away had simply not yet been put into place; and the erosion occurred because work on the rock fill chute downstream of the weir was incomplete. However, the only part of the "floodplain" affected was the area on Slovak territory already cleared. And the downstream effect of this event was in a sense beneficial since it washed downstream sediments that have settled and improved the eroded riverbed of the old Danube.

(3) *On the Hungarian side, the desiccation that started in the mid-1960's 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 comprehensively (Chapter 4).*

What has happened in the Hungarian floodplain is entirely the result of Hungary's abandonment of the G/N Project, which had provided for the restoration of the side arm systems on both sides of the river. On the Slovak side, it is not the impoundment of the side branch system but the intake at Dobrohošť supplying water to the Slovak side arm system that is most significant. As can be verified by a site visit, this is restoring the floodplain there to its pre-1960s condition. Vol. III, Ch. 4 establishes on the basis of current data and monitoring that the "riverine wetland character" of the Slovak side arm has not been changed comprehensively, as Hungary's "evaluation" wrongly predicts (without the slightest attempt to consider what has actually happened after more than two years of operation). See, also, Vol. III, Chs. 3 and 5.

2.4.3 IMPACTS OF VARIANT C ON NAVIGATION

After closure of the Danube in late October 1992, navigation was directed through the power canal using the locks at Gabčíkovo. Accidents at both locks interrupted navigation in early 1994 for several weeks, since the Old Danube could not be used for navigation during the incomplete status of Phase 1 (no ship lock installed at the Čunovo complex).

Since the diversion of the flow through the power canal several new flood sections have developed downstream of Sap between rkm 1808-1800 restricting the available low-flow depths by several decimetres.

2.4.4 FLOOD PROTECTION IN VARIANT C

(based on Laczay, 1994b and OVIBER, 1994)

Flood release

While the Dunakiliti weir was ready to release all the floods as planned, the structures at Čunovo were in various stages of construction when the Danube was closed by October 27 in 1992. In Phase I only the by-pass weir and the floodplain weir (plus the intake for the Mosoni Danube) could be used for flood release at the Čunovo structure. In addition, the construction of these weirs was not finished at the time of the dam closure. As stated in the CEC Working Group Report of 1992 (p. 8), on November 22, 5 out of 20 tainter gates of the floodplain weir were not mounted yet and only 10 of the gates had a short downstream bed protection of 10 instead of 50 m. At that time 5 turbines had been installed at Gabčíkovo with a capacity of 610 m^3/s each, the two ship locks had a maximum discharge capacity of 1,970 m^3/s (CEC, 1992, p. 4). There are several different discharge capacities for the turbines in different sources, ranging from 500 to 610 m^3/s; the calculation is based on 570 m^3/s used by OVIBER (1994).

The hydraulic capacity for flood release of Variant C has to be measured at the same safety standards that were adopted for the Original Project (*Chapter 2.3.3.*). This means that the release of the 100-year and the 1,000-year flood, respectively, should not use the entire discharge capacity available and sufficient freeboard allowance should be left. In addition, in case of emergency the Čunovo structure should be able to convey the 100-year flood alone.

This is obviously not the case for Phase I of Variant C. The operational guidelines, presented by the Slovak side to the Borders Water Commission in 1993, said that for the 100-year flood (calculated to be 10,600 m^3/s) 4,820 m^3/s should be released through Gabčíkovo. This means that 5 out of the 6 turbines so far installed and both ship locks would need to be used, using 89% instead of the previous 50% of the discharge capacity. In this case Čunovo would have to release 5,780 m^3/s compared to an available capacity of 6,085 m^3/s which is 95% (CEC, 1992). Actually this discharge capacity was not available immediately after the closure of the Danube; the Čunovo complex could hardly manage the 2,250 m^3/s that had to be released during the November flood in 1992.

OVIBER (1994) calculated the available discharge capacity of Phase I considering the safety conditions which were adopted in the Original Project (*Table 2.8*). According to these calculations the design floods could not be released in Phase I with the same safety standards as in the Original Project. In addition, in case of emergency the Dunakiliti weir would have, in the Original Plan, been able to release the 100-year flood alone with a smaller freeboard allowance. This again, is not possible with the Čunovo structures in their present condition (Phase I).

With the completion of Phase II (by the end of 1995?) the Čunovo structure will be able to discharge an additional 6,300 m^3/s through a ship lock, spillway gates and small turbines (CEC, 1992). Then the total discharge capacity will be 17,585 m^3/s, exceeding the 10,000-year flood.

1

It can be concluded that the Slovak side has accepted additional risks when implementing Variant C with uncompleted flood release structures called Phase I. In case of an uncontrolled rise of the water level up to the crest of the reservoir dyke, large protected areas in the Szigetköz could possibly be endangered by inundation.

Since the closure of the Danube three major floods occurred. Considering the incomplete flood release structures of Phase I, it was only good luck that the unusual November flood did not cause more damage. Although only 2,250 m^3/s had to be discharged through the Čunovo weir, about 3 million m^3 of sediment were washed away from the downstream floor of the bypass weir and the floodplain weir. A longer flood release could have endangered the weir structure. The damage to protecting structures, cross-dykes in the side arms, etc., on the Hungarian side amounted to around 11 million HUF. For further long-term consequences of this event, see *Chapter 2.4.2*.

In July 1993, a common summer flood with a discharge peak of about 5,100 m^3/s occurred; although there is a mutual agreement for joint action in flood fighting, there was no prior information on the actual flood release at the Čunovo weir. Within a few hours the discharge in the Old Danube was raised from 350 to about 1,600 m^3/s which was followed by a decrease to 750 m^3/s and another increase to 1,600 m^3/s within the next two days. These rapid water level fluctuations resulted in similar damage to the Hungarian side branches as in November 1992.

***Table 2.8**: Safety level at flood release for Variant C, Phase I (as calculated by OVIBER, 1994).*

Design flood	Gabčíkovo	Čunovo	Free-board	Actual Discharge Capacity	Missing discharge capacity
100-year 10,600 m^3/s	release through 3 turbines (50%), 1 ship lock including the filling system (50%); capacity: 3,530 m^3/s	release through 15 gates of the floodplain weir (75%), 3 gates of the bypass weir (75%); capacity: 5,310 m^3/s	1.5 m	8,840 m^3/s (83% of the design flood)	1,760 m^3/s
1,000-year 13,000 m^3/s	release through 3 turbines (50%), 2 ship locks including the filling systems (100%) capacity: 4,630 m^3/s	release through 18 gates of the floodplain weir (90%), 3 gates of the bypass weir (75%); capacity: 6,150 m^3/s	0.5 m	10,780 m^3/s (83% of the design flood)	2,220 m^3/s

Ice release

As stated above (*Chapter 2.3.3*) the release of ice floes and broken ice is a delicate operation, and the installation of a large reservoir promotes the development of an ice cover. Slovak authorities have presented insufficient information about the planned handling of icy floods. Supposing a similar release operation as originally planned at Dunakiliti, some questions arise.

The sill levels of the bypass and floodplain weirs at Čunovo are at 126.5 m asl. and 128.0 m asl., respectively, compared to 120.7 m asl. of Dunakiliti. This means, that the reservoir level cannot be lowered enough to safely discharge the broken ice (water depths of less than 2.0 m at the sills of the gates must be regarded as unsafe for ice release). On the other hand higher reservoir levels than 130.0 m asl. would not result in the required flow velocities to move the ice towards the gates.

As opposed to the Dunakiliti release structures, no tilting gates have been mounted at the Čunovo sector gates which would allow more precise gate operation. In addition, no ridges were constructed to guide the broken ice towards the Čunovo gates.

These conditions led to a dangerous situation in January 1993 when drifting ice accumulated in front of the Čunovo structure, and the ice flow turned into the power canal. Subsequently a 1.5-2 m thick ice jam developed in rkm 11.2-13.4 which could not be removed by ice breaker actions. Navigation was stopped for a week until the problem was solved by a thaw.

2

It can be concluded, that in terms of ice release, the Variant C structures cannot fulfil the requirements of the Original Project plans and can lead to blockage of navigation.

2.5 EVALUATION OF REMEDIAL MEASURES ("UNDERWATER WEIRS")

3

The term "underwater weir" disguises the fact that the proposed structures are regular fixed weirs of several metres height with backwater reaches of several kilometres in length (*Table 2.9*). At normal flow conditions in the Old Danube, i.e., 50/200 m^3/s for the Original Project and around 200 m^3/s base flow for Variant C, the free flowing Old Danube would be turned into a sequence of impounded reservoirs (*Figure 2.7*). As a matter of fact, there are plans to install small hydropower units in each weir structure.

Experiences from the Upper Rhine at the barrage of Rhinau (*Plate 3*) with similar weirs in the "rest-Rhine" show that such weirs may not have the desired effects on the adjacent groundwater levels. Kalkowski (1986) compared water levels for surface and groundwater with pre-dam conditions after 20 years of operation of the barrage of Rhinau (operating since 1964). He found:

- that the measured surface water levels up to a total discharge of 1,500 m^3/s (i.e., 15 m^3/s in the "rest-Rhine") are lower at the upper end of the impoundments than the average annual water level for pre-dam conditions,
- that even at flood flows the weirs are hydraulically effective and no continuous water level exists at any discharge,
- that the gradient of the groundwater level does not follow the drop of the surface water level at the weirs,
- that the groundwater level is governed by the low surface water levels at the upper end of the impoundments and not by the higher impounded levels near the weirs. For instance, the average groundwater-table adjacent to the channel of the dry year 1976 was almost identical with the pre-dam low flow water level of the Rhine in 1961, although the impoundments rise the surface water levels 70-80 cm above the previous average water level of the river.

(1) *It can be concluded that the Slovak side has accepted additional risks when implementing Variant C with uncompleted flood release structures called Phase I. In case of an uncontrolled rise of the water level up to the crest of the reservoir dyke, large protected areas in the Szigetköz could possibly be endangered by inundation.*

Hungary's contention here is that, while the Treaty Project adequately provided for the release of floods, phase 1 of Variant "C" could not fulfill the same standards, thus exposing Hungary to danger (although Hungary does grant that when phase 2 is completed during 1996 the problem of flood release will have been resolved). But this makes no sense. In the event of the "uncontrolled rise" of water - which has never happened - the worst that could happen is that the flood would reach the original right bank dyke of the Dunakiliti reservoir. No areas would be endangered or, if so, they would anyway have been endangered under the Treaty Project. This is a purely prejudicial argument of no relevance to the questions put to the Court. It is also factually incorrect - see, SC-M, para. 8.53, et seq.. Hungary admits that during phase 1, three major floods occurred, none of which caused any appreciable damage in the Hungarian side.

(2) *It can be concluded, that in terms of ice release, the Variant C structures cannot fulfil the requirements of the Original Project plans and can lead to blockage of navigation.*

This is misleading. Vol. III (Ch. 12, Sec. 3) describes the events that took place in January 1993 in detail. Navigation is always interrupted on the Danube during extreme ice conditions. The handling of ice release under phase 1 of Variant "C" has been routine, and phase 2 will bring improvements.

(3) *The term "underwater weir" disguises the fact that the proposed structures are regular fixed weirs of several metres height with backwater reaches of several kilometres in length (Table 2.9). At normal flow conditions in the Old Danube, i.e., 50/200 m^3/s for the Original Project and around 200 m^3/s base flow for Variant C, the free flowing Old Danube would be turned into a sequence of impounded reservoirs (Figure 2.7). As a matter of fact, there are plans to install small hydropower units in each weir structure.*

This is a total misdescription of the underwater weirs. Although the final design and location of the weirs was never decided on by the Treaty parties, the basic concept was agreed under the G/N Project. Reference to the weirs is even made in the 1977 Summary of the Joint Contractual Plan appearing at HM, vol. 3, annex 24, being translated as "bottom sills". The general design is shown at SC-M, Annex 24, at p. 34; how they are to function is shown in Illus. No. CM 12, appearing at SC-M, para. 8.11. Hungary also ignores the fact that the EC Working Group of Experts expressed approval of these weirs.

There are no plans to install small hydropower units in each weir structure.

These findings show that the construction of "underwater weirs" cannot replace the natural regime of the former river with respect to groundwater levels. Considering the absence of water level fluctuations up to 1,500 m^3/s (mean flow at this section of the Rhine ca. 1,100 m^3/s), the changes imposed on the groundwater regime by "underwater weirs" significantly affects the wetland ecosystem in the floodplain.

Table 2.9: Location, height, and width of "underwater" weirs as proposed by the Slovak side (CEC, 1993b)

Location (rkm)	Height (m)	Width (m)
1814.21	5.85	210
1816.60	3.10	290
1821.30	3.80	270
1824.43	4.95	270
1828.35	4.05	270
1831.70	3.95	300
1834.90	4.15	230
1843.00	4.05	300

In addition to the water levels, *Figure 2.7* shows the velocity profiles of the Old Danube for 50, 200 and 350 m^3/s with and without "underwater weirs" as proposed by the Slovak side (*Table 2.9*). Three phenomena can be observed from these graphs:

-with "underwater weirs" the flow velocities would be reduced to about one third of flow conditions, without backwater effects,

-without "underwater weirs" the variability of the flow velocity along the river is considerably larger,

-the backwater from the conjunction with the power canal affects the Old Danube up to rkm 1820-1825.

The magnitude and variability of the flow velocity govern the morphological pattern of the remaining riverbed. The construction of "underwater weirs" would lead to rather uniform flow conditions with the consequence of rather uniform riverbed habitats. Prevailing low flows during most of the year would lead to the silting up of a great part of the remaining riverbed; flood discharges would wash out most of these fine sediment. Thus the series of "underwater weirs" would represent nothing else than a sequence of weirs with backwater reaches in a small river with the well known resulting changes in the aquatic habitat.

1

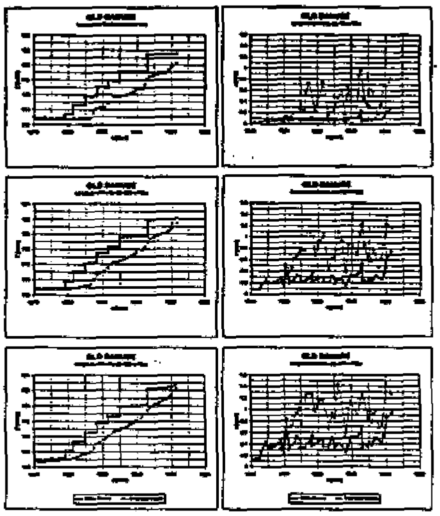


Figure 2.7: Water levels and velocity profiles in the Old Danube with and without "underwater weirs" for 50, 200 and 350 m^3/s (no peak operation at Gabčíkovo) (produced by VITUKI Consult Rt in September 1994)

2

2.6 ALTERNATIVE MANAGEMENT STRATEGIES

2.6.1 RIVERBED DEGRADATION

It is claimed in the Slovak Memorial that the problem of riverbed degradation is one of the main reasons for the implementation of the G/N Project (SM, paras 1.18, 2.85, 2.86). It has been stated above that in the Hungarian reach of the Danube the elevation of the riverbed is closely related to deposition of sediment and the impacts of dredging. There is no indication that the reduced level of sediment supply from upstream or river training has caused degradation of the bed. No certain conclusion can be drawn for the Slovak river reach because of the lack of dredging data.

In the case that bed degradation would have to be prevented by other means than stopping the industrial exploitation of gravel (and moving it to the floodplain), international experience points to less detrimental solutions than barrage building (Kern, 1994b).

At the Upper Rhine, barrage construction ended in 1977 with the barrage of Iffezheim. In 1975, France and Germany signed a treaty stipulating the construction of still another barrage at Neuburgweier mainly to prevent the down-cutting of the river below Iffezheim. Already in 1970, Karl Felkel published a paper with the title "Reflections on the possibility of preventing erosion of a movable riverbed –Upper course of the Rhine River taken as an example" (Felkel, 1970). After a series of field tests with sediment addition to replace the eroded bed material starting in 1975 below the barrage of Gambsheim (operating since 1974), Germany and France agreed in 1978 to continue the tests below the barrage of Iffezheim. In 1982, both countries signed an amendment stipulating that sediment addition would be carried out below Iffezheim instead of barrage construction at Neuburgweier. This decision was based on ecological as well as on economic considerations.

Between 1978 and 1992, a total volume of 2.3 million m^3 of gravel was added to the riverbed. As a result the navigational low-flow water level could be maintained within the prescribed margins. Intensive monitoring of the riverbed proved that the sediment addition is a feasible solution to riverbed degradation.

Encouraged by the Upper Rhine experience, preliminary field tests are being carried out in the Austrian reach of the Danube to stabilise the river below the last barrage, although only slight erosion tendencies were predicted there. Unlike at the Upper Rhine, the Austrian sediment addition is intended to develop an armoured layer of coarse sediment rendering a permanent bed protection which not only resists the hydraulic forces of flood flows but also of ship propellers. General model tests proved the feasibility of this procedure (Kern, 1994b).

2.6.2 NAVIGATION

(based on Laczay, 1994a)

Both the Danube Commission and the EEC regulations require 2.5 m draft with a minimum underkeel clearance of 0.2 m. The EEC and the DC recommend a fairway width of 80 m and 100 m, respectively.

The river training concept adopted in the early 1960s (*Chapter 2.2.3*) stood on sound scientific and professional grounds. Due to expected impoundment effects of the planned G/N Project, construction was not fulfilled on the entire reach. Along the stretch rkm 1842-1816, from Rajka to Sap, where training measures have been consistently performed, conditions of navigation improved and achieved a tolerable level. Apart from a few deficiencies in width, no major obstacles or "bottlenecks" were known in this particular reach. Shallow sections near Dunakiliti were caused by the construction of the inlet and outlet canal of the Dunakiliti weir.

In a re-evaluation of traditional concepts of navigational river training, it was concluded by VITUKI (1991) that a traditional solution without canalisation by major structures may be feasible, provided that careful morphological studies have been carried out. The special situation of this aggrading Danube reach will probably require some permanent maintenance. Similar conclusions were drawn by a recently completed Dutch-Hungarian study (Delft, 1994).

It is common practice in traditional river training to perform some dredging for navigational purposes, e.g. at the Rhine, the busiest fairway of the world, permanent dredging has to be carried out to maintain the required navigational depths (BMV, 1987).

2.6.3 FLOOD PROTECTION

In terms of flood protection there is and was no need for the G/N Project. The provisional construction of Phase I of Variant C might lead to an uncontrolled flood release, even in protected areas of the Szigetköz.

With the construction of a relatively large reservoir, ice conditions of the river have deteriorated. As opposed to pre-dam conditions, the development of a solid ice cover has to be anticipated almost every winter. Discharging ice from a reservoir is a most delicate task imposing additional risks, even with appropriate construction and proper operation. The structures of Variant C, Phase I, do not even fulfil the design requirements which were agreed for the Original Project.

Especially downstream of Győr there are some areas with insufficient flood protection on the Hungarian side where the dykes need to be heightened. The completion of the Slovak Reservoir dykes in this section *after* Hungary abandoned the G/N Project puts Hungary in an unfavourable situation because these dykes are 0.2-0.6 m higher than the required 100-year flood level. So Hungary will be forced to raise the dyke system in this reach to the same level to prevent increased and unacceptable risks from a higher level of flooding.

2.7 CONCLUSIONS

2

It was claimed in the Slovak Memorial, that the G/N Project is the *only* reasonable solution

- for harnessing the potential energy of this river reach;
- for solving flood protection problems;
- for mitigating navigation problems; and
- for solving the problems of bed degradation.

(1) *Thus the series of "underwater weirs" would represent nothing else than a sequence of weirs with backwater reaches in a small river with the well known resulting changes in the aquatic habitat.*

The need for underwater weirs is: (i) to increase the water level to allow the reconnection of the old Danube with the side arm system; (ii) to raise the ground water level; and (iii) to put a definitive end to erosion of the riverbed. Hungary mistakenly relies on experience on the Rhine with entirely different kinds of weirs to suggest that these results would not occur - see, Comment 5 to "Scientific Evaluation" p. 8, above.

There is no evidence to suggest that changed velocities would create anything but desirable changes in aquatic habitat or would be so reduced as to create colmatation problems. Indeed, the construction of underwater weirs in the old Danube will have a long term beneficial impact on flora and fauna. It does not entail a loss of natural ecological functioning, but rather allows for a further increase in habitat diversity by offering an increased variety in water flow rates, water depths and velocities. Hungary does not contest the beneficial nature of such variety, which it describes at p. 7 of its "Scientific Evaluation" as forming part of the natural system. In areas behind the underwater weirs and close to the riverbank, velocities would decrease. This would provide a favourable habitat for young fish, just as the areas behind the groynes that were erected on the main channel riverbed for navigation purposes. The suitability of this new habitat is shown in Illus. No. R-9 (appearing at SR, para. 12.45), a photograph showing teeming young fish gathered for feeding in the lower velocity area behind a groyne (a structure used to concentrate flows into a central channel so as to improve navigation conditions). By contrast, in the centreline of the underwater weir, higher velocities would remain. This variety of velocities and potential habitats is far closer to the river's natural state than the old high velocity main channel. The riverbed will no longer be a smooth, eroded surface; and riverbed bottom irregularities will develop, leading to an increase in habitat diversity.

(2) *Alternative Management Strategies*

It was claimed in the Slovak Memorial, that the G/N Project is the only reasonable solution
- *for harnessing the potential energy of this river reach;*
- *for solving flood protection problems;*
- *for mitigating navigation problems, and*
- *for solving the problems of bed degradation.*

It is not necessary for Slovakia to claim that "the G/N Project is the only reasonable solution" to solve the problems listed. It was the solution agreed pursuant to the 1977 Treaty by the Treaty parties. Under the Special Agreement, the Court has not been requested to devise or approve "alternative management strategies" as an alternative to what the Treaty parties decided. Accordingly, this whole discussion is irrelevant.

FLOOD PROTECTION

It is pointed out in this chapter that there was no need of this project to solve flood protection problems. Repeated reinforcements of the dyke systems after large floods have eventually led to an appropriate level of flood protection in the flood prone areas of the Szigetköz. Downstream of Győr minor tasks for flood protection have to be fulfilled. As a matter of fact, the installation of a large reservoir has increased the potential danger of ice problems, and the incomplete state of construction of Variant C, the so-called "Phase I", imposed additional risks on both sides.

NAVIGATION

There is clear evidence that the remaining obstacles for navigation can be removed by traditional river training methods including regular maintenance on short reaches. The Danube Commission requirements in depth for free flowing river sections can be met over the entire reach without a barrage system. Thus there is no reason to talk about a bottleneck in an important international fairway. The remaining restrictions in width and radii can be handled by careful navigation. The diversion of the Danube to the power canal has caused some additional ford sections downstream of Sap.

BED DEGRADATION

Unlike at the river Rhine, the degradation of the Danube bed in the Hungarian-Slovak reach and the subsequent lowering of the low flow levels was caused by excessive gravel mining combined with ford dredging and not by river regulation or bedload retention of upstream dams. The G/N Project simply compensates for the sinking of the water levels by impounding the free flowing river including the side branch system while ignoring the basic essentials of wetland ecosystems. Those who pretend to "save the Danube's inland delta" merely ignore the adverse environmental effects of the G/N Project.

ENERGY PRODUCTION

The entire G/N System was optimised for energy production. The construction of a large reservoir and the size of the power canal as well as the downstream barrage of Nagymaros were necessary for peak operation. Daily water level fluctuation up to 4.5 m in the Nagymaros reservoir had been accepted by the project planners caused by rapid daily rise and fall of the discharges released at Gabčíkovo during peak operation. For optimal use of the discharge at the turbines only 50 m^3/s should be released in the old riverbed during most of the year. The detrimental

impacts on the aquatic and riparian flora and fauna in the entire project reach have been emphasised in this chapter. Even at Nagymaros a considerable peaking operation was planned with high variability of releases to the free flowing river. The characteristics of the peaking are unmatched in European navigational lowland rivers, contrasting with the Slovak statement that the G/N Project is just another normal barrage system, similar to others in Europe.

No especial comments.

CHAPTER 3

SURFACE AND GROUNDWATER

SUMMARY

Riverbed aggradation below Bratislava has led to the formation of the wetland systems of the Szigetköz and Žitný Ostrov, located on a deep alluvial cone which forms the largest high quality groundwater aquifer in Central Europe. 1 The Danube flows have regularly flushed the complex system of side-arm branches, but the Danube main channel has primarily determined the groundwater recharge and groundwater levels throughout the Kisalföld.

Further downstream, the alluvial aquifers are much less extensive, but nevertheless are widely used for bank-filtered groundwater supply, including the supply to Budapest. In addition, there is some limited connection with the Karst groundwater of the Transylvanian mountains.

SURFACE WATER QUALITY

2 Historical trends of surface water quality show a dramatic increase in the nutrients Nitrogen and Phosphorus, which are no longer limiting for eutrophication. Increased algal biomass has occurred, and a change in phytoplankton communities. Bacteriological quality remains poor. Some heavy metal concentrations in water exceed permitted values; similarly heavy metals in sediment sometimes exceed relevant standards. The highest pollutant concentration tend to be associated with the fine sediment fractions.

3 Impacts of the Original Project in terms of water quality were neglected in the early studies of environmental impact, and even today have yet to be fully explored. One example is the effect of peak power operation on the Mosoni Danube. Flow reversal is likely to lead to unacceptable water quality given either wastewater discharges or stormwater overflows. A second example concerns the effects of the dams on eutrophication. Recent simulation results show a near-doubling of algal biomass due to the Dunakiliti Reservoir, and the effect of increased biomass on biochemical oxygen demand can exceed the impacts of wastewater discharges. However, prediction uncertainties remain high.

Anticipated effects of Variant C are similar in many respects, although Variant C is less unfavourable with respect to eutrophication. Current observations of water quality for 1993 and 1994 show some conflicting trends and are insufficient to identify long-term effects. Adverse water quality changes in the Mosoni Danube lead to fish mortalities.

GROUNDWATER

Prior to the diversion of the Danube, groundwater levels throughout the Szigetköz and adjacent areas were determined by Danube water levels. In addition to the direct supply to vegetation from near-surface groundwater, capillary rise can provide a significant source of natural sub-irrigation, where groundwater levels reach the covering fine soil horizons. The typical seasonal pattern of Danube flows generated maximum groundwater levels in the summer period of maximum water requirement for plants.

4 Some groundwater from the Szigetköz is used for supply, but the resource is as yet largely unexploited. Estimates of yield are similar to the needs of a capital city such as Budapest. The smaller alluvial aquifers downstream are more extensively used, in particular for the Budapest water supply.

Impacts of the Original Project have been investigated by groundwater simulation. The regional flow patterns change radically. The primary recharge sources become the reservoir itself and the side-arm system. 5 Groundwater increases occur near the reservoir, but decreases in groundwater levels are predicted to exceed 3 m and to affect an area of approximately 300 km^2 on the Hungarian side. Sub-irrigation would be reduced or lost over 167 km^2. However, results are sensitive to the uncertain effects of clogging associated with the deposition of fine sediment.

6 Further downstream, there is a likely degradation of Karst waters due to backwater effects of the Nagymaros dam, but the main issues concern bank-filtered wells, which are considered separately.

Impacts of Variant C are quantified for the Szigetköz and adjacent areas. These are shown to vary, depending on the level of former Danube flows. Up to 240 km^2 have suffered reduced groundwater levels. Under high flow conditions, 22 km^2 suffer reductions in excess of 3 m. In comparison with 1990, 127 km^2 suffered reductions in groundwater sub-irrigation during the growing season.

GROUNDWATER QUALITY–THE SZIGETKÖZ AND ADJACENT AREAS

Under natural conditions, recharge from the Danube is of high chemical quality and this water determines the present groundwater quality. However, sediment deposition in the side-arms has led to important chemical changes. Organic decay consumes oxygen; under reducing conditions, iron, manganese, and ammonium are readily released.

7 There are serious concerns for groundwater quality associated with the Original Project. Sediment deposition in the Dunakiliti Reservoir is expected to decay, and may lead to the water quality problems outlined above. This is confirmed by international experience and acknowledged by Slovakia and the CEC Fact-Finding Mission. Predictions are highly uncertain, but suggest that such occurrence is likely in the reservoir. 8 These effects are already observed in the side-arm system, which would become the other main source of groundwater recharge. There is a significant risk that the aquifer, over a period of years and decades, would become unfit for water supply.

9 Following construction of Variant C, groundwater quality adjacent to the side-arm system has generally been found to have unacceptable levels of iron, manganese, and ammonium, with some examples of arsenic release.

BANK-FILTERED WATER SUPPLIES

Concern for bank-filtered water supplies includes problems of yield and chemical quality. Where gravel layers in the riverbed have been reduced, for example, in the vicinity of Budapest, well yield has been reduced and there is an increased risk of pollutant ingress. Changes to river sediment have also led to the deposition of fine sediment adjacent to wells, with observed long-term water quality deterioration, documented here for the Surány Waterworks on Szentendre Island.

In the back-water reach of the Nagymaros dam, sediment deposition is calculated to affect the quality of existing waterworks. 10 Just downstream, two existing wells have had serious water quality degradation due to bed sediment changes, believed to be associated with the Nagymaros coffer dam.

Downstream of Nagymaros, dredging was to have taken place and simulations show that further bed degradation is expected due to erosion. These effects are compounded by changing patterns of sediment deposition. 11 It is concluded that there is a serious risk of yield reduction and water quality deterioration in the major well fields providing water supply to Budapest.

3.1 INTRODUCTION

3.1.1 THE NATURAL SYSTEM

As noted in *Chapter 2*, the Danube emerges from a gap between the Alps and Carpathian mountains at Bratislava to flow through the Kisalföld, or Little Danube Plain, to the Danube Bend and Budapest (*Plate 1.1, Volume 5*). River morphological development was discussed to explain the history of riverbed aggradation and the formation of the complex wetland systems of the Szigetköz and the Žitný Ostrov. On the geological time-scale a large alluvial cone has been formed, which reaches depths of 600 m in the Szigetköz and forms a groundwater aquifer which is the largest groundwater resource in Central Europe. Downstream of Gönyü, the gravel layers are substantially thinner, and discontinuous, but they have been extensively developed for bank-filtered water resources, and in particular for water supply to Budapest, where some 800 wells supply up to 1 million m^3 per day.

12 Throughout the Danube reach from Bratislava to Budapest, there is an intimate interrelationship between surface waters and groundwater. The dominant source of recharge to the alluvial groundwater is in general the main Danube channel. Hence groundwater levels are primarily determined by Danube water levels, and their temporal variability reflects the Danube flow regime. This has also been the case for the Szigetköz, although the situation is more complex, due to the periodic filling of the braided system of side-arm channels under high Danube flow conditions.

The Danube flow regime and associated groundwater levels have had a dominant and defining influence on the regional environment. As discussed in *Chapter 5*, this is reflected in the patterns of soil development. In *Chapter 4*, the ecological dependence on these hydrological characteristics is presented. It should be noted that where shallow groundwater occurs, it may be directly accessible to vegetation. However, if the water-table is located within a fine-textured soil profile, capillary action can provide a significant plant water supply through a natural process of sub-irrigation. This has been an important factor in both the natural ecology of the Szigetköz and the agricultural development of this region.

It can be seen that the natural systems of the region, and particularly the Szigetköz and adjacent areas, have evolved, over a time-scale of centuries and longer, to form an integrated system with complex inter-dependencies.

3.1.2 METHODOLOGY OF IMPACT ASSESSMENT

The aim of this chapter is to explain our understanding of the surface water and groundwater regime under pre-dam conditions, and to discuss the actual and potential impacts of the Original Project and Variant C. However, the complexity of the problem, involving physical, chemical and biological inter-relationships, some of which are poorly understood, should not be underestimated, nor the methodological implications.

13 To illustrate the complexity, it can be noted that changes in Danube flows affect groundwater directly, but also have impacts on surface water quality and the deposition/mobilisation of river sediment. In turn, the distribution and depth of sediment modify surface water-groundwater inter-relationships, and chemical changes in surface water and sediment can have major implications for groundwater quality.

3. COMMENTS TO HUNGARY'S "SCIENTIFIC EVALUATION", CHAPTER 3: SURFACE AND GROUNDWATER

(1) *The Danube flows have regularly flushed the complex system of side-arm branches, but the Danube main channel has primarily determined the groundwater recharge and groundwater levels throughout the Kisalföld.*

Hungary exaggerates the importance of the "Danube main channel" in terms of groundwater recharge. The main channel has only existed since the 19th Century. Recharge through the side arms largely ceased from the 1960s because these received so little water. But recharge continues through the side arms if they are not deprived of water.

(2) *Historical trends of surface water quality show a dramatic increase in the nutrients Nitrogen and Phosphorus, which are no longer limiting for eutrophication. Increased algal biomass has occurred, and a change in phytoplankton communities. Bacteriological quality remains poor. Some heavy metal concentrations in water exceed permitted values; similarly heavy metals in sediment sometimes exceed relevant standards. The highest pollutant concentration tend to be associated with the fine sediment fractions.*

This gives a misleading impression. The water in the Danube is improving in quality (see, Vol. III, at Chs. 1 and 2), and Hungary has elsewhere given the impression that the overall quality is good: "The Danube water quality can according to Hungarian classification be categorised as 1st class regarding the majority of the components ..." see, EC Working Group report of 2 November 1993, HM, Vol. 5, Annex 18 (emphasis added). See, also, Hungary's 1989 study at HC-M, Vol. 4, Annex 13 (at p. 535).

No perceptible trend can be detected in terms of Nitogen and Phosphorus content in the period 1989-1994. See, Vol. III, Ch. 2, Figs. 2.10 and 2.11.

There is no link between poor bacteriological quality and the G/N Project (save to the extent that the Treaty parties were to construct waste water treatment plants as part of related national investment, i.e., the G/N Project would have had a beneficial impact).

(3) *Impacts of the Original Project in terms of water quality were neglected in the early studies of environmental impact, and even today have yet to be fully explored.*

This assessment is incorrect. The primary aim of Hungary's 1985 EIA was to verify the Project's impact on water resources. See, SC-M, para. 7.74. Water quality was one of the matters studied under the massive 1976 Bioproject of Czechoslovakia, updated in 1986, as well as in follow-on studies - see, SM, para. 2.17, et seq., and Annex 24. It was also a matter of continual study and monitoring by the Joint Boundary Waters Commission - see, SM, para. 3.10, et seq..

(4) *Some groundwater from the Szigetköz is used for supply, but the resource is as yet largely unexploited.*

"As yet largely unexploited": The Committee for Water Management Sciences of the Hungarian Academy of Sciences stated in April 1992: "The geographical location of the area renders, as a matter of course, the conveyance of water via the water mains over long distances uneconomical" - see, HM, p. 411. Failing a population explosion in Szigetköz, this resource will remain largely unexploited by Hungary, but not by Slovakia, where it is

the source of water for Bratislava. The reason is simple. Bratislava is located near to the alluvial aquifer whereas Budapest is at a great distance.

(5) Groundwater increases occur near the reservoir, but decreases in groundwater levels are predicted to exceed 3 m and to affect an area of approximately 300 km² on the Hungarian side. Sub-irrigation would be reduced or lost over 167 km².

Hungary's figures are incorrect, on the basis of its own data. <u>See</u>, HC-M, Vol. 5, plate 3.11, which shows a simulated decrease in excess of 3m only where discharge into the old Danube would be limited to 50 m^3/s, <u>i.e.</u>, a non-Project situation, and then only in a very narrow strip along the Danube. Ground water level decreases would anyway be eliminated by direct recharge into the side arms. Hungary actually built an offtake into the side arms in the Dunakiliti weir with a capacity of 250 m^3/s. The correct utilisation of this would eliminate all decreases in groundwater levels on Hungarian territory, save for in a narrow strip along the Danube main channel. The construction of underwater weirs in the main channel would eliminate the decrease in this strip.

(6) Further downstream, there is a likely degradation of Karst waters due to backwater effects of the Nagymaros dam, but the main issues concern bank-filtered wells, which are considered separately.

Degradation of karst waters has been caused by mining activity on Hungarian territory. Due to excess water drainage, the water pressures close to the Danube changed alongside ground water flow patterns. This led to an infiltration of Danube ground water into karst waters. Karst waters are also polluted by seepage waters from the Hungarian military areas in Toked. The G/N Project has nothing to do with these impacts and, once mining activities are halted, the previous flow pattern of karst water towards the Danube will be restored. <u>See</u>, HM, Vol. 5, Annex 4 (quoted at SC-M, para. 7.76, fn. 115).

(7) There are serious concerns for groundwater quality associated with the Original Project. Sediment deposition in the Dunakiliti Reservoir is expected to decay, and may lead to the water quality problems outlined above.

Leaving to one side the absence of any support for this assertion in the Bechtel, HQI and EC Working Group reports, such "concerns" are refuted by the evidence of the monitoring of the actual status of the Čunovo reservoir and the sediment quality of the Danube. <u>See</u>, Vol. III, at p. 25 which shows that there has been <u>no</u> release of organic micropollution or heavy metals from sediments into ground water. The impact that such pollutants/metals could possibly have is, in any event, exaggerated by Hungary. Sediments are not shown to be significantly polluted and the heavy metals by in large come from upstream rock formations not from industrial pollution. <u>See</u>, <u>ibid</u>., at p. 35. <u>See</u>, also <u>ibid</u>., at p. 15, confirming that there are no significant concentrations of pollutants which could propagate into ground water by ground water recharge from the Danube.

(8) These effects [contamination of water quality by sediment] are already observed in the side-arm system, which would become the other main source of groundwater recharge. There is a significant risk that the aquifer, over a period of years and decades, would become unfit for water supply.

Poor water quality has existed in the Hungarian side arms due largely to the long term lack of water flow which has allowed stagnant water to remain for long periods in the branches. Since the implementation of the recharge into the Slovak side arms, surface water quality has not deteriorated and recharge into the aquifer has improved. <u>See</u>, Vol. III, p. 17. In fact, the damming has led to a general "improvement of groundwater

quality". Ibid. See, also, EC Working Group report of 2 November 1993, HM, Vol. 5, Annex 18 (at p. 707) and of 1 December 1993, ibid., Annex 19 (at pp. 782-783).

After the construction of the underwater weir in rkm 1843 to which Hungary now has agreed (Agreement of 19 April 1995), an improvement on the Hungarian side will necessarily occur.

(9) *Following construction of Variant C, groundwater quality adjacent to the side-arm system has generally been found to have unacceptable levels of iron, manganese, and ammonium, with some examples of arsenic release.*

This is true only for Hungary. Poor water quality existed in the Hungarian side arms prior to Variant "C". Increased flow into the side arms will remedy this situation and lead to an improvement in ground water quality, as it has already done on the Slovak side. See, Vol. III, p. 17.

(10) *Just downstream, two existing wells have had serious water quality degradation due to bed sediment changes, believed to be associated with the Nagymaros coffer dam.*

Although Hungary has not furnished the relevant data, this is clearly not correct. Hungary complains of water quality deterioration "in the early 1980s" (at p. 113). The Nagymaros coffer dam was constructed in 1987/1988.

(11) *It is concluded that there is a serious risk of yield reduction and water quality deterioration in the major well fields providing water supply to Budapest.*

There is no support for such a conclusion which is radically different from that reached by the 1980-1985 research and development program carried out by Budapest waterworks. See, SC-M, paras. 7.65-7.72 and Vol. I, para. 12.03, et seq. It is also unsupported by Hungary's 1989 study by Somlyody et al. - see, HC-M, Vol. 4, Annex 13 (at p. 576).

(12) *Throughout the Danube reach from Bratislava to Budapest, there is an intimate interrelationship between surface waters and groundwater.*

This is incorrect. The "intimate interrelationship" exists along certain stretches only, namely in Žitný Ostrov/Szigetköz, where the Danube flows along the top of an alluvial cone and therefore defines (in part) ground water levels. See, Vol. III, p. 2. This is concisely described in a paper given by independent consultants from the PHARE project: "The entire area [Žitný Ostrov/Szigetköz] forms an alluvial aquifer, which throughout the year receives in the order of 25 m^3/s infiltration water from the Danube in the upper parts of the area and returns it into the Danube and the drainage channels in the downstream part." HC-M, Vol. 4, Annex 12 (at p. 514). Thus, downstream, the Danube flows along a valley that drains surplus ground water. See, e.g., Hungary commenting on the Gönyü to Nagymaros stretch ("Scientific Evaluation", at p. 81): "Continuous recharge from the Danube does not occur." In fact, for the large part, no recharge occurs in this downstream sector.

(13) *To illustrate the complexity, it can be noted that changes in Danube flows affect groundwater directly, but also have impacts on surface water quality and the deposition/mobilisation of river sediment. In turn, the distribution and depth of sediment modify surface water-groundwater inter-relationships, and chemical changes in surface water and sediment can have implications for groundwater quality.*

For hydrologists who have studied the impacts over many years, the careful monitoring of water quality, quantity and sedimentation allows an acceptably accurate understanding of

impacts. Moreover, "complexity" itself does not imply negative effects, as Hungary seems to suggest.

please turn to next page

Methodologically, the only way to quantify change in such a complex set of interrelated processes is through simulation models based on extensive field data, but model strengths and limitations must be clearly understood. The application of integrated models to such complex systems is at the leading edge of research, and it must be recognised that techniques available for uncertainty analysis of such complex models are limited, and that levels of uncertainty may be very high. For example, although simulation methods for sediment transport are well developed, their results, particularly for bed-load, are typically subject to order of magnitude uncertainty. Processes of sediment clogging have received relatively little scientific attention, and there is no agreed basis to quantify effects on groundwater recharge. Modelling of chemically reductive processes in sediment and groundwater is in its infancy, and predictive results should be regarded as speculative, at best. It is evident that the combined models should therefore be seen as a way of informing judgement on impacts of change, but levels of uncertainty must be recognised in the context of risk assessment.

In our view, an integrated programme of modelling is an essential prerequisite for an environmental impact analysis of the Original Project. This is clearly recognised on the Hungarian side (Somlyódy *et al.*, 1989), and equally clearly recognised by Slovak and international experts. For example, Mucha (1990), discussing groundwater quality, notes process complexity, lack of knowledge, and the need for modelling. "In addition, biological and microbiological activity plays a decisive role in the game of groundwater quality considering the whole system from rainfall to the rivers, soil and the groundwater itself. . . .We must admit that this system and the processes occurring in it are not fully understood. It is an unquestionable fact, however, that such a complex system can be examined only by means of a model . . ." Discussing the PHARE project, Refsgaard *et al.* (1994) note that "To understand and analyse the complex relationships between physical, chemical and biological changes in the surface and subsurface water regime requires multidisciplinary expertise in combination with advanced mathematical modelling techniques" and conclude that information from the integrated modelling system "constitutes a necessary basis for subsequent analysis of flora and fauna in the floodplain."

However, Mucha also clearly recognises the limitations of modelling as well as its strengths. To continue his previous quotation, ". . .by means of a model, which nevertheless are still far from simulating the real complexity of the process. Last but not least, we are not even able to define our common understanding of nature conservancy and groundwater protection."

On both the Hungarian and Slovak sides, strenuous efforts are being made to quantify potential impacts using advanced modelling methods, and results from ongoing Hungarian studies are reported below. However, we reiterate our view, reinforced by Mucha and Refsgaard *et al.*, above, that such modelling is, and was seen in 1989 to be, an essential prerequisite for environmental impact assessment. It is, additionally, our view that such assessment is and was essential prior to

proceeding with the Original Project. The fact remains that it is not yet fully in place on either side.

3.1.3 SCOPE OF THE CHAPTER

In the following sections surface flow characteristics of the natural system, Original Project *(Plate 1.1, Volume 5)*, and Variant C *(Plate 1.2, Volume 5)* are briefly defined (*Chapter 3.2*), surface water quality is reviewed in *Chapter 3.3*, and the succeeding three sections evaluate the groundwater flow system (*3.4*), groundwater quality aspects of the Szigetköz and adjacent areas (*3.5*), and finally consider impacts on bank-filtered wells in the lower reaches (Gönyü to Nagymaros and Nagymaros to Budapest).

3.2 SUMMARY OF SURFACE WATER HYDROLOGY

by Klaus Kern

3.2.1 THE NATURAL SYSTEM

The discharge regime of the Danube is characterised by a seasonal variability which is governed by the Alpine catchment of the river, yielding higher discharges in early summer (mean annual flood 5,300 m³/s) and a low-flow period in the winter (average 848 m³/s). *Figure 3.1* shows the long-term monthly hydrograph of the Bratislava gauge.

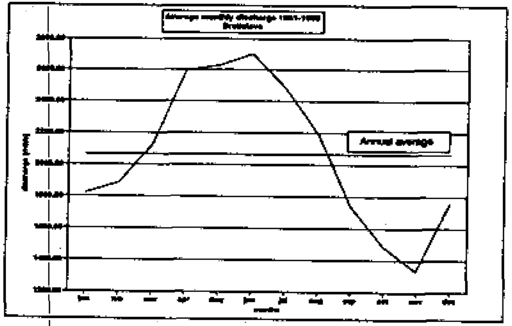


Figure 3.1: Average monthly discharge at Bratislava between 1981 and 1990

The design of the Original Project was based on the following characteristic discharges at Bratislava and Nagymaros (JCP, 0-1, 1977):

	Bratislava	**Nagymaros**
Period:	1901-1950	1901-1950
Average flow:	2,025 m³/s	2,421 m³/s
Lowest flow (year):	570 m³/s (1948)	590 m³/s (1947)
Highest flood (year):	10,400 m³/s (1954)	8,180 m³/s (1965)
20 year flood:	8,750 m³/s	7,650 m³/s
100 year flood:	10,600 m³/s	8,700 m³/s
1,000 year flood:	13,000 m³/s	10,000 m³/s
10,000 year flood:	15,000 m³/s	11,100 m³/s

Before the degradation of the riverbed started in the 1960s, many of the side branches were still open. The discharge in the side branches of the Szigetköz and Žitný Ostrov, e.g. in the reach of Gabčíkovo (rkm 1833-1816), amounted to about 20% for a total discharge of 1,005 m³/s. At 1,958 m³/s which is exceeded on 168 days per year the side branches carried up to 500 m³/s (Mucha, 1993).

1

After degradation of the riverbed and the closure of entrances of side-arms to improve navigation, the threshold for the branch system inflow increased to 2,500 m³/s which typically occurs for 75-100 days per year.

The following data in *Table 3.1* represent the situation in 1980.

Table 3.1: Flow regime of the Danube in 1980 (after CEC, 1992 and WORKING GROUP REPORT, pp. 16-17)

Characteristic flow situation	**Discharge 1980-conditions (m³/s)**	**Water levels at Dunaremete (m)**	**Flow velocity in main channel at Dunaremete (m/s)**	**Average duration (days/year)**	**Frequency (events/year)**
Flow largely confined to groynes within main channel	< 1,000	2.3	→ 1.4	13 days	Several times per year
Flow in main channel and permanent branches	1,000-1,800	3.7	1.4-1.8	42 days	Several times per year
Flow in a few river arms	1,800-2,500	3.7-4.5	1.8-2.0	122 days	Several times per year
Flow in some river arms	2,500-3,500	4.5-5.2	2.0-2.2	78 days	Several times per year
Flow in almost all river arms	3,500-4,00	5.2-5.6	2.2-2.3	17 days	Several times per year
Complete inundation of floodplain	> 4,500	5.6	2.3	4 days	Once per year
Deep inundation of floodplain	6,000	6.2	2.4	< 1 day	Once per 3-4 years

3.2.2 HYDRAULIC AND HYDROLOGICAL IMPACTS OF THE G/N SYSTEM

2

Water distribution according to the Joint Contractual Plan (OVIBER, 1994)

The water distribution, according to the Joint Contractual Plan (OVIBER, 1994) was specified to be:

Old Danube: 50 m³/s

200 m³/s (considered for the vegetation season)

(1) *After degradation of the riverbed and the closure of entrances of side-arms to improve navigation, the threshold for the branch system inflow increased to 2,500* m^3/s *which typically occurs for 75-100 days per year.*

"75-100 days per year": According to Hungary's table (at "Scientific Evaluation", p. 52), flow in "almost all river arms" occurred for only 17 days per year.

(2) *Water distribution according to the Joint Contractual Plan (OVIBER, 1994).*

As noted at Comment 4 to "Scientific Evaluation" p. 1, above, Hungary relies on a version of the Treaty Project which it calls the "Original Project" and which takes no account of the modifications made to mitigate the Project's impact on the environment. Moreover, Hungary refers to an unpublished 1994 document that has not been placed in evidence and which Slovakia has never seen. In sum, Hungary's comments relate to an "Original Project" and a "Joint Contractual Plan" that is not the Project as it evolved and would have been implemented in 1989 or 1992; and on the basis of this fictional "Original Project", Hungary develops its theories of environmental harm. However, Slovakia rejects Hungary's basic thesis and starting point: that the "Original Project" would inevitably have caused harm.

An increased discharge up to 200 m^3/s could be released, if necessary, during the growing season (it was not specified, in which case and in which period this should be done). The amount of 50 m^3/s is a guaranteed minimum discharge, which may be partially satisfied by seepage water from the reservoir.

Flood discharges exceeding 4,000 m^3/s would be released at Dunakiliti into the bed of the Old Danube (for more information on flood release, see *Chapter 2.3.3*).

Hungarian branch system:	13.5-16.9 m^3/s [average of 15 m^3/s] (Dec. - Feb.) 23.5-26.9 m^3/s [average of 25 m^3/s] (Mar. - Nov.)

According to the Joint Contractual Plan, 13.5-16.9 m^3/s from Dec.-Feb. and 23.5-26.9 m^3/s from Mar.-Nov. would be supplied to the Hungarian floodplain branch system. The lower values apply after clogging of the branch system. Facilities to release up to 250 m^3/s from the Dunakiliti ship lock into the side branches had been installed, but there was no agreement concerning the use of this capacity. Actually, it was agreed that any extra withdrawal of water from the reservoir exceeding the guaranteed amounts would be compensated to the other side by a corresponding reduction of the shared part of the produced energy.

1

Hydrological effects of the implementation of the Original Project

Mosoni Danube:	10 m^3/s (Jan. - Feb.) 20 m^3/s (Mar. - Dec.)

Dunakiliti-Hrušov Reservoir:

impounded volume	200 million m^3
rise of water level	ca. 2 m at Bratislava
reduction in flow velocity	from ca. 2 m/s to ca. 0.30 m/s
daily water level fluctuations	ca. 1 m due to peak operation (see *Figure 2.5a*)

Old Danube:

drop of water levels	2-3 m drop of water levels below the navigational low-flow level
reduction in flow velocity	from about 2 m/s to less than 1 m/s (see *Figure 2.7*)
daily water level fluctuations	during peak operation at Gabčíkovo water level fluctuations of about 4 m would occur at the conjunction with the power canal; the backwater of this sudden rise of water level would reach up to rkm 1823 in the old riverbed reversing the flow direction during the rise (see *Figure 2.5c*)
seasonal water level variations	no water level fluctuations for about 350 days per year

The Szigetköz floodplain:

Natural flow into the side branches and the floodplain would occur only for rare flood events. At 6,500-7,500 m^3/s, which is a 5-10 year flood event, there would be flow in some side branches only, and at 7,500-8,500 m^3/s corresponding to a 10-25 year flood almost all branches and parts of the floodplain would be inundated.

Nagymaros Reservoir:

change of water levels	+ 6 m at Nagymaros - 2 m at Sap (tailwater dredging of Gabčíkovo)
daily water level fluctuations	dependent on the peaking mode, e.g. for mean flow: 4.4 m at rkm 1801 (Sap) 2.6 m at rkm 1793 1.0 m at rkm 1768 (Komárom) (see *Figure 2.5c*)
daily fluctuations in flow velocity	from 0.3-1.6 m/s (*Table 2.4*)

Hydraulic and hydrological impacts of Variant C

Čunovo Reservoir:

The reduction in flow velocity is similar to that discussed above; to the best of our knowledge, the water level is kept at a constant level.

Water releases in the Old Danube:

The water releases in the Old Danube *(see Plate 3.1, Volume 5)* were kept to a base level of 200-250 m^3/s in 1993 with an increase to about 350 m^3/s from May to June. In 1994 the base level of discharges was lowered to about 200 m^3/s and no increase was made in the summer (data from daily discharge measurements at gauge Rajka).

Flood discharges above 3,000 m^3/s – corresponding to the capacity of 6 turbines at Gabčíkovo – were released in the old riverbed. For further information on flood release refer to *Chapter 2.4.4*.

Hungarian branch system:

A lock in the connecting canal to the Mosoni Danube is used to convey some water into the Szigetköz side branch system. In 1993 the discharges varied between 2-10 m^3/s (OVIBER, 1994).

Mosoni Danube:

A monthly average of 10-20 m^3/s were released into the Mosoni Danube until September 1994. In October 1994 the discharge was increased to about 25-35 m^3/s.

3.3 SURFACE WATER QUALITY

by László Somlyódy

3.3.1 THE NATURAL SYSTEM

The present section discusses briefly the water quality of the Danube between Bratislava and Budapest. It considers the situation in the late 1980s and early 1990s together with the trends observed and thus indicates how water quality might have evolved if the project had not been implemented (for a detailed overview of the late 1980s see Somlyódy *et al.*, 1989). It also discusses the water quality observed in 1993, and through it, some of the first impacts of Variant C. Since water quality is characterised by a number of physical, chemical, biological and other attributes which may be affected differently, the analysis will deal separately with different groups of components and types of problems.

Due to the large number of parameters for assessing the water quality, classification schemes of a few categories are used in most countries in order to quickly assess the water quality and its changes. Since there are no broadly accepted international systems – particularly not in Central Europe being in a state of strong political and economic transition – each country employs a specific scheme which may or may not correlate. To avoid confusion, the discussion starts with the definition of class limits. Actually, due to historical reasons, three different systems will be specified as follows:

(i) The previous Hungarian classification system, valid between 1985 and the end of 1993, which consisted of three rather coarse classes (Class I indicated good quality while Class III the poorest). The basis of the classification was the 80% duration value of water quality (i.e., only 20% of all the samples taken in a year could exceed the limits of the particular class identified). It is noted that for bacteriological purposes, four classes were employed.

(ii) The new scheme, introduced 1 January, 1994, follows the recommendations of the European Union. It incorporates five categories (Classes I to V) and is based on the 90% duration level. It is finer and more stringent than the previous one.

(iii) Finally, the six-class system is presented, agreed upon by Hungary and Slovakia to evaluate the joint water quality observations (this system was actually used by several earlier COMECON countries prior to 1990).

For the purposes of effective comparison and evaluation of the water quality discussed later on, *Tables 3.2a-c* incorporate the class limits of the three systems for oxygen budget and nutrients. As can be seen, first class oxygen budget limit values of the old scheme are similar to the corresponding second class limit of the new system. With regards to the nutrient content, the earlier Class I is approximately equivalent to Class III of the new system. The two more sophisticated systems, (ii) and (iii) are very similar.

(l) Facilities to release up to 250 m^3/s from the Dunakiliti ship lock into the side branches had been installed, but there was no agreement concerning the use of this capacity. Actually, it was agreed that any extra withdrawal of water from the reservoir exceeding the guaranteed amounts would be compensated to the other side by a corresponding reduction of the shared part of the produced energy.

Hungary acknowledges here the existence of the Dunakiliti offtake with its ample capacity to supply the side arms (on the Hungarian side only).

"No agreement": It is unclear what was not agreed, for as to compensation for extra withdrawal using Dunakiliti, Hungary goes on to say: "... it was agreed". In fact, there is no substance to the underlying contention that Hungary was somehow restricted in the use of the Dunakiliti offtake. If the only restriction was the reduction of its share in the electrical production at Gabčíkovo, which in turn led Hungary to decide to restrict flow into its side arms, Hungary would simply be sacrificing environmental considerations for economic benefits.

Table 3.2a: Hungarian surface water quality classification system, valid until December 1993

Component	Limit value		
	Class I	Class II	Class III
Oxygen budget			
Dissolved oxygen (mg l^{-1})	> 6	4	< 4
Biochemical oxygen demand BOD_5 (mg l^{-1})	< 5	10	> 10
Chemical oxygen demand COD_{KMnO_4} (mg l^{-1})	< 8	15	> 15
Chemical oxygen demand $COD_{K_2Cr_2O_7}$ (mg l^{-1})	< 25	40	> 40
Saprobity (Pantle-Buck) index	< 2.5	3.5	> 3.5
Nutrients			
Ammonium ion (mg l^{-1})	< 1	2.5	> 2.5
Nitrite ion (mg l^{-1})	< 0.1	0.3	> 0.3
Nitrate ion (mg l^{-1})	< 20	40	> 40
Ortho-phosphate ion (mg l^{-1})	< 0.3	2	> 2
Total phosphorus (mg l^{-1})	< 1	3	> 3

Table 3.2b: Hungarian surface water quality classification system valid since January, 1994

Component	Limit					Notes
	Class I	Class II	Class III	Class IV	Class V	
Oxygen budget						
Dissolved oxygen (mg l^{-1})	> 7	6	4	3	< 3	
Biochemical oxygen demand BOD (mg l^{-1})	< 4	6	10	15	> 15	
Chemical oxygen demand COD_{KMnO_4} (mg l^{-1})	< 5	8	15	20	> 20	
Chemical oxygen demand $COD_{K_2Cr_2O_7}$ (mg l^{-1})	< 12	22	40	60	> 60	
Saprobity (Pantle-Buck) index	< 1.8	2.3	2.8	3.3	> 3.3	
Nutrients						
Ammonium ion (NH_4-N) (mg l^{-1})	< 0.2	0.5	1.0	2.0	> 2.0	
Nitrite ion (NO_2-N) (mg l^{-1})	< 0.01	0.03	0.1	0.3	> 0.3	
Nitrate ion (NO_3-N) (mg l^{-1})	< 1	5	10	25	> 25	
Ortho-phosphate ion (PO_4-P) (mg l^{-1})	< 0.05	0.1	0.2	0.5	> 0.5	Surface waters not flowing into reservoirs or lakes.
Total phosphorus (mg l^{-1})	< 0.1	0.2	0.4	1.0	> 1.0	
Ortho-phosphate ion (PO_4-P) (mg l^{-1})	< 0.02	0.05	0.1	0.25	> 0.25	Surface waters flowing into reservoirs or lakes
Total phosphorus (mg l^{-1})	< 0.04	0.1	0.2	0.5	> 0.5	

Table 3.2c: Classification system applied in the joint Hungarian-Slovak water quality monitoring programme

Component	Limit value					
	Class I	Class II	Class III	Class IV	Class V	Class VI
Oxygen budget						
Dissolved oxygen (mg l^{-1})	> 8	6	5	4	2	< 2
Biochemical oxygen demand BOD (mg l^{-1})	< 2	4	8	15	25	> 25
Chemical oxygen demand COD_{KMnO_4} (mg l^{-1})	< 5	10	20	30	40	> 40
Chemical oxygen demand $COD_{K_2Cr_2O_7}$ (mg l^{-1})	< 15	25	50	70	100	> 100
Saprobity (Pantle-Buck) index	< 1.0	1.5	2.5	3.5	4.0	> 4.0
Nutrients						
Ammonium ion (NH_4 -N) (mg l^{-1})	< 0.1	0.2	0.5	2.0	5.0	> 5.0
Nitrite ion (NO_2-N) (mg l^{-1})	< 0.002	0.005	0.02	0.05	0.1	> 0.1
Nitrate ion (NO_3-N) (mg l^{-1})	< 1	3	5	10	20	> 20
Ortho-phosphate ion (PO_4-P) (mg l^{-1})	< 0.008	0.065	0.16	0.33	0.65	> 0.65
Total phosphorus (mg l^{-1})	< 0.016	0.13	0.33	0.65	0.98	> 0.98

3.3.1.1 Traditional chemical components

The quality of the Danube stretch considered is generally acceptable (due to the high dilution rate). For instance, in the 1980s it was evaluated as Class I and Class II according to the old classification system. It was of Class I for most of the

parameters, except for instance BOD_5, NO_2-N, NO_3-N, PO_4-P (characterising organic material and some of the nutrients), pH, oil and phenol (VITUKI, 1987). Observations performed after 1989 resulted in Class I and Class I-II for dissolved oxygen and BOD_5 respectively, according to the new Hungarian scheme (KGI, 1993). Nutrient contents were categorised as Class III-IV. System (iii) led to similar results when evaluating the 1993 observations of the joint Hungarian-Slovak monitoring programme: dissolved oxygen was of Class I, BOD_5 was of Class II (deteriorating downstream towards Budapest), P was of Class III, while N was of Class II-V (Hungarian-Slovak Boundary Water Commission, 1994).

To illustrate the average concentrations in addition to classes, at Komárom – which are typical of the Rajka-Budapest section – the 90 % duration values for the period 1986-1992 were as follows: DO (dissolved oxygen) = 8.3 mg/l, BOD_5 = 5.4 mg/l, COD_p = 7.5 mg/l, COD_d = 23 mg/l, NH_4^+ = 0.6 mg/l, NO_3^- = 14.8 mg/l, TN = 4.6 mg/l and TP = 0.4 mg/l (see KGI, 1993, for details).

The tributaries of the Danube (e.g., the Morava, Váh, Ipoly and other minor rivers, *Plates 1.1* and *1.2, Volume 5*) show a poorer water quality (VITUKI, 1987; KGI, 1993 and Hungarian-Slovak Boundary Commission, 1994). Thus, longitudinally, the Danube's quality is slightly deteriorating (again depending on the particular component considered). Due to a slow mixing rate, there are also transverse variations for many water quality parameters: the lower quality close to the left side bank shows the impact of the larger tributaries to the same side.

Trend analyses, based on data of the regular monitoring programme for the period 1976-1985, showed moderate changes (VITUKI, 1987). Generally, BOD_5, NO_3-N, PO_4-P, specific conductivity and total dissolved solids slightly increased, while DO and COD improved. Evaluation of trends for the period 1986-1992 showed significant improvements primarily due to the introduction of wastewater treatment and a reduction of industrial emissions in the upstream catchment area (also influencing heavy metals – see later) (KGI, 1993). Accordingly, BOD_5, COD, ammonia and orthophosphate concentrations improved by 4-7%/yr (average values for the Rajka-Budapest stretch), while other parameters did not change significantly (KGI, 1993).

The quality of the right side tributaries exhibited larger variations prior to the mid 1980s. The trend of deterioration could reach 10%/yr. These negative trends appear to have decreased recently at several tributaries (for details see KGI, 1993 and Csanády *et al.*, 1994).

Longer term historical changes up to the 1980s can be evaluated, for example, by comparing the minimum and maximum values of measurements performed by Liepolt in 1960 at Rajka (Liepolt, 1965) with the corresponding values of the regular monitoring programme for the period 1981-1985, for each component (VITUKI, 1987). The drastic increase in most of the parameters (see *Table 3.3*) is apparent. Particularly striking is the change in the two most important nutrient

No especial comments.

forms, NO_3-N and PO_4-P. The latter demonstrates an order of magnitude increase (as noted before, the current trend has slightly changed but nevertheless does not influence the excess supply of nutrients, crucial from the viewpoint of eutrophication (discussed in *Chapter 3.3.1.2*)).

Trends in water quality are also reflected by increasing seasonal variability. Due to growing eutrophication and associated algae activity (see *Chapter 3.3.1.2*) the diurnal fluctuation of dissolved oxygen has been increasing significantly in the vegetation period and oversaturation can frequently be observed. Simultaneously an increase in pH can be observed (for the same reason; KGI, 1993). Forms of nitrogen and ortho-phosphate also show increasing seasonal alterations (KGI, 1993). Despite this, PO_4-P remains permanently in abundance.

Table 3.3: Changes in water quality on the Danube at Rajka
(Liepolt, 1965 and VITUKI, 1987)

Component	Dimension	1960 (Liepolt, 1965)		1981-1985	
		Min.	Max.	Min.	Max.
Total dissolved material	$mg\ l^{-1}$	183	272	181	380
pH	-	7.5	7.9	7.3	8.9
COD_p	$mg\ l^{-1}$	4.4	9.3	3.2	15.2
BOD_5	$mg\ l^{-1}$	0.6	5.3	1.0	9.8
Total hardness	$mg\ l^{-1}$	99	126	78	143
NH_4^+	$mg\ l^{-1}$	0.12	0.40	0.10	1.70
NO_2^-	$mg\ l^{-1}$	0.03	0.10	0.04	0.26
NO_3^-	$mg\ l^{-1}$	0.6	5.0	4.4	17.0
PO_4^{3-}	$mg\ l^{-1}$	0.00	0.16	0.12	1.46

3.3.1.2 Eutrophication and hydrobiology

The increase in nutrient levels outlined earlier and the improvement of light conditions due to the sediment retention of dams constructed on the upstream Danube section led to enhanced eutrophication (between the late 1950s and the late 1970s the average suspended solids concentration was approximately halved on the Rajka-Budapest reach; Berczik, 1993; Berczik and Kiss, 1994). Actually inorganic P and N are abundant in the water and they no longer limit algal growth. This explains why, in comparison to the early 1960s, there was approximately an order of magnitude increase in algal parameters such as algal count, biomass, chlorophyll-a and others. For instance, at Göd (30 km downstream of Nagymaros),

where detailed weekly observations have been available from the late 1970s, nowadays the algal count number, the biomass and the chlorophyll-a value can reach annual peak values of 60 million ind/l, 50 mg/l and 200 mg/m³, respectively, all indicating hypertrophic conditions (Berczik and Kiss, 1994). At the same time the seasonal dynamics have also changed. From the early 1970s, these have been characterised by the occurrence of abundant algal communities in spring and increased fluctuation in dissolved oxygen levels, influenced by photosynthesis and respiration.

The development of eutrophication was accompanied by a change in the structure of phytoplankton. In the 1960s, the algal composition was dominated by diatoms, while today it has shifted towards lake phytoplankton communities as a result of increased residence time in the upstream reservoirs. The composition of phytoplankton shows seasonal dynamics. In winter, diatoms dominate, during spring and autumn diatoms, green algae and yellow-green algae are predominant, while in summer, green algae, blue-green algae and Flagellates are the most common (Hungarian-Slovak Boundary Water Commission, 1994 and KGI, 1993). The zooplankton biomass correlates with the algae biomass; its composition is also typical for slow flowing, eutrophic waters (Hungarian-Slovak Boundary Water Commission, 1994).

Longitudinal changes in algal biomass along the river are also significant. Under low water conditions the chlorophyll-a concentration at Göd can be 50-100% higher than at Rajka. It is noted that for the period 1977-1986 the mean chlorophyll-a value at Baja was approximately double the value at Rajka (see *Chapter 3.3.2.3*). This increase is primarily due to the travel time of 3-4 days under low flow between Rajka and Baja (which suggests significant biomass increase for the planned Dunakiliti Reservoir having a comparable mean residence time; Berczik, 1993).

Parameters related to eutrophication exhibit changes on different time scales (such as a day, a season, a year, a decade or decades). Up until now, year to year alterations have not yet been touched upon. They should be primarily interpreted in terms of the annual peak biomass. It can be readily demonstrated that given the present excess supply of nutrients, the maximum value depends basically on the coincidence of low flow conditions with warm, sunny days (high temperature and solar radiation). For instance, a flood – quickly reducing the residence time within a given river stretch and increasing turbidity – almost immediately collapses an algal bloom otherwise under development. Thus, the year-to-year changes strongly depend on the combined variability of meteorology and the hydrologic regime. Accordingly, the scatter is high in the peak chlorophyll-a values, and for instance, between 1977 and 1986 it varied between 70 mg/m³ and 196 mg/m³ at Rajka.

The conditions in the Szigetköz side-arm system, the total length of which is several times that of the main river and within which there is a large diversity in biotic and abiotic factors and hence also in life conditions (Berczik, 1993), very much depends on their water supply. Prior to the diversion of the Danube, the side-arm system was characterised by an intensive water exchange above 1,800 m³/s

Danube flow from the total length of the associated main river. The duration of such exchange periods in a year – depending on the hydrologic regime and floods – was about 35-40 days (KGI, 1993).

As long as there is a supply to side-arms, circumstances in terms of dissolved oxygen and algal growth are similar to that of the Danube (with the difference that the residence time is usually higher). As far as the composition of phytoplankton is considered, the report of the Hungarian-Slovak Boundary Water Commission, 1994, is referred to. If inflow stops and the side-arms become disconnected, they start to behave more as lakes or ponds (their residence time can increase to several months since they are separated from the main stem for about 180 days in a year) and chlorophyll-a values close to 800-1,000 mg/m³ can be observed (Berczik, 1993). All the changes depend very much on morphology, bed volume of individual side-arms and the water regime and thus the mosaic-like behaviour is one of the major attributes of the Szigetköz (Horváth and László, 1994). Dead arms also belong to this mosaic of waterbodies, and are characterised by phytoplankton and zooplankon communities typical of stagnant waters (KGI, 1993). The macro-zoobenthos incorporates among others rare species, atypical of the rest of the Szigetköz.

The composition of zooplankton (see Hungarian-Slovak Boundary Water Commission, 1994, for details) and fish populations depend on the hydrologic regime and the connection of the side-arm system to the main river. Their composition is characteristic of moderately polluted surface waters (Berczik, 1993). Observed changes are primarily due to eutrophication, discussed above.

The Mosoni Danube is generally of poorer quality than the main river (Hungarian-Slovak Boundary Water Commission, 1994). Downstream it is strongly impacted by the wastewater of Győr and possible backwater effects of the Danube.

The organic pollution of a river and heterotrophic bacteria decomposing in it is characterised by the so-called Pantle-Buck saprobic index which is in the ß-mesosaprobic, ß-α mesosaprobic range for the Danube stretch in question (Berczik, 1993). At the upstream section it corresponds to Class III of the new evaluation scheme outlined in *Table 3.2b*, while at Budapest it is of Class IV (KGI, 1993 and Hungarian-Slovak Boundary Water Commission, 1994).

3.3.1.3 Bacteriological water quality

Waters used for swimming should not contain infecting micro-organisms, pathogenic bacteria, fungi, parasites, their eggs etc. All these attributes are incorporated into the bacteriological water quality assessment system, characterised by nine parameters (see *Chapter 3.3.1*). Evaluations of the mid 1970s showed a Class II-III quality (WHO-VITUKI, 1976 and Deák, 1977). In the late 1980s (KVM, 1988) the entire Danube stretch upstream to Budapest belonged to Classes III and IV, i.e. the river – due to the discharge of untreated wastewater – was not suitable for bathing

(Class II is required for resorts used for bathing purposes). Recent studies report a categorisation in the Classes IV-V according to the new system (KGI, 1993 and Hungarian-Slovak Boundary Water Commission, 1994).

3.3.1.4 Micropollutants

The first heavy metal observations were performed in 1974 at Szob (WHO-VITUKI, 1976). Later several systematic longitudinal profile measurements covering Hg, Cd and Pb were made covering the entire Hungarian Danube stretch (VITUKI, 1981). The average mercury and lead concentrations were below the drinking water standards (used for comparison), while the maximum values sometimes exceeded the permitted values. For Cd, average values were significantly below the standard, while the peak concentrations exceeded it (VITUKI, 1981).

Under the framework of the joint Hungarian-Slovak water quality monitoring programme eight components are investigated. In 1993 all metals – except mercury – belonged to Class I of the accepted evaluation scheme outlined earlier in the Rajka-Medve section (and to Class I-II between Komárom and Budapest; see KGI, 1993 and Hungarian-Slovak Boundary Water Commission, 1994, for details). For Hg a few higher values were monitored between Rajka and Medve resulting in a classification in categories III-V (Hungarian-Slovak Boundary Water Commission, 1994). The impact of accidental pollution is suspected in this respect. Another reason could be the inadequacy of the monitoring programme. The sampling frequency was much smaller than usual for traditional components, which is associated with the little knowledge available on the dynamics of Hg. Thus the degree to which these observations are representative is questionable.

As far as organic micropollutants are concerned, more than ten compounds (such as lindane, atrazine, aldrin, dieldrin, DDT, PCBs) were investigated in the upper stretch of the Hungarian Danube and upstream of the capital. The latter were considered as the most important results from the viewpoint of drinking water supply and toxic impacts.

Atrazine is a typical pesticide present in the Danube water owing to its widespread use in agriculture. Higher concentrations occur during application periods and intensive runoff events (non-point source impact). Sometimes highly fluctuating concentrations of volatile chlorinated solvents are observed in the Danube. However, even in the case of the above mentioned organic micropollutants, the characteristic concentrations were below the limits considered hazardous for aquatic life or drinking water.

Most of the other organic micropollutants were not detectable or their concentration was much smaller than the corresponding standard (KVM, 1988; Csanády, 1993; Horváth and László, 1994 and Hungarian-Slovak Boundary Water Commission, 1994). Thus, they do not form a problem at present.

No especial comments.

3.3.1.5 Sediment contamination

The first sediment heavy metal measurement (from the top 5 cm layer) was performed in 1977 which was followed by a number of other studies. For the purpose of the evaluation the monitored sediment concentration was compared to natural ("unpolluted") background levels and to soil standards used in agriculture (these specify values still tolerable by plants, see below). The average sediment heavy metal concentrations did not exceed the standards, however the maximum values were permanently larger than the limit (except for Cu). In 1987 observations were made in side-arms of the Szigetköz and in the vicinity of bank filtered wells within the impact area of the GNBS. The smallest values were obtained in the upper reach of the Danube, while the highest values were found in the middle stretch, between Tát and Göd (VITUKI, 1988b).

From among the organic micropollutants the highly resistant compounds tend to be accumulated in the sediment, that is why it contains chlorinated hydrocarbon type pesticides, polyaromatic hydrocarbons and oil. The evaluation of sediment quality has not yet been standardised (this is the reason why soil standards are used). Recent efforts focus on the application of internationally accepted methods, among others in the frame of the Cousteau programme (Equipe Cousteau, 1993). The same study showed that the contamination of the Danube sediment for the organic micropollutants was inferior to those measured in some comparative western rivers (this statement applies to the entire Danube characterised by 52 sampling points of which 6 were located between Bratislava and Budapest). In contrast, heavy metals in the sediment span a wide range of concentrations "which overlaps those of 'uncontaminated' and 'polluted' rivers" used for comparison (Equipe Cousteau, 1993).

The contamination of sediment largely depends on flow conditions and particle size distribution. In stagnant zones where accumulation is fast, sediment core sample analyses showed that the thickness of the contaminated layer can be several metre (VITUKI, 1983). Detailed assessment revealed that for all the pollutants the smallest fraction (< 90 μm) had the highest concentration. Here even the average metal concentrations exceeded the standard (VITUKI, 1988b). Unfortunately, our available knowledge is inadequate for the understanding of the transport and accumulation of fine sediment fractions and associated micropollutants, as well as their possible harmful effects.

3.3.2 IMPACTS OF G/N SYSTEM ON SURFACE WATER QUALITY

The construction of a barrage can influence all the different aspects of water quality discussed above in many different ways, through a number of complicated processes which can be interrelated. One of the most critical issues in relation to the GNBS was that a comprehensive impact assessment on water quality was not prepared (the 1985 EIA hardly incorporated any analysis on water quality). This 1

situation would have been acceptable in the early or mid 1970s when possible negative impacts of damming on water quality were not yet widely recognised, however for the late 1980s the presence of such an evaluation – by using models and other methodologies to compare future impacts of alternative solutions of various projects – was considered essential in the developed world. Standards of assessment methodologies have developed tremendously during the past decade or so, and the procedure to be followed, virtually on a compulsory basis, is becoming increasingly elaborate (see *Chapter 7*). It suffices to refer to the Environmental Assessment Sourcebook of the World Bank and its sections dealing with water, water quality, dams and reservoirs (World Bank, 1991).

3.3.2.1 Uncertainty in understanding and lack of an impact assessment

Damming influences surface water quality primarily by increasing the sedimentation and residence time. In addition to these, peak operation mode has a further, largely unexplored impact. Most of these impacts seem to lead to negative changes, although their order of magnitudes are hard to quantify (given the present level of knowledge and studies performed). There can also be positive water quality changes among the many sided and interrelated effects.

For instance, growing residence time leads to increased organic material removal and associated dissolved oxygen concentration reduction. In turn, the latter can be compensated by enhanced oxygen re-aeration due to the increased surface area, wind impact and the effect of turbines. In fact for the Danube, changes in the dissolved oxygen budget in the main waterbody seem to be insignificant (see VITUKI, 1978 also for the simplifying assumptions employed). At the same time, increased residence time together with improved light conditions due to enhanced sedimentation of suspended solids (which also leads to the deposition of contaminants attached to the particles) intensifies algal production leading to the production of organic material inside the reservoir or reservoirs (known as internal or secondary organic material load) and associated dissolved oxygen changes.

In turn however, barrage construction usually has a positive effect on bacteriological water quality (see Csanády, 1993) – depending on concentration and other conditions.

In a slightly broader sense, damming can influence sediment transport (including sedimentation and erosion), eutrophication, organic material contamination, dissolved oxygen conditions close to the bottom due to the decomposition of organic material deposited, clogging and the impact on groundwater quality (i.e., by the appearance of iron, manganese and ammonia under anaerobic conditions; see *Chapter 3.5.2.3*). The transport of fine sediment, crucial from the viewpoint of the fate of micropollutants (see *Chapter 3.3.1.5*), the transversal distribution of deposition/erosion in cross sections at reaches with differing flow conditions and various interface processes outlined above are hard to quantify on the basis of

information and assessment available for the GNBS and they cause significant scientific uncertainty. The impact of peak operation leads to an additional element of the uncertainty.

The issue is further complicated by different time scales of impacts. For instance, changes in the dissolved oxygen budget (in the waterbody) appear relatively quickly. The development of eutrophication in a freshly constructed reservoir and its observation, taking into account year-to-year fluctuations, may take several years. Impacts associated with interface processes (deposition, erosion, clogging, influence on groundwater, etc.) may appear even on a longer time scale (i.e., a decade or more).

The lack of analyses and the level of uncertainty related to the above complex potential water quality changes, are illustrated subsequently by two examples – stressing that a detailed systematic evaluation is missing even today. Due to temporal effects and ongoing changes, a comprehensive assessment may not be possible within a short period of time: this raises important questions as to the possibilities of operational corrective measures.

3.3.2.2 Impact of the peak operation on the dissolved oxygen budget of the Mosoni Danube

The impact of the GNBS project on the oxygen budget of the main Danube was analysed using the traditional Streeter-Phelps model in 1978 (VITUKI, 1978) which in fact is too limited for the given problem since the impacts of the N and P cycles were neglected. The conclusions were twofold: due to reasons outlined in the previous section, BOD will improve by 0.5-1.0 mg/l and at the same time as a penalty, dissolved oxygen will somewhat deteriorate, but it will remain larger than 7 mg/l under summer low flow conditions which still indicates a good quality. The effect of peak operation was neglected (together with several other factors) which is probably a reasonable assumption for the main river, however not for the Mosoni Danube. This recognition led to an order of magnitude type of analysis in 1989 (Somlyódy *et al.*, 1989) which is outlined below.

The Mosoni Danube is heavily loaded by the raw wastewater of the town of Győr (about 80,000 m^3/d) which causes an approximate 2 mg/l dissolved oxygen reduction in the Mosoni Danube prior to the junction to the main river (under low flow conditions for both rivers). The operation of the GNBS would seemingly improve the situation since the daily average dilution rate increases according to the plan. However, the designed peak operation would induce a tidal-like back-and-forth motion resulting in a significant increase in the local travel (or residence) time.

Detailed studies show that three periods of different flow conditions will develop repeatedly each day: a downstream flow of about 8 hours duration, a reversed flow of approximately 6 hours and finally again a downstream flow of 10 hours. On the

basis of hydrodynamic model computations absolute values of the velocity range between 0.3 m/s and 0.5 m/s depending on the flow regime and the type of the operation. Thus, when reversed flow develops, pollution is transported upstream while organic material removal and dissolved oxygen consumption proceeds, which then continues after the change in flow direction, particularly when the river water already poor in dissolved oxygen again meets the wastewater discharge.

The phenomenon was handled as a first estimate by the classical Streeter-Phelps equations which should be incorporated into a set of longitudinal dispersion equations (using velocities as inputs from the hydrodynamic model). These can be solved numerically (for details see Somlyódy *et al.*, 1989). Results are to be seen in *Figure 3.2a*. It is apparent from the figure that the dissolved oxygen reduction is larger than under the present conditions even if biological treatment is introduced, and at the mouth of the Mosoni Danube, dissolved oxygen values below 4 mg/l can develop. 2

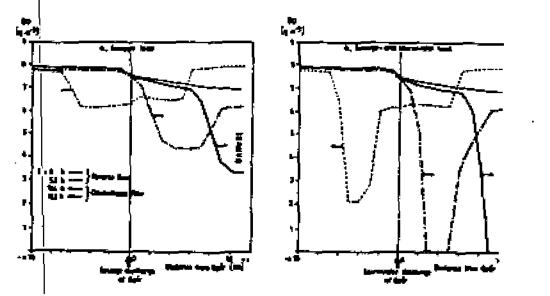


Figure 3.2a and b: Changes of dissolved oxygen levels in the Mosoni-Danube due to peak operation of the Gabčíkovo-Nagymaros river barrage system (after Somlyódy, 1991)

More striking is the situation under stormwater conditions: a rainfall event occurring once a year – an assumption, typically used for design purposes – can lead to complete oxygen depletion in the Mosoni-Danube (see *Figure 3.2b*). Thus, wastewater treatment alone does not lead to a satisfactory solution. In addition, the construction of a detention basin is needed or the stormwater should be diverted to the main Danube where the rate of dilution is much larger than in the Mosoni branch. Unfortunately, however, this issue was not raised at all, clearly indicating that water quality impacts were ignored in the course of planning and possible prevention or mitigation measures were not considered. 3

(1) *One of the most critical issues in relation to the [G/N Project] was that a comprehensive impact assessment on water quality was not prepared (the 1985 EIA hardly incorporated any analysis on water quality).*

This is an incorrect assertion that Hungary's own evidence refutes. One of the prime focuses of the 1985 EIA was water quality - see, SC-M, para. 7.74. The 1985 EIA's identification of impacts on, inter alia, water was reviewed by Hungary in its "Scientific Evaluation" (see, HC-M, Vol. 4, Annex 23) and rated "A", i.e., "generally well performed, no important tasks left incomplete" (at p. 907).

(2) *It is apparent from the figure that the dissolved oxygen reduction is larger than under the present conditions even if biological treatment is introduced, and at the mouth of the Mosoni Danube, dissolved oxygen values below 4 mg/l can develop.*

Slovakia has only limited data concerning the pollution of the Mosoni Danube, which flows solely through Hungarian territory. In terms of dissolved oxygen content, it is stressed that the water discharge into the Mosoni Danube from the Čunovo weir is characterised by good oxygen conditions. The dissolved oxygen content of the surface water in the reservoir is 8.0-8.5 mg/1, i.e., first class, and it is this water which flows into the Mosoni Danube. See, Vol. III, p. 25. Therefore, Hungary is solely responsible for the alleged poor oxygen conditions in the Mosoni Danube. Given the increase in flow in the Mosoni Danube and the increase in velocity, it is questioned whether Hungary's calculations are at all correct, in any event.

(3) *Thus, wastewater treatment alone does not lead to a satisfactory solution.*

Wastewater treatment, e.g., at Vienna and Bratislava, has led to greatly improved water conditions in the Danube - increased oxygen content and declining organic matter. SR, Annex 7, brings up to date the extensive measures taken by Czechoslovakia (and now Slovakia) to deal with the problem of background pollution of the Danube.

Hungary here is trying to deflect attention from the most important factor affecting the quality of the water of the Danube - the lack of wastewater treatment at cities like Györ, where raw sewage is discharged into the Mosoni, which then flows into the Danube (far downstream of the Gabčíkovo section of the Project) and on down to Nagymaros and Budapest.

3.3.2.3 Eutrophication

1

The impact of the GNBS on eutrophication can be evaluated by nutrient cycling models well known from literature which among others describe changes in the biomass due to growth, death, sedimentation and convective transport. The growth rate is a complicated, non-linear function of the temperature, solar radiation, suspended solids concentration and the biomass itself (called the self-shading effect). The death rate depends primarily on the temperature.

The transport term is a function of the flow influencing the residence time. Due to storage, it increases in the Dunakiliti Reservoir by a factor of 4-5 compared to the pre-dam situation. The consideration of convection necessitates the incorporation of reaction terms into transport equations which use velocities and geometric parameters as inputs from a hydraulic model. Since residence times are significantly higher in the floodplain regions of the Dunakiliti Reservoir than in the main channel (and other parameters such as the thickness of the photic zone relative to the water depth are also different), the two-dimensional effects should be accounted for. Due to its different nature, the Nagymaros Reservoir can be well approximated by a one-dimensional treatment.

It is noted that the study of Somlyódy *et al.*, 1989, used several assumptions which then were refined by Bakonyi, 1994. In addition, the first effort considered only critical summer conditions, while the recent, more comprehensive study simulates a year or several years.

During low flow conditions (approximately 1,000 m^3/s) the theoretical, average value of the residence time can reach about 70 hours in the Dunakiliti Reservoir (associated with a mean velocity of about 0.05 m/s), while under higher flows (4,000 m^3/s) it would be less than 20 hours (in the 95 km long Nagymaros Reservoir of throughflow character the increase of the residence time would be smaller than in the upper one (at Dunakiliti) and velocities would remain in the domain 0.35-1.4 m/s depending on the flow).

As noted earlier, a sudden change from low water to high water conditions due to floods leads to a fast reduction in the residence time which can quickly counteract the impact of algal growth and can flush out blooms within a day or so, a well known phenomenon. The impact of variability of flow and meteorological factors, and seasonal changes are well reflected by *Figure 3.3* which illustrates chlorophyll-a changes in the Rajka cross-section of the Danube. The figure shows at the same time that the above algae model acceptably describes the observed changes (for the computation of the Rajka section the upstream river system was replaced by an equivalent river stretch utilising the presence of excess nutrient supply) and thus it can be used for the analysis of future changes of different alternatives in a relative sense. The year 1976 was used for calibration while 1986 was employed for validation.

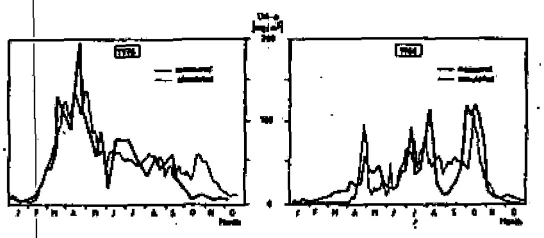


Figure 3.3: Computed and measured chlorophyll-a concentrations: Danube at Rajka (Somlyódy, 1991)

The coupled hydrodynamic-water quality model covering the entire Hungarian Danube stretch gave similarly good agreements between simulations and observations. For the model, data of the Rajka cross-section were used as upper boundary conditions, and flow and chlorophyll-a at Baja were computed. The unsteady flow model was calibrated and validated as a first step (see *Figure 3.4*). Calibration and validation results of the eutrophication model are shown in *Figure 3.5* (Bakonyi *et al.*, 1991; Somlyódy and Varis, 1993 and Bakonyi, 1994).

Model computations showed that the increase of algal biomass in the main channel of the reservoir is relatively small, about 10% since the residence time here changes only by a small extent. The situation is different in floodplain regions as the residence time can be much longer than in the main channel. Also the water depth is significantly less and thus the relative photic zone is much thicker than in the main river. As a result of all these factors, chlorophyll-a can increase from the assumed 40 mg/m^3 at the inlet of the reservoir to more than 200 mg/m^3. At the outlet the chlorophyll-a concentration is about 100 mg/m^3, i.e., as an impact of the reservoir the biomass can approximately double. These effects would be further amplified by the Nagymaros Reservoir which would induce some additional algal growth (it would be significantly smaller than for the upstream reservoir not only due to the smaller increase in the residence time but also due to the greater average depth and the smaller relative thickness of the associated photic zone).

Unfortunately the uncertainty of the estimate of the impact of the Dunakiliti Reservoir is relatively high. This was studied in the frame of a sensitivity and a Monte Carlo analysis framework (Somlyódy *et al.*, 1989) which resulted in 30% standard deviation of the outflow chlorophyll-a concentration estimate (and higher values for the floodplain regions).

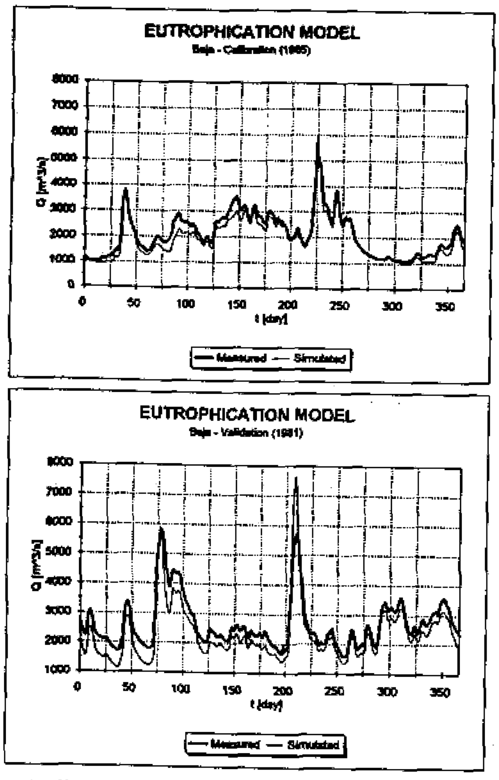


Figure 3.4: Unsteady hydrodynamic model calibration (1985) and validation (1981) Flow at Baja

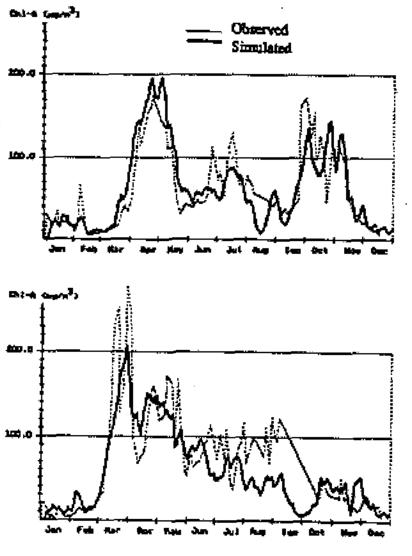


Figure 3.5: Calibration and validation of the eutrophication model. Observed and simulated chlorophyll-a content at Baja (after Somlyódy and Varis, 1993)

As noted before the above estimate was obtained for summer conditions by assuming a fixed inflow chlorophyll-a concentration. Full-year dynamic simulations were performed by Bakonyi, 1994 for the period 1977-1986 to investigate the impacts of the Original Project and their variability. The increase in the annual biomass as an impact of the Dunakiliti Reservoir (expressed in terms of chlorophyll-a) ranged between 45% and 90%, reflecting also the role of the hydrologic regime and meteorological condition (*Figure 3.6*). The error of this estimate is similar to that outlined before, again primarily due to the role of the floodplain (Bakonyi, 1994).

2

The estimated impact of the Dunakiliti Reservoir, taken as a whole, is close to the chlorophyll-a increase observed between Rajka and Baja (see *Chapter 3.3.1.2*). The additional percentage increase of the chlorophyll-a concentration at Baja is

(1) *The impact of the [G/N Project] on eutrophication can be evaluated by nutrient cycling models well known from literature which among others describe changes in the biomass due to growth, death, sedimentation and convective transport.*

Slovakia has carried out an in depth monitoring program devoted precisely to the impact of the Variant "C" reservoir in terms of eutrophication - see, Vol. III, at pp. 25-32. Actual monitoring results are necessarily more accurate than evaluation by modelling. The key overall finding is that Variant "C" has not led to an increase in phytoplankton biomass that would give rise to concern (at p. 32). In other words, eutrophication is shown not to be problematic as Hungary claims.

"The first two years of monitoring of the phytoplantkon in the reservoir and of the impact of the Project on the Danube water quality indicate that, in accordance with the prognosis, water impoundment in the reservoir does not result in significant phytoplankton biomass increase in the Danube."

(2) *The increase in the annual biomass as an impact of the Dunakiliti Reservoir (expressed in terms of chlorophyll-a) ranged between 45% and 90%, reflecting also the role of the hydrologic regime and meteorological condition (Figure 3.6).*

The actual monitoring results do not support these predictions. In the four year period prior to the implementation of Variant "C", the average annual biomass growth (in the Bratislava - Hrušov stretch) was in the range 4.1 - 23.4%. In 1993, it was 21.0% and in 1994 it was 22.1% - i.e., in both cases below the previous maximum figure.

In the Hrušov - Medvedov stretch, the pre-damming range was 9.0 - 16.1%. A relatively high percentage growth was recorded in 1993 - 45.4% but absolute values were low i.e., the high percentage increase merely reflected the fact that the biomass was low at the beginning of the year. But this was reversed in 1994, which saw an actual biomass decrease - by 0.49%. See, Vol. III, at p. 30.

The results of monitoring establish that no adverse increase in biomass occurred during this period and that concentration limits under hygiene standards were not reached. It is stressed that increases in biomass are not necessarily adverse in any event, leading to increased microbenthos and consequently more food supply for fish and other higher species.

Note that the maximum value for chlorophyll-a was recorded in the reservoir in August 1994, being 74.1 $\mu g.l^{-1}$. This must be compared to the maximum recorded measurements of water of the Danube at Budapest, which are more than twice as high. In the summer of 1991, the maximum value at Budapest was 160 $\mu g.l^{-1}$; in the summer of 1992 it was 170 $\mu g.l^{-1}$; and in the summer of 1993 it was 130 $\mu g.l^{-1}$. Hungary's modelled predictions as to chlorophyll-a in the reservoir (at "Scientific Evaluation", p. 70) have been demonstrated by actual monitored results to be completely wrong; and recorded increases remain half the recorded concentrations at Budapest. See, Vol. III, p. 26.

anticipated to be smaller than outlined above, primarily due to the discharge of the largely untreated wastewater of Budapest which from the point of view of algal growth, leads to less favourable light conditions downstream of the capital (Csanády, 1993 and Bakonyi, 1994).

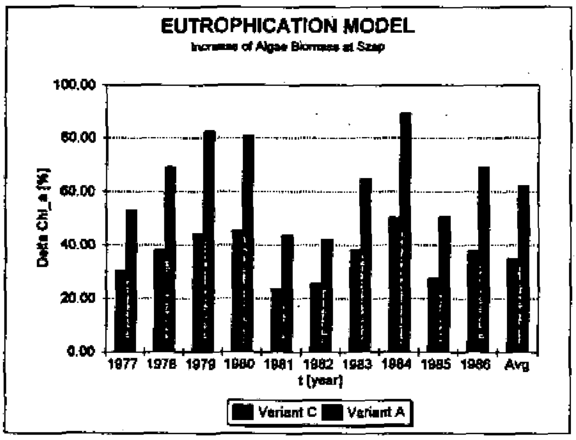


Figure 3.6: Change in the chlorophyll-a content at Sap due to the Original Project and Variant C (assuming historical records of hydrology and meteorology to demonstrate variability)

It is noted that the impact of peak operation and episodic wind events on algal growth was neglected in the scope of all the studies performed until now. Both phenomena can increase sediment re-suspension and reduce light penetration which would tend to diminish the above effect.

1

The increased biomass can require the modification of the technology of the surface waterworks of Budapest which is used primarily during the summer period. Methods of upgrading are known, (some changes were already performed, Csanády, 1993); however, they are expensive. It is also noted that due to the drop in water consumption during the past four years, this intake plays a somewhat more reduced role than before.

Increased biomass causes an internal load of organic material which – unlike organic material of sewage origin – increases downstream in the vegetation period

when algal growth exceeds mortality. Ironically, in the vegetation period the BOD_5 increase stemming from algal growth can be equivalent to (or larger than) the total external organic material load between Rajka and Budapest, and thus BOD_5 levels would not improve even if all the wastewater were treated biologically. Clearly, the solution of the eutrophication problem of the Danube stretch considered does not depend on wastewater treatment along the given reach, but it would require a co-ordinated international programme to reduce the phosphorus in the entire upstream basin.

2

3.3.3 POTENTIAL IMPACTS OF VARIANT C ON WATER QUALITY

Very few water quality studies are available on the impact of Variant C. The brief evaluation given here is based on Csanády (1993), Horváth and László (1994) and Bakonyi (1994).

3.3.3.1 Eutrophication

Most of the impacts are as discussed for the Original Project, but from the viewpoint of eutrophication, Variant C should be considered less unfavourable than Variant A: due to the reduced volume the residence time increases to a lesser extent and thus the increase in algal biomass is also smaller. This behaviour is clearly reflected by model computations (Bakonyi, 1994); using historical data for 1977-1986 – as for the analysis of the effect of the Dunakiliti Reservoir – the annual average increase in the biomass at Sap ranges between 25% and 50% (see *Figure 3.5*). This is smaller than the natural variability at Rajka (the mean of yearly average chlorophyll-a concentrations is about 30 mg/m^3 for the same period of time, while the minimum and maximum values are 16 mg/m^3 and 44 mg/m^3 respectively, i.e., ±50% around the mean). The observations of 1993 – data for 1994 were not yet available when the present document was prepared – are in harmony with the above findings (Csanády, 1993): on the basis of this single year no impact can be observed. Knowing the natural variability of chlorophyll-a and the estimated impact of Variant C, probably more than a decade is needed to detect the trend with statistically acceptable accuracy.

3.3.3.2 Other impacts on the main river quality

As a result of diverting the Danube in 1992 and increased sedimentation in the new reservoir, the suspended solids concentration dropped markedly in 1993: the annual average at Medve was 24 mg/l in comparison to 48, 47, 36 and 36 mg/l monitored in the course of the preceding four years (1989-1992; Horváth and László, 1994). It is noted that the reduction is higher in the variance and extreme values characterising fluctuations within the year. Simultaneously, the chemical and biological quality also showed slight changes: COD_p and COD_d mean values were somewhat reduced (due to increased sedimentation and organic material removal in the reservoir). Dissolved oxygen also seems to alter (reasons discussed earlier) which is shown primarily by the smaller minimum value detected (6.2 mg/l) in comparison to previous years (7.6, 6.8, 7.4 and 7.4 mg/l in the same sequence as before). Certainly, experiences of a single year can offer the first signs of changes, but they are not satisfactory for drawing stronger conclusions.

Bacteriological quality for 1993 suggests an improvement (Csanády, 1993) which – as outlined earlier – is a likely impact of the operation of the Čunovo Reservoir. However, the recent reduction in industrial emissions referred to several times may also have contributed to this. In spite of this improvement valid for the entire Danube stretch upstream to Budapest water is still far from being suitable for swimming.

Data available for 1994 do not support the improving trend in bacteriological quality which could be suspected from the 1993 observations (Csanády *et al.*, 1994). Our earlier remark is repeated once more: conclusions on water quality impacts can not be drawn on the basis of the measurements of a single year.

3.3.3.3 Impacts on water quality of the Szigetköz and the Mosoni Danube

The diversion of the Danube drastically affected water supply to the side-arm system (*Chapter 3.2.2*). In the past, these laterals carried fresh water during split conveyance of flood flows, but were drained rapidly as the river stages dropped. During periods between floods, water remained in the deeper side-arms alone, or these were recharged with groundwater seeping towards the main stream. After the diversion, as an attempt to feed the side-arms, a maximum flow of 10-12 m^3/s was introduced in the second half of summer in 1993 into the flood bed recharging system from the flow released to the Mosoni Danube. The recharging system impacted the side-arms along the lower Szigetköz, over a length of about 20 km (Horváth and László, 1994).

Observations revealed that the water quality of the five side-arm systems on the Hungarian side responded perceptibly to the changes of water supply. Without going into detail (see Horváth and László, 1994), a basic difference was induced in the nature and type of water supply. The irregular, dynamic water supply along the entire Szigetköz (driven by the hydrologic regime) was replaced by a more or less steady limited flow supply only from upstream changing drastically connections and disconnections, as well as their spatial and temporal patterns. The mosaic-like nature of the system has changed which is leading to a basically different pattern of water quality than in the past. This is again an issue which requires several years of observations before we can see the total impact.

The water supply of the Mosoni Danube also changed as a result of the diversion. The impacts in 1993 appeared primarily in dissolved oxygen conditions due to

upstream eutrophication, the occasionally poor quality of water released by the Slovak side and hydrometeorological conditions. These resulted jointly in periods of low dissolved oxygen level and fish mortalities in August.

3.4 GROUNDWATER

by Howard Wheater

3.4.1 THE NATURAL SYSTEM

3.4.1.1 The Szigetköz and Adjacent Areas

The geological development of the Little Danube Plain has been intimately linked with the morphological development of the Danube, leading to the formation of an extensive Quaternary alluvial aquifer (*Plates 3.2* and *3.3, Volume 5*). The Hungarian aquifer in the Szigetköz is estimated to have a volume of some 21.8 km^3 (Erdélyi, 1994) and is overlain by a spatially variable upper layer of fine soil, from 0-5 m in depth (*Plate 3.4, Volume 5*) and underlain by a sandy-clayey complex, which holds thermal waters at depth. The pattern of recharge is indicated by regional groundwater levels (*Plate 3.5, Volume 5*) and stable isotope tracer analysis (*Figure 3.7*). The Danube has been the dominant recharge source of the Szigetköz and Žitný Ostrov aquifers; water originating from the Danube has been found at depths of several hundred metre in the Szigetköz, and beyond the Mosoni Danube. In contrast, rainfall recharge is small (for this part of Hungary, potential evapotranspiration exceeds rainfall by 30% (Petrasovits, 1988)). However, beyond the Mosoni Danube, other recharge sources become progressively more important.

Knowledge of the aquifer has developed significantly during the 1980s and 1990s (Liebe, 1994). In particular the spatial complexity has become increasingly apparent, and more information has become available on the behaviour of the aquifer at depth. What was originally seen as a homogenous system has been found to be strongly anisotropic (first estimates indicated a 4:1 ratio of horizontal:vertical permeability; this has been revised to up to 30:1) and spatially heterogeneous, reflecting the complex and changing pattern of alluvial deposition. Flow velocities are highest at 50-100 m depth. The horizontal hydraulic conductivity varies from as little as 20 m/d in the upper aquifer to up to 300 m/d at depth. This indicates flow velocities in the range 200-300 m/year, consistent with the stable isotope results.

Hydraulic connection with the main Danube channel occurs throughout the Rajka-Gönyű reach, and prior to construction of the Variant C reservoir, Danube flows determined the groundwater levels throughout the Szigetköz and beyond. *Plate 3.5 (Volume 5)*, discussed above, presents the average water-table elevations in 1990 (which are representative of the later 1980s response) from which approximate flow directions can be inferred. In fact the response is more complex; under high

(1) *The increased biomass can require the modification of the technology of the surface waterworks of Budapest which is used primarily during the summer period. Methods of upgrading are known, (some changes were already performed, Csanády, 1993); however, they are expensive. It is also noted that due to the drop in water consumption during the past four years, this intake plays a somewhat more reduced role than before.*

It is not possible to tell whether Hungary is writing of actual impacts of increased biomass at Budapest or of alleged Project impacts. Clearly, biomass will increase in the summer months. But this has always been the case. There is no evidence to suggest a significant increase in biomass due to the G/N Project, as monitoring to date has shown (<u>see</u>, Vol. III, at p. 32), and no evidence whatsoever to suggest an adverse impact on the Budapest waterworks (which are located 150 km downstream of the Dunakiliti reservoir).

(2) *Clearly, the solution of the eutrophication problem of the Danube stretch considered does not depend on wastewater treatment along the given reach, but it would require a co-ordinated international programme to reduce the phosphorus in the entire upstream basin.*

The nutrient concentration in the Danube's waters is indeed high and would remain high even after waste water treatment in the Project area. But it is absurd to suggest that Hungary can ignore wastewater treatment in this stretch merely because it would not alone resolve the eutrophication problem (<u>see</u>, Comment 3 to "Scientific Evaluation" p. 68, above).

Coordinated international programmes are desirable and are being actively sought from the EC or specifically within the PHARE program by Slovakia. It (alongside neighbouring states <u>including</u> Hungary in some cases) is currently seeking approval for the following programmes:

- **Introduction of phosphate free detergents in the Danube basin (participants: Slovakia, Hungary and Bulgaria);**

- **Nutrient balances for Danube countries and options for surface and ground water protection (participants: Slovakia, Hungary and Austria);**

- **Present and future role in nutrient removal from surface water by wetlands, floodplains and reservoirs (participants: Slovakia, Czech Republic, Slovenia and Romania).**

Danube flow conditions the predominant groundwater flow direction changes from south-east to south, reflecting the importance of high flow recharge to the Szigetköz. Groundwater levels in the Szigetköz follow closely the variation in Danube water levels, but with decreasing amplitude as distance from the Danube increases. Thus adjacent to the Danube, groundwater fluctuations in excess of 2.0 m can be observed. Close to the Mosoni Danube these have reduced to 1.0 m or less.

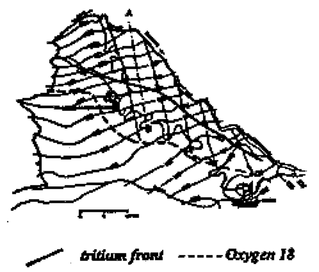


Figure 3.7a: Groundwater levels m asl.(after Liebe, 1994)

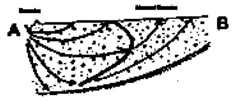


Figure 3.7b: Stable isotope analysis of tritium (after Liebe, 1994)

The depth of the water-table below the surface is of major importance for capillary moisture supply. If the water-table rises into the fine soils overlying the coarse alluvium of the aquifer, the water can rise up the soil profile by capillary action and provide an important contribution to the water use of both natural vegetation and agriculture (see *Chapter 5*).

The *average* water-table depth below ground surface is given in *Plate 3.6 (Volume 5)* for 1990 conditions. This can be compared with the thickness of the fine-grained sediment (*Plate 3.4, Volume 5*), from which it can be seen that capillary supply becomes progressively more important moving from the Upper to the Middle to the Lower Szigetköz. However, average water-tables underestimate the importance of this effect. Flood flows in the Danube characteristically occur in late spring/early summer and may be followed by late summer floods. Hence the highest groundwater levels coincide with the period of high water demand by

plants and maximum climatic stress. This provides a natural sub-irrigation which has been an essential feature of the ecology and agriculture of this area.

1

When considering groundwater in the Szigetköz, historical trends should be noted. The degradation of the Danube bed due to excessive gravel removal at Bratislava has been discussed extensively in *Chapter 2*. This has had the effect of reducing Danube water levels, and hence groundwater levels. The average water-table depths in the period 1956-1960 are shown in *Plate 3.7 (Volume 5)*. The average depth was very close to the surface (< 1 m) in the floodplain, generally between 2 and 3 m elsewhere in the Szigetköz, and deeper than 3 m to the south-west of the Mosoni Danube.

Historical Danube water levels in the Upper, Middle, and Lower Szigetköz are shown in *Figure 3.8*. At Rajka, mean water levels in the 1970s had decreased by 25 cm, in the 1980s by a further 45 cm, and in the early 1990s by an additional 70 cm. This was reflected in reduction of groundwater levels in the Upper Szigetköz of in excess of 1 m (*Plate 3.6* and *Plate 3.7, Volume 5*). In contrast, Danube water levels in the Middle and Lower Szigetköz remained relatively stable until the early 1990s. A recent decline at Nagybajcs is probably due to dredging for navigation, and an observed decrease in groundwater levels in the south-east is due in part to groundwater abstraction.

Historical groundwater levels are shown in *Figure 3.9* from a transect of 3 wells (indicated on *Plate 3.13, Volume 5*). The general decrease in amplitude of groundwater fluctuations with distance from the Danube is illustrated, and it can be noted that the amplitude of variations, indicated on *Plate 3.7 (Volume 5)* for 1956-60, remained largely unchanged prior to construction of Variant C.

As discussed above, the Danube is the primary source of recharge to the Szigetköz, and it is estimated from groundwater modelling (Simonffy, 1994) that average recharge from the Danube to the Hungarian floodplain was 8.1 m^3/s under average (1981-1990) conditions, and from the floodplain to the Szigetköz beyond was 5.2 m^3/s.

As already noted, the volume of the Szigetköz aquifer is estimated to be 21.8 km^3 and contains approximately 5.4 km^3 of groundwater. It is thus a unique resource of good quality water, which at present is mostly not utilised. The larger waterworks in the area are Győr, Kisbajcs-Szőgye and Győrújfalu. Together with Mosonmagyaróvár, production is estimated to be 70,000 m^3/d. In addition, minor amounts are extracted by numerous small settlements. This can be compared with resource estimates of the National Water Management Masterplan (1984) of 750,000 m^3/d. However, this underestimates the additional induced yield which could be generated by bank-filtered wells. It can be seen that there is a sufficient resource to supply a major city (the same order as Budapest), and as such this is regarded as of national strategic significance.

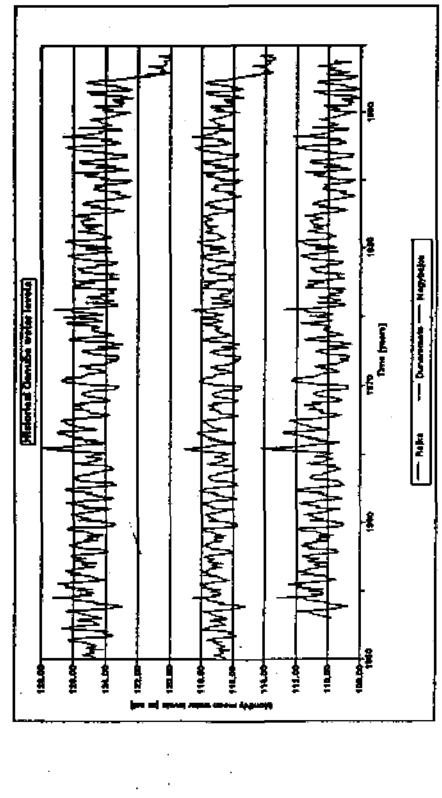


Figure 3.8: Water levels of the Danube 1950-1994 at Rajka, Dunaremete and Nagybajcs

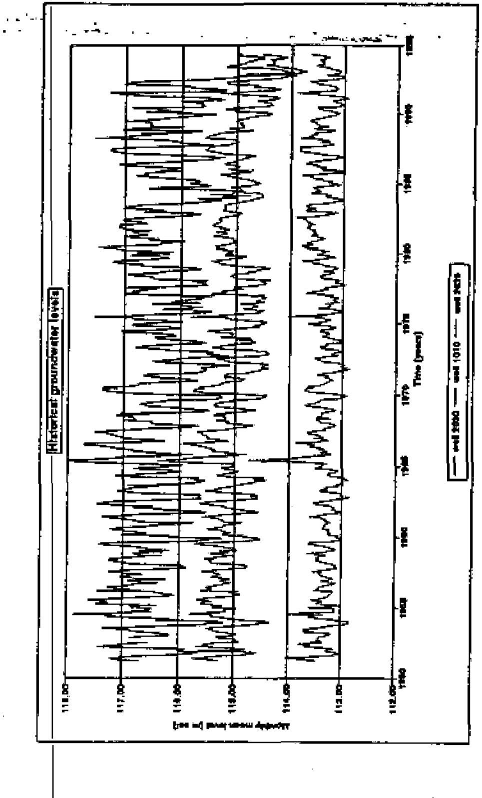


Figure 3.9: Groundwater levels from 1950-1994 at wells 2630,1010 and 2639

(1) When considering groundwater in the Szigetköz, historical trends should be noted. The degradation of the Danube bed due to excessive gravel removal at Bratislava has been discussed extensively in Chapter 2.

"Due to excessive gravel removal at Bratislava": Hungary's Chapter 2 cites this as the principal cause of bed degradation. Regarding the oversimplification and errors in Hungary's analysis - as well as its general irrelevance - see, Comments to Chap. 2 of "Scientific Evaluation", above.

3.4.1.2 *Gönyü to Nagymaros*

Considering the right bank of the Danube between Gönyü and Dunaalmás, the gravel aquifers adjacent to the Danube are much thinner (a few tens of metres in depth), and discontinuous. Continuous recharge from the Danube does not occur. Generally, some infiltration into the Danube takes place from off-river sources. From Nyergesujfalu towards Nagymaros, the right bank aquifer, comprising coarse clastic formations, becomes wider and deeper in the Dorog basin. Further downstream, discontinuous alluvial formations recur, on both sides of the river, with a wider and deeper formation in the Pilismarót basin.

Throughout this reach, there are important bank-filtered waterworks (*Plate 3.8, Volume 5*), and significant unused additional resources. The issues of bank-filtered water supply are considered in detail in *Chapter 3.6*, below.

1

There is also an inter-relationship with the karst water of the Transdanubian Mountain range which is the largest, and economically most important, karst water resource in Hungary (Lorberer, 1994). The regional erosion base of the north-east mountain range is the Danube, and thermal karst springs emerge along the river at faultlines at locations which include Dunaalmás, Esztergom and Budapest. These have a centuries old history of use for water supply and medicinal baths.

The progressive development of mining in the Transdanubian Range led to the need to pump substantial volumes of water from this karst system, and by the late 1960s, extraction exceeded natural recharge. As a result, water levels and spring discharges have decreased. Under natural conditions, the levels of the Danube influence the yield and quality of the springs and adjacent groundwaters. Following the influences of mining activity the head (i.e., potential energy) in parts of the aquifer has fallen to below Danube water levels, leading to some ingress of Danube water to the karst aquifer. These rates increased up to 1991, but following recent decreases in mining activity, have started to decline.

3.4.1.3 *Nagymaros to Budapest*

2

The alluvial aquifer between Nagymaros and Budapest is the major source of water supply for the capital. Almost all of the water supply for Budapest comes from bank-filtered wells. 64% of this water comes from the Nagymaros-Budapest reach, principally from a 10-20 m deep aquifer underlying the Szentendre island (*Plate 3.9, Volume 5*). At mean Danube flow levels, the groundwater has a depth of 10-15 m which is decreased by 2-3 m due to the depression of the wells. At low flows, a further reduction in water-table height of approximately 2 m occurs, with an associated decrease of the filter area of the channel bed.

3

The issues of water supply from this resource are of major national strategic importance, and are discussed in detail in *Chapter 3.6* below. However, it can be noted that bed changes, due to dredging and river training, have given rise to serious problems of loss of yield and degradation of water quality.

3.4.2 IMPACTS OF THE ORIGINAL PROJECT

3.4.2.1 *The Szigetköz and adjacent areas*

The construction of the Dunakiliti Reservoir is associated with a complex set of process interactions which cannot be quantified without high levels of uncertainty, and which potentially imply extremely serious adverse consequences for the Szigetköz. The concerns which existed in 1990 are fully documented by Liebe (1994).

The raising of water levels in the reservoir would have undoubtedly led to initially increased local groundwater levels. However, a significant proportion of the inflowing suspended sediment load of the Danube would have settled in the reservoir. The spatial distribution of the settled sediment is uncertain, but clogging of the bed could be expected. Extensive research was undertaken at VITUKI, including laboratory tests and large-scale field experiments, which suggested that clogging was likely to occur and to increase bed resistance to infiltration by a factor of 30 (Starosolszky, 1966, 1981). This was consistent with international experience (Darmendrail, 1986, 1988).

4

The Original Project envisaged a discharge of 50 m^3/s in the main Danube downstream, hence the natural pattern of groundwater recharge would have been profoundly modified. Minimal recharge would have derived from the Danube river bed in this downstream reach; initially substantial recharge would have occurred from the reservoir, but this was expected to have progressively reduced due to sedimentation. The expected effects included a radical change to the patterns of groundwater flow; initially increased groundwater levels in the vicinity of the reservoir, and significantly reduced groundwater levels throughout most of the Szigetköz and beyond.

In an attempt to reduce the uncertainty surrounding the impact assessment, a programme of groundwater modelling was put in place by the Hungarian government, supported by an extensive set of field characterisation studies. Modelling results are now becoming available (Simonffy, 1994). A 3-dimensional groundwater flow model (MODFLOW), initially developed by the United States Geological Survey, has recently been extended to allow a more complete representation of river-aquifer interactions and is being used in the first phase of simulations. Further development at VITUKI has incorporated evaporation from riparian ecosystems and sub-irrigated agriculture. A regional model has been used, including the Žitný Ostrov, to establish boundary conditions for more detailed modelling of the Szigetköz and adjacent areas. The model represents the aquifer by 11 vertical layers, with a variable horizontal mesh (minimum grid size 200x500 m). This results in approximately 50,000 model elements (*Figure 3.10*). The model includes a representation of the side-arm system.

5

As noted above, the effects of clogging are highly uncertain and were not considered in the modelling undertaken prior to 1989. *Plate 3.10 (Volume 5)* shows the model simulation of the pre-dam situation and a simulation of the average groundwater levels as a result of the Original Project, but with the optimistic assumption of a discharge of 200 m^3/s to the Danube channel. It is assumed that a moderate amount of clogging would take place in the reservoir and in the side-arm system (leakage factors 0.03-0.5 and 0.05-2.0 day^{-1}, respectively; this latter effect is conditioned on current experience of side-arm response).

6

7

Plate 3.11 (Volume 5) and *Table 3.4* illustrate the differences in average groundwater levels between these two cases. It can be seen that close to the dam, water level rises of in excess of 3 m occur, due to the impoundment. However, the loss of Danubian recharge results in significant changes throughout most of the Szigetköz. In a riparian strip alongside the Danube of an area 48.5 km^2, a 2-3 m decline in water level is predicted. An area of 128 km^2 has a decline of greater than 1 m; the total area affected by reduced *average* water levels is 282 km^2. In the lower Szigetköz, below the confluence of the Danube and tail-race canal, this decline is primarily due to the proposed dredging of the river bed.

Considering the case of a 50 m^3/s discharge in the Danube, a greater lowering of groundwater levels is predicted (*Table 3.4* and *Plate 3.11, Volume 5*, right-hand side map). A riparian area of 20 km^2 is now affected by a groundwater decline of 3 m or more; the total area affected by reduced levels is 310 km^2.

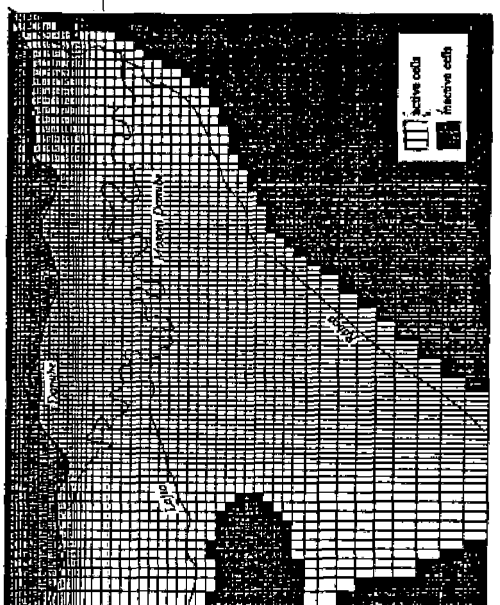


Figure 3.10: Mesh of the detailed groundwater model of the Kisalföld

(1) *There is also an inter-relationship with the karst water of the Transdanubian Mountain range which is the largest, and economically most important, karst water resource in Hungary (Lorberer, 1994).*

"The quality of the karstic water is far more influenced by the pollution washed in ... from the Middle Transdanubian region than the water reaching these layers with low probability and filtered by the alluvial layers from the Danube water. On the basis of this the pressure pattern altered by the [G/N Project] will not hamper the quality of the Middle Transdanubian Mountains water treasure": Hungary's 1985 EIA, HM, Vol. 5, Annex 4. See, also, Comment 6 to "Scientific Evaluation" p. 46, above.

(2) *The alluvial aquifer between Nagymaros and Budapest is the major source of water supply for the capital.*

It is stressed again that there is no connection between the "aquifers" between Nagymaros and Budapest and the upstream aquifer that underlies Žitný Ostrov and Szigetköz. In fact, it is confusing to use the term "alluvial aquifer" for downstream water sources, which depend on the Danube's waters as exploited through a series of bank-filtered wells, i.e., wells that are situated close to the river and that receive the river's waters after they have been filtered through the Danube's riverbanks. The upstream aquifer supplies not one drop of drinking water to Budapest.

(3) *The issues of water supply from this resource are of major national strategic importance, and are discussed in detail in Chapter 3.6 below. However, it can be noted that bed changes, due to dredging and river training, have given rise to serious problems of loss of yield and degradation of water quality.*

"Strategic importance": Clearly the water supply to Budapest is of major importance to Hungary - as is reflected in the 1976 Joint Contractual Plan Agreement and in the attention actually paid to this water resource in the 1980-1985 research and development program of Budapest waterworks and the 1985 EIA. See, SC-M, paras. 7.68 - 7.70 and 7.73 - 7.76. Self-imposed bed changes in this sector of Danube due to commercial dredging have caused problems for Hungary - see, HM, p. 432 and HC-M, Vol. 4, Annex 6 at p. 378. But neither of the comprehensive assessments carried out by Hungary in the 1980s found that Budapest's water sources were threatened by the G/N Project.

The quality of Budapest's drinking water is, however, directly affected by unrelated background pollution.

(4) *The expected effects included a radical change to the patterns of groundwater flow; initially increased groundwater levels in the vicinity of the reservoir, and significantly reduced groundwater levels throughout most of the Szigetköz and beyond.*

"The expected effects": The significantly reduced groundwater levels are based on Hungary's formulation of the "Original Project", i.e., they do not take into account Project modifications specifically designed to address impact on groundwater levels. No adverse impact would have occurred had the Dunakiliti offtake been correctly used and underwater weirs been constructed in the main channel.

(5) *As noted above, the effects of clogging are highly uncertain and were not considered in the modelling undertaken prior to 1989.*

This assessment is contrary to the findings of the EC Working Group of Experts, who did not raise a problem of uncertainty. It was found that no colmatation would take place in the old riverbed and that direct supply into the side arm system led to the removal of the fine sediment clogging the side arm beds. See, reports of 2 November and 1 December 1993, HM, Vol. 5, Annexes 18 and 19 (at p. 707 and pp. 782-783 respectively).

(6) *It is assumed that a moderate amount of clogging would take place in the reservoir and in the side-arm system (leakage factors 0.03-0.5 and 0.05-2.0 day^{-1}, respectively; this latter effect is conditioned on current experience of side-arm response).*

Clogging (i.e., colmatation) may take place in the reservoir, but only in those areas to which sediment is directed by means of two directional dykes. This creates no problem because plastic sheeting buried below the reservoir bottom isolates those areas where considerable sedimentation will take place and, overall, the reservoir remains a good source of recharge. See, Vol. III, at p. 7. No clogging will take place in the side arms with a correctly regulated water recharge system - see, EC reports at Comment 5 above. See, also, Vol. III, at p. 8, which confirms that the recharged side arms are now an important source of supply into the aquifer.

(7) *However, the loss of Danubian recharge results in significant changes throughout most of the Szigetköz. In a riparian strip alongside the Danube of an area 48.5 km^2, a 2-3 m decline in water level is predicted. An area of 128 km^2 has a decline of greater than 1 m; the total area affected by reduced average water levels is 282 km^2.*

These predictions are based on Hungary's concept of the "Original Project" and therefore do not allow for adequate recharge through the Dunakiliti offtake and ignore the agreed construction of underwater weirs in the old riverbed. They are irrelevant and, in any event, now outmoded in the light of the Agreement of 19 April 1995 concerning the construction of the underwater weir in rkm 1843, allowing direct recharge of the Hungarian branch system through the Dunakiliti intake structure.

It is noted that Hungary also ignores the existence of the previously deteriorating ground water levels. See, Vol. III, at p. 5.

"The long-term decrease of the water level in the Danube was one of the factors leading to the decrease of ground water levels and to changes in the ground water flow directions and velocities. This resulted, among other things, in changes in ground water flow quantities and in a general decrease of the utilisable ground water resources for example at locality Pečniansky les and Rusovce-Ostrovné Lúčky."

please turn to next page

Table 3.4: Areas where changes in the groundwater levels would have been observed, before and after the implementation of the Original Project

Changes in water level	Areas (km²)	
	discharge = 50 m³/s	discharge = 200 m³/s
decrease	310.8	281.5
> 3 m	20.4	–
2 m - 3 m	55	48.5
1 m - 2 m	89.4	79.2
0 m - 1 m	146.0	153.8
increase	76.5	95.5
0 m - 1 m	44	63
1 m - 3 m	18.4	18.4
> 3 m	14.1	14.1

The uncertainty in the effects of clogging is also illustrated in *Plate 3.16 (Volume 5)* for the 200 m³/s flow conditions. Assuming a more pessimistic but not unrealistic scenario for sediment deposition and clogging, gives further reductions in groundwater level of up to 2 m, including some areas where a 1-2 m decline is already predicted.

Apart from a reduction in levels, changes in the magnitude of direction of groundwater flows occur. The annotation on *Plate 3.10 (Volume 5)* indicates a reversal of flows in the vicinity of the main Danube channel. Recharge from the channel is replaced by drainage towards it. The changing role of the main Danube and side-arms in providing recharge sources is shown schematically in *Figure 3.11.*

The effect on the supply of groundwater to vegetation by capillary rise is illustrated for average groundwater levels in *Plate 3.12 (Volume 5)*. It can be seen in *Figure 3.12* and, for the cross-sections in the Upper and Middle Szigetköz in *Plate 3.13 (Volume 5)*, that in the pre-dam state, average groundwater levels only just intersect the fine covering layer in the upper cross-section. After dam construction, the water levels are lower, and recharge from the side-arm system occurs. In the second cross-section, average water-table conditions lie within the fine layer pre-dam, but would fall below after implementation of the Original Project. 1

The supply of groundwater as sub-irrigation by capillary rise depends on the position of the water-table in relation to the depth of fine soil, and the groundwater levels vary according to the seasonal pattern of flows, high levels usually

coinciding with the period of maximum vegetation need. Hence three classes of area can be identified, namely:

a) those areas for which the water-table is permanently above the fine soil interface;
b) areas for which it is above the interface under average groundwater conditions, and
c) areas for which it temporarily reaches the fine soil, under conditions of high Danube water levels.

Average groundwater levels underestimate the full impact of the Original Project. The natural annual variability of groundwater levels has been represented in *Plate 3.7 (Volume 5)*, which demonstrates that over most of the Szigetköz, groundwater levels in the spring/early summer are up to 1 m higher than the average values. After construction of the Original Project, according to the Joint Contractual Plan, this seasonal variation would be lost. Hence the seasonal maximum post-dam would be represented by the average condition. The implications of this are illustrated in *Plate 3.12 (Volume 5)* and *Table 3.5.* Before dam construction, seasonally varying water-tables would reach the fine soil layer over approximately 350 km². It will be seen that the discussion of steady-state conditions after dam construction would reduce this to approximately 186 km², i.e. a 50% reduction (55% in the Szigetköz alone). 2

Table 3.5: The relative position of the groundwater and the covering layer before and after the implementation of Original Project

Relative position	Area (km²)		
	Before Original Project	After Original Project	Differences
continuously sub-irrigated	135	116	19
sub-irrigation under average groundwater conditions	125	57	68
temporarily sub-irrigated during high Danube water levels	93	13	80

The impacts on soils, ecology, agriculture and forestry are discussed in the following chapters. It should be noted, however, that in the vicinity of Sap, where flows return to the main Danube channel, a diurnal cycle of water level variation would be imposed by peak power generation. The effect on soils is discussed in *Chapter 5*.

There are also important concerns relating to water quality. They are discussed and quantified in *Chapter 3.5*, below. They relate principally to the problem of sediment degradation in the reservoir, leading to a loss of aerobic conditions and mobilisation of metals in the groundwater, and also to the impact of changing

regional groundwater flows. The loss of Danube recharge would lead to the ingress of poorer quality waters from adjacent areas and also a change in flow paths from existing known and unknown point sources of pollution. Where groundwater levels increased, new sources of pollution might alter the groundwater system.

During the discussions following the initial agreement of the Original Project, solutions were proposed to reduce adverse effects by some increase of Danube flows, the construction of weirs in the main Danube channel, and supplementary recharge systems.

The evaluation of these systems is highly complex, and even with a current state of the art capability for integrating flow, sediment deposition/erosion, sediment clogging and chemical degradation, groundwater flow and groundwater quality models, a high level of prediction uncertainty is inevitable. It was certainly the case that the effects of these proposals could not be adequately estimated in 1989, and despite strenuous technical efforts by both sides, that remains the situation at present. Principal concerns for groundwater relate to the effects of sedimentation on clogging and chemical degradation, and the impact of reduced levels of temporal variability. 3

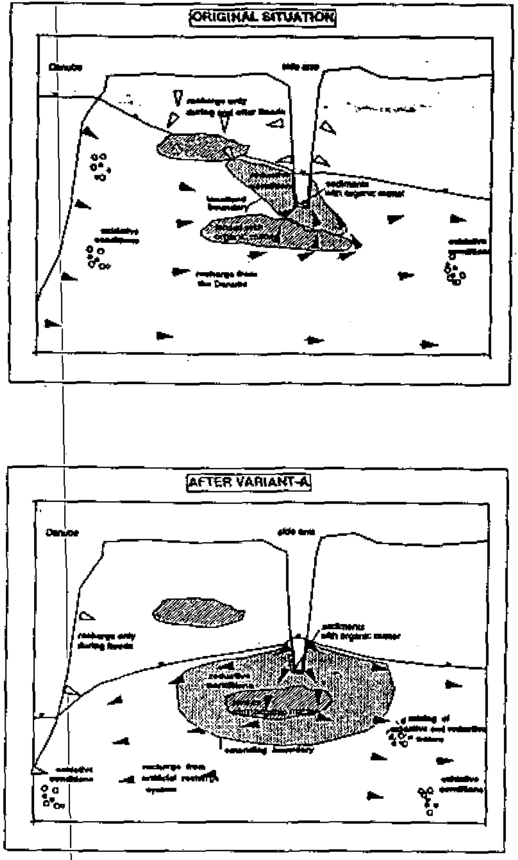


Figure 3.11: Schematic diagram of Szigetköz recharge sources

(1) *After dam construction, the water levels are lower, and recharge from the side-arm system occurs. In the second cross-section, average water-table conditions lie within the fine layer pre-dam, but would fall below after implementation of the Original Project.*

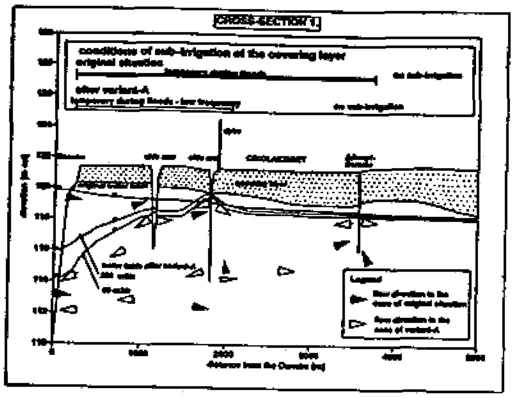
> **Ground water levels have been lower where there has been no recharge from the Dunakiliti offtake. Thus, levels would only fall below the soil line if Hungary persisted in its refusal to implement the recharge of water into its side arms. Note: where direct recharge of water into the side arms has been implemented, i.e., on the Slovak side, there has been no negative impact on the soil/water conditions and, in fact, there has been a generally positive impact on ground water levels. See, Vol. III, at p. 12.**
>
> **"From the comparison of the three maps [Figs. 18-20] it is obvious that the ground water levels have in general increased after the damming of the Danube to nearly the level which existed in the 1960s. The situation has particularly improved, in comparison with the pre-dam situation, mainly in the area close to the reservoir, downstream of Bratislava and its right bank borough Petržalka."**

(2) *Before dam construction, seasonally varying water-tables would reach the fine soil layer over approximately 350 km^2. It will be seen that the discussion of steady-state conditions after dam construction would reduce this to approximately 186 km^2, i.e. a 50% reduction (55% in the Szigetköz alone).*

> **Predictions are based solely on Hungary's conception of the "Original Project", i.e., on the wrong data. As noted above, dam construction has had a beneficial impact on soil/water conditions in Slovakia. See, Vol. III, at pp. 12-13.**
>
> **"After the putting of the Gabčíkovo Project in operation, there is an improvement of the water supply to soils via capillary transport in the upper part of the area in comparison with the pre-dam conditions. The improvement for deep rooting plants and trees has occurred also at the places where the rising ground water level has not reached the overlying finer sediments, as it is just downstream of Bratislava. Figs. 17 to 23, showing the thickness of soils overlying the gravel and depth of ground water level below surface, also show that except in the inundation area there is no water logging, which means improvement in the inundation area in comparison with pre-dam conditions. There is also no additional water logging of agricultural soils resulting from the putting of the system into operation, contrary to the situation which existed in certain areas in the 1960s."**

(3) *It was certainly the case that the effects of these proposals could not be adequately estimated in 1989, and despite strenuous technical efforts by both sides, that remains the situation at present.*

> **"Could not be adequately estimated in 1989": This is incorrect - an acceptable evaluation of Project impact on groundwater was possible in 1989, as it is possible today. In any event, it is difficult to see the point of Hungary's insistence on hypotheticals. Either effects of the proposals were, or were not, adequately estimated; and it is perfectly possible to carry out an assessment of the actual situation. It is evident that ever since 1989 Hungary has preferred to point to supposed uncertainties rather than to accept the findings of such independent assessments as those conducted by Bechtel and HQI, and more recently, by the EC Working Group.**



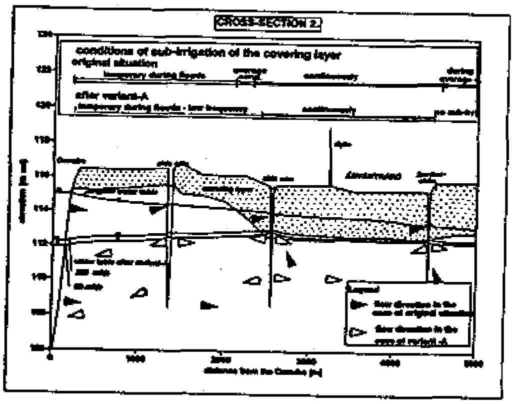


Figure 3.12: Groundwater levels before and after Original Project.
a) cross-section 1; b) cross-section 2 (cf. Plate 3.13, Volume 5*).*

3.4.2.2 Gönyű to Nagymaros

1

The reach from Gönyű to Nagymaros would have been affected by the backwater of the Nagymaros Reservoir. A major concern here is the effect of sediment deposition on the yield and quality of bank-filtered wells. This is discussed in detail in *Chapter 3.6* below.

2

An additional problem concerns the impact of elevated surface water levels on groundwater. Solutions were proposed to remedy the patterns of water-table rise in adjacent low-lying areas, principally the Esztergom and Komárom lowlands. This involved the continuous pumping of groundwater from an extensive set of relief wells and interception canals (Ujfaludi, 1994). It was noted that particular problems were likely to arise in the islands of this reach and that strategic sites, e.g., the Primás palace (an important historical monument) were at risk. While such solutions are technically feasible, if expensive in terms of capital and, in particular, running costs, there are also associated risks. These obviously include pump failure, but poor quality of installation and/or maintenance can cause local damage.

The relationship between the karst water of the Transdanubian Mountains and the Danube was introduced above. In the late 1980s, there was extensive discussion of the potential impact of the Nagymaros Dam on the inter-connections, and a divergence of opinion between hydrogeologists concerning the impact (Erdélyi, 1984, 1989 and Lorberer 1989a, 1989b). Current understanding is reviewed by Lorberer (1994), based on a detailed field investigation programme undertaken from 1987 to 1989, and subsequent numerical analysis.

3

At Esztergom, the reduction in karst water levels induced inflow of Danube water from 1984 onward, and it is believed that this may have led to an observed drop in temperature and concentration of solutes in the water supply from a former spring to an open-air swimming pool. Additional ingress to the aquifer is likely due to the Nagymaros backwater effects with potential adverse effects on hot springs and wells. Given the localised nature of flow in karst systems, this is difficult to prevent, although grouting and other rock sealing measures have been proposed as a possible solution. Modelling of karst systems is highly uncertain, given the potential importance of (unknown) preferential flow-paths, but simulations indicated pressure increases of 3.3 m due to the dam and increased infiltration from the Danube of 1.5-2.0 m^3/min (*Figure 3.13*).

It was suggested that at Dunaalmás the main effect on the karst system would be indirect, leading to increased infiltration of 1.2-1.5 m^3/min, although two former springs could provide direct communication.

It was also noted that proposed pumping measures to control water levels in the Kis-Duna would increase the transport of background pollution at Esztergom.

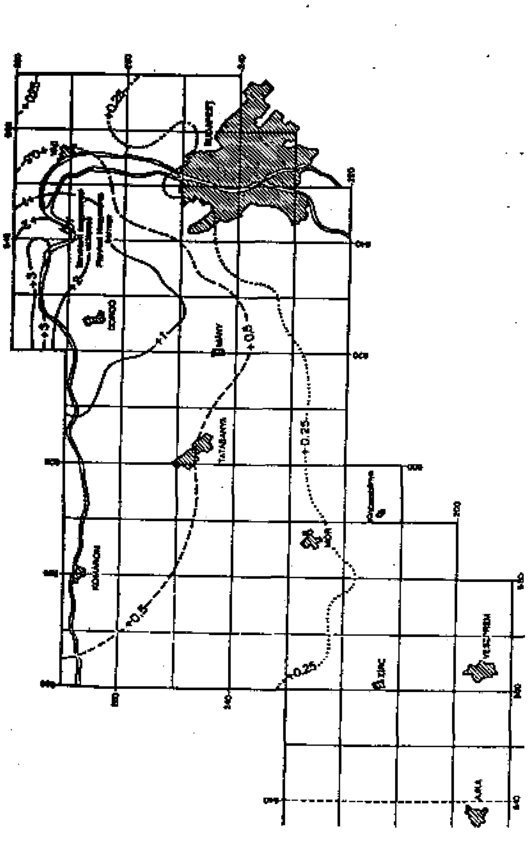


Figure 3.13a: Additional head increase (m) due to the operation of the Nagymaros barrage from 1992, calculated using the regional model, scale 1:2000 (after Lorberer, 1994)

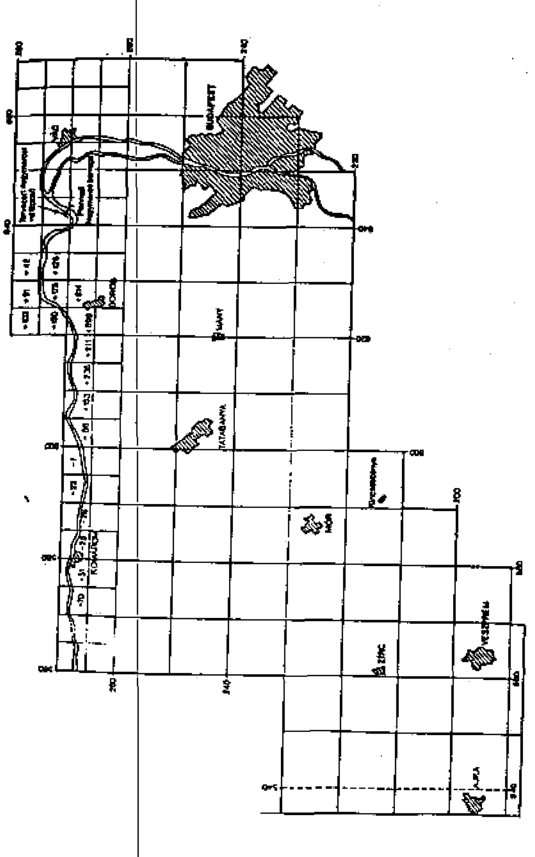


Figure 3.13b: Additional trans-percolations (m^3/d) due to the operation of the Nagymaros barrage from 1992, calculated using the regional model, scale 1:2000 (after Lorberer, 1994)

(1) *The reach from Gönyü to Nagymaros would have been affected by the backwater of the Nagymaros Reservoir. A major concern here is the effect of sediment deposition on the yield and quality of bank-filtered wells.*

The increased water levels upstream of Nagymaros would have increased the flow of Danube, i.e., good quality water into the bank-filtered wells, reducing polluted water infiltration from background sources.

(2) *An additional problem concerns the impact of elevated surface water levels on groundwater.*

This "additional problem" existed primarily for Slovakia, not Hungary. On the Hungarian side, the terrain slopes down to the Danube so elevated surface water levels have no impact except in limited areas. In any event, as Hungary accepts, "technically feasible" solutions such as drainage canals and pumping stations were available and were incorporated into the Project. In fact, such drainage canals and pumping stations were actually constructed by Czechoslovakia as part of the Nagymaros section of the Project.

(3) *Additional ingress to the aquifer is likely due to the Nagymaros backwater effects with potential adverse effects on hot springs and wells.*

"Additional ingress" has been caused solely by Hungarian mining activities. Hungary accepts (in the same paragraph) that this has been a problem "from 1984 onward". It has nothing to do with the Project. See, Comment 6 to "Scientific Evaluation" p. 46, above.

"Aquifer": It is confusing, although correct, to refer to the Žitný Ostrov/Szigetköz alluvial aquifer, the karst waters and the Budapest bank-filtered well system all as aquifers. This might lead to the entirely wrong conclusion that these different water supplies are in some way connected or that impacts in relation to one will be felt by all. They are quite separate and different sources of water.

3.4.2.3 Nagymaros-Budapest

The primary impacts anticipated in this reach are associated with the yield and quality of Budapest water supply, and are discussed in *Chapter 3.6*, below. Impacts on thermal waters are expected to be limited.

3.4.3 IMPACTS OF VARIANT C

Impacts of Variant C on groundwater have been, on the Hungarian side, mainly related to changes in groundwater levels, fluxes, and flow-directions in the Szigetköz.

1

As noted above, under pre-dam conditions, groundwater levels reflect Danube water levels. Following construction of Variant C, average Danube water levels have fallen by 4 m at Rajka, 3 m at Dunaremete (*Figure 3.8*). The observed groundwater changes under average flow conditions are shown in *Plate 3.13 (Volume 5)*. Maximum reductions in excess of 3 m occur in the close proximity of the main Danube in the upper Szigetköz. A riparian strip 1.5 km wide experiences reductions in excess of 2 m along most of the affected main Danube channel. A total of 297 km² suffers water level reductions (*Table 3.6*). Groundwater level increases of up to 0.25 m occur over an area of 24 km².

Table 3.6: Areas where changes in the groundwater have been observed, before and after the implementation of the Variant C

Changes in water level	Areas (km²)	
	average Danube flows	high Danube flows
decrease	297	346
> 3 m	3	22
2 m - 3 m	24	47
1 m - 2 m	51	35
0 m - 1 m	219	242
increase		
0 m - 0.25 m	24	0

Considering typical high flow conditions in the Danube, as expected, impacts are greater (*Plate 3.13, Volume 5*). The total area affected by reductions in groundwater levels is not much larger (346 km²), but the extent of major reductions is significantly increased. Reductions of 3 m or more apply to a 22 km² strip, 1-2 km wide and some 25 km long. Reductions of 2 m or more apply to an area of 69 km², extending nearly 5 km from the Danube (*Table 3.6*). The results confirm the nature of changes presented in the Original Project simulations. The average groundwater levels are shown in *Plate 3.14 (Volume 5)*. The main Danube channel, formerly a major recharge area, is now acting as a drain. The primary recharge to the aquifer is from the reservoir, and the side-arm system.

The impacts on capillary rise are presented in *Table 3.7* for the growing season April-August. A total area of 127 km² suffers reduction in water availability, and 37 km² now have a total loss of sub-irrigation supply.

The time-series of groundwater fluctuations across the two sections indicated in *Plate 3.13 (Volume 5)* confirm the dramatic change in both groundwater levels and variability following implementation of Variant C.

Table 3.7: The relative position of the groundwater and the covering layer before (1990) and after (1993) the implementation of Variant C

Relative position	Area (km²)		
	Before Variant C April-August 1990	After Variant C April-August 1993	Differences
continuously sub-irrigated	112	78	34
sub-irrigation under average groundwater conditions	81	25	56
temporarily sub-irrigated during high Danube water levels	90	53	37

3.5 GROUNDWATER QUALITY

by Howard Wheater

3.5.1 THE NATURAL SYSTEM

The groundwater flow regime in the Szigetköz and adjacent areas has been discussed above. In the pre-dam situation, groundwater in the Szigetköz was recharged primarily from the gravel bed of the main Danube channel. The quality of this recharged water was excellent, as shown by analysis of the quality of bank-filtered groundwater along the length of the main channel between Rajka and Ásványráró, rkm 1849-1815 (Horváth and Tóth, 1994). In particular, the water was aerobic; the dissolved oxygen content was sufficient to oxidise the low amounts of degradable organic material, and hence reduced redox species such as iron, manganese and ammonium were only present in low concentrations (*Table 3.8*).

2

Table 3.8: Mean concentrations of reduced redox species in bank-filtered water in 1991. Samples taken along the main channel of the Danube between Rajka and Ásványráró, 1849-1815 rkm (Horváth and Tóth, 1994).

Mean concentration (mg/l)		
Fe^{2+}	Mn^{2+}	NH_4^+
0.05	0.02	0.05

The influence of Danube water on the groundwater of the Kisalföld is illustrated in *Figure 3.7*, which is based on stable isotope analysis. Oxygen-18 data indicate the spatial distribution of Danube water, and hence its influence on groundwater quality. Tritium, which peaked in surface waters some thirty years ago as a result of atmospheric nuclear tests, has now penetrated to the middle of the Szigetköz. This 30-year old front provides an important illustration of the time-scale of contaminant transport in groundwater; travel times indicated are in the range 250-400 m/yr (Liebe, 1994).

As the influence of Danube water decreases, adverse changes in groundwater quality are observed. To the south-west of the Szigetköz there is an increase in dissolved solids, including a substantial increase in iron, manganese and ammonium. In the lower Szigetköz, in the vicinity of Győr there is also an increase in the reduced redox species, in samples from deeper wells a mixing with Pliocene water has been observed, too. However, for the Szigetköz in general, groundwater quality is good. Where pollutants have been observed, they have been limited to the top 20 m of the aquifer and result from isolated cases of point source pollution, usually nitrates from agricultural or domestic wastes. In the deeper groundwater used for public supply, highest nitrate values (10 mg/l) occur between the Mosoni Danube and the river Lajta to the south-west, but are well below the drinking water standard (Liebe, 1994).

The influence of organic-rich sediment on groundwater recharge is discussed in detail in *Chapter 3.5.2.1*. Degradation of organic material can consume the available oxygen, leading to chemical reduction, and the mobilisation of iron, manganese and ammonium. Examples are presented from international experience of dams and associated floodplains, and, in *Chapter 3.6*, from bank filtered wells in Hungary.

The side-arm systems of the Szigetköz are rich in organic sediment, and, as discussed below, are observed to give rise to reducing conditions. However, in the pre-dam situation their impact on groundwater recharge was minimal. As will be discussed below, this is no longer the case.

3.5.2 IMPACTS OF THE ORIGINAL PROJECT

3

3.5.2.1 International experience of groundwater quality degradation

Several published studies provide convincing evidence of groundwater quality degradation associated with river impoundment, e.g. Hahn *et al.* (1979), Märki (1971). More recent Austrian examples are particularly relevant. Frischherz *et al.* (1986) report the effects of the Danube Power Station Abwinden-Asten on an adjacent well field of capacity 48,000 m³/d. They note the following primary changes:

- increase in water level of the reservoir
- decrease in flow velocity in the backwater reaches
- decrease in water level fluctuations

which lead to:

- increased sedimentation
- oxygen depletion during infiltration of water through the sediment into the groundwater
- resolubilisation processes from the sediment due to the anaerobic conditions

In this case, the deposited sediment had a high organic load, but the time-scales and consequences are important. The reservoir was constructed between 1976 and 1979. In 1979 manganese was observed for the first time in one well, followed by the appearance of ammonium (mid-1980) and dissolved iron (1981). In a second well, ammonium appeared for the first time towards the end of 1980, followed by manganese in mid-1982 and iron in mid-1983. The consequence was the occurrence of bacterial slimes in the water supply system, giving rise to "significant technical problems."

4

Possibly the most intensely-studied Danube reservoir has been the Altenwörth, also in Austria (Hary and Nachtnebel, 1989). Investigations of groundwater quality in the vicinity of the Altenwörth barrage, in comparison with non-impounded river reaches, showed the following impacts of the barrage system:

- increased sedimentation in the reservoir due to lower flow velocities;
- infiltration from the reservoir to groundwater occurring through sediment with a high organic content;
- a decrease of groundwater fluctuations, with subsequent reduction of oxygen supply to the soil;

(1) *Maximum reductions in excess of 3 m occur in the close proximity of the main Danube in the upper Szigetköz. A riparian strip 1.5 km wide experiences reductions in excess of 2 m along most of the affected main Danube channel.*

According to Hungary's own data, this is simply not true for "average conditions" - see, HCM, Vol. 5, plate 3.13. In any event, the construction of underwater weirs in the old Danube, coupled with direct recharge into the side arms, would deal with the problem - as implicitly admitted by Hungary's Government in early 1994 (see, SC-M, para. 8.11) and in it signature of the Agreement of 19 April 1995 (see, SR, Annex 1).

(2) *In particular, the water [recharged from the Danube] was aerobic; the dissolved oxygen content was sufficient to oxidise the low amounts of degradable organic material, and hence reduced redox species such as iron, manganese and ammonium were only present in low concentrations (Table 3.8).*

The dissolved oxygen content of the Danube's water was carefully monitored in the years preceding the damming of October 1992. Oxygen conditions were found to be first class. Monitoring from October 1992 to December 1994 shows that oxygen conditions are still first class and that there has, in fact, been an improvement due to slight increase in dissolved oxygen content. See, Vol. III, at p. 23:

"On the basis of comparison of characteristic and average values of these parameters of oxygen regime from the period prior to the putting of the Project into operation and afterwards a slight increase of dissolved oxygen content within the range of the first class of water quality, and small decrease of BOD5, COD Mn, and COD Cr values in the range of the second class of water quality has been observed."

Note, in any event, the harmful impact on Szigetköz groundwater of the poor water quality in the Hungarian side arms (in both the pre-dam and post-dam situation). Hungary's 1985 EIA found that for "nearly 300 days" each year the Szigetköz side arms were "permanently stagnant water bodies, where eutrophication, sedimentation occurs" - see, HM, Vol. 5, Annex 4. The EC Working Group of Experts noted the tendency to "stagnant", i.e., anaerobic water in the side arms prior to damming: "In drier years a negative trend has been observed with high pH, high organic matter and low oxygen contents" - see, HM, Vol. 5, Annex 14.

(3) *International experience of groundwater quality degradation.*

Hungary relies on international experience, rather than examining actual monitoring results from Variant "C". It is difficult to see the relevance of the impacts of quite different projects except to the extent they have contributed to the formulation of remedial measures that avoid any groundwater deterioration in the G/N Project.

Note, also, the comment of Hungary's 1989 study annexed at HC-M, Vol. 4, Annex 13 (at p. 563): "It should be emphasised that, morphologically, the Dunakiliti reservoir differs totally from the riverbed reservoirs of the German-Austrian section, which means that any experience gained there cannot be applied here automatically."

(4) *Possibly the most intensely-studied Danube reservoir has been the Altenwörth, also in Austria (Hary and Nachtnebel, 1989).*

Undoubtedly the "most intensely-studied Danube reservoir" is the Variant "C" reservoir, which is directly relevant as it is essentially the same as the Dunakiliti-Hrušov reservoir,

save for its reduced size. Hungary shows no interest in the huge amount of data collected in relation to this reservoir, which is unfavourable to its case.

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– the possibility of permanent waterlogging of soil horizons with a high organic load;

– the prevention of large-scale inundations, and hence the reduction of supply to soils and groundwater of oxygen-rich surface waters.

These changes in the surface and groundwater flow regimes led to the formation of areas of reduced or zero oxygen content, the subsequent mobilisation of iron, manganese, and ammonium, and some increase in organic load and heavy metals. For example, it is noted that "In the northern floodplain, for which extensive data is available, the groundwater quality indicates an oxygen-depleted or oxygen-free zone. Simultaneously, increased iron and manganese concentrations were found after a period of delay of a few years after the power station construction."

3.5.2.2 Impacts of the Dunakiliti-Hrušov Reservoir

The impoundment of the Danube at Dunakiliti would have led to substantial changes in the groundwater flow regime. This in itself can lead to problems of groundwater quality, since changing groundwater flow paths can modify the direction and time of travel of existing pollutants. However, the changing pattern of groundwater recharge may also be associated with complex and extensive problems of water quality degradation. These are explained below, but are also fully recognised and discussed in the annexed paper by Mucha (1990) and in Mucha and Paulikova (1991).

In the Dunakiliti Reservoir, settling of suspended sediment and clogging of the reservoir bed were expected. Hence filtration through the accumulated silt could be expected to be associated with anaerobic conditions due to organic degradation, as discussed elsewhere.

It should be recognised, as is evident from the international experience, that these processes may not appear for some years. It must also be acknowledged that a highly complex set of process interactions is involved, including sediment spatial deposition patterns, the physical effects of consolidation and clogging, and chemical degradation, which can only be predicted, given the current state of the art, with a high level of uncertainty.

1

Water quality changes in the infiltrating water from the reservoir have been estimated (László, 1994b), based on a calculation of redox conditions, considering the sequential oxidation of biodegradable organic material, and the subsequent application of the geochemical equilibrium model, MINTEQ (Batelle Pacific North West Laboratory).

A sensitivity analysis was undertaken, considering the ranges of uncertainty in the key parameters (*Table 3.9*). These calculations were carried out for the following parameter sets:

1. The parameter values most favourable for aerobic conditions;
2. The parameter values least favourable for aerobic conditions;
3. A mean parameter set.

The results indicated reducing conditions in cases 2 and 3. Given the uncertainties, it is considered that the mean parameter values provide the most reliable prediction.

The MINTEQ model considers metal speciation under chemical equilibrium based on thermodynamic relationships. It was similarly applied in a sensitivity analysis, considering a realistic range of parameter values (*Table 3.10*). It must be recognised that a high degree of uncertainty is involved, in particular due to limited information about the solid iron and manganese species. Nevertheless, the mean parameter values result in maximum concentrations of 25 mg/l iron and 5 mg/l manganese in anoxic groundwater, compared with Hungarian and WHO (1993) drinking water standards of 0.2-0.3 mg/l for iron and 0.1 mg/l for manganese (*Table 3.11*).

The impact on the groundwater system will depend on the distribution of sediment within the reservoir. On the assumption that aerobic conditions can be maintained under the former river channel within the reservoir, *Plate 3.15 (Volume 5)* indicates the water quality implications.

2

In the Original Project, groundwater recharge would have occurred from the reservoir and from other recharge sites, associated with the supplementary floodplain recharge system. Anaerobic groundwater is also expected from these sites (*Plate 3.15, Volume 5*), and from the subsequently proposed remedial measures, field evidence is discussed below, in the context of Variant C.

Table 3.9: Parameter Ranges for Redox Calculations

• Dissolved oxygen level in the reservoir water	3-<u>10</u> g/m³
• Nitrate level in the reservoir water	5-<u>10</u> g/m³
• BOD of the reservoir water	2-6 g/m³
• Amount of settling fines	<u>0.01</u>-0.05 m/year
• Biodegradable fraction of settling fines	<u>0.5</u>-1 %
• Seepage velocity	0.02-<u>0.1</u> m/d

(Underlined numbers are the most favourable for aerobic conditions)

Table 3.10: Parameter Ranges for Chemical Speciation Modelling

water temperature	5-15 °C
redox potential	0-50 mV
pH	6.5-7.5
hydrogen-carbonate	150-250 mg/l
sulphate	25-35 mg/l
chloride	15-25 mg/l
calcium	30-70 mg/l
magnesium	10-30 mg/l
sodium	5-10 mg/l
potassium	2-6 mg/l

Iron and manganese precipitations initially present in the solid matrix and subject to equilibrium dissolution

Table 3.11: Comparison of International Drinking Water Standards for Selected Parameters

		EC (1980)		Hungarian (1989)		WHO (1993)
		Guide level	MAC	Guide level	MAC	MAC
Nitrates	NO_3 mg l^{-1}	25	50	20	40	50
Ammonium	NH_4 mg l^{-1}	0.05	0.5	0.1	0.5	1.5
Iron	Fe µg l^{-1}	50	200	200	300	300
Manganese	Mn µg l^{-1}	20	50	100	100	100
Arsenic	As µg l^{-1}	-	50	-	50	10

MAC=Maximum Admissible Concentration
EC (1980): European Community Drinking Water Directive (80/778/EEC)
Hungary (1989): Hungarian Drinking Water Standards (HSS, 1989)
WHO (1993): World Health Organisation Guidelines for Drinking Water Quality

3.5.2.3 Impacts of Variant C

3

Hungary does not have access to groundwater quality or sediment data from the existing reservoir. However, potential threats to the quality of the Bratislava water supply from the Samorin waterworks as a result of the project were identified by the CEC (1992). It is known that substantial efforts were made by Slovakia to minimise sediment deposition in that part of the reservoir adjacent to existing water supply wells (see Refsgaard *et al.*, 1994), and that it was considered necessary to re-site wells to prevent degradation of the quality of the water supply (CEC, 1992/1993 reports). This is evident confirmation of the risks discussed above.

Hungarian observations have focused on the quality of groundwater recharged from the side-arm system of the Szigetköz. A set of 62 observation wells in 11 groups were established along the banks of side-dams and canals (*Table 3.12* and *Plate 3.15, Volume 5*), sampling the upper 14.5 m. Data include in situ temperature and conductivity, and laboratory analysis of major ions, metals, organics, and nitrogen redox species. Results from August and September 1994 are illustrated in *Figures 3.14* to *3.19*. It can be seen that in general reductive conditions predominate. Although the data display considerable variability, for 9 of the 11 well groups, mean levels of iron exceed EC Maximum Allowable Concentrations for drinking water, and mean levels of manganese exceed EC guide levels. For all sites, maximum levels of ammonium exceed EC guide levels. Nitrate levels suggest that well groups 1 and 2 on the side-arm recharge system maintain aerobic conditions (although unacceptable levels of iron occur at 1), and these sites have, as yet, little sediment deposition, in contrast to locations 3-6 on the side-arm system where clearly reducing conditions apply. 4

Toxic elements are generally present below limit values for drinking water, but a notable exception is arsenic, for which mean values exceeded WHO limits at some of the well groups. Again, this occurrence is associated with the release of naturally occurring arsenic under reducing conditions.

Well group 11, very close to the main Danube channel is of particular interest. It was noted (*Table 3.12*, below) that recharge from the Danube was of high quality water. In 1994, the water quality at this site has clearly shown reducing conditions and unacceptable groundwater quality, following the change in recharge pattern.

It can be concluded that:

Before the damming of the Danube, good quality bank-filtered water recharged the alluvial aquifer from the gravel bed of the Danube.

After the damming, the recharge pattern has dramatically changed. Although subject to uncertainty, calculations indicate that recharge from the reservoir is

(1) *Water quality changes in the infiltrating water from the reservoir have been estimated (László, 1994b), based on a calculation of redox conditions, considering the sequential oxidation of biodegradable organic material, and the subsequent application of geochemical equilibrium model, MINTEQ (Batelle Pacific North West Laboratory).*

This conflicts with the carefully monitored impact of the Variant "C" reservoir, which shows no redox conditions, no change in chemical composition and no change of quality of water infiltrating into the reservoir. <u>See</u>, Vol. III, at p. 25:

"The monitoring of the water quality development in the reservoir has revealed that with regard to chemical composition the Danube water has not changed as a result of its passage through the Project structures. Not even indications of forecasted phenomena, characterised by the release of organic micropollutants and heavy metals from the reservoir sediments in the course of infiltration, were recorded."

"

(2) *In the Original Project, groundwater recharge would have occurred from the reservoir and from other recharge sites, associated with the supplementary floodplain recharge system. Anaerobic groundwater is also expected from these sites (Plate 3.15, Volume 5), and from the subsequently proposed remedial measures, field evidence is discussed below, in the context of Variant C.*

There is no basis for the expectation of anaerobic water recharge (i) from the reservoir, or (ii) from the side arms. <u>See</u>, Comment 1 above and Vol. III, p. 15:

"The Danube water quality is well suited for ground water recharge. Dissolved oxygen is slightly increasing and COD decreasing, which means an improving tendency of Danube water quality. There are no significant concentrations of pollutants which could propagate into ground water by ground water recharge from the Danube."

(3) *Hungary does not have access to groundwater quality or sediment data from the existing reservoir. However, potential threats to the quality of the Bratislava water supply from the Samorin waterworks as a result of the project were identified by the CEC (1992). It is known that substantial efforts were made by Slovakia to minimise sediment deposition in that part of the reservoir adjacent to existing water supply wells (see Refsgaard et al., 1994), and that it was considered necessary to re-site wells to prevent degradation of the quality of the water supply (CEC, 1992/1993 reports). This is evident confirmation of the risks discussed above.*

Hungary <u>does</u> have access to data relating to the Variant "C" reservoir (data furnished to the EC). The EC Working Group did not discover "potential threats" to the Šamorín waterworks, unless 95% of the Danube's waters were channelled through the Čunovo weir, leaving the downstream reservoir virtually stagnant. <u>See</u>, SC-M, para. 7.36. The actual impacts of Variant "C" on the water quality at the Kalinkovo and Šamorín waterworks are summarised at Vol. III, p. 16. As to Kalinkovo, the changes are very small, being mainly a slight decrease in nitrate (which is favourable). No significant changes have been recorded at Šamorín.

"The Šamorín water supply well field is in the impact area of the lower part of the reservoir. The measurements show that the changes in the ground water chemistry are not significant."

<u>See</u>, also, Vol. III, Ch. 2.

(4) *Data include in situ temperature and conductivity, and laboratory analysis of major ions, metals, organics, and nitrogen redox species. Results from August and September 1994 are illustrated in Figures 3.14 to 3.19. It can be seen that in general reductive conditions predominate.*

It is expected that "reductive conditions" should predominate where there is very little water coming into the Szigetköz side arms. But this was only because Hungary had not taken steps to supply water directly into its side arms. See, SC-M, para. 8.11. See, now, SR, para. 1.03, et seq. Monitoring of the actual situation on the Slovak side shows no problem in relation to reductive conditions. See, Vol. III, at pp. 15, 17 and 32.

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1

likely to be of poor quality. Concern over this issue is evident from Slovak activities. It has been demonstrated from Hungarian data that poor water quality has occurred adjacent to the side-arm system. The clear implication is that recharge will result in long-term adverse changes to the quality of this major alluvial aquifer. Recharge quality in general exceeds drinking water standards for iron and manganese and ammonium. In some cases the toxic element arsenic is also present in unacceptable concentrations. Similar effects are also expected as a result of the remedial measures.

Table 3.12: Characteristic parameters of the observed well groups

Identification number of well group	Number of the wells observed for the water quality	Range of horizontal distances of the observed wells from the surface water (m)	Range of depth of well filters of the observed wells (m)
1	6	2-17	1.2-14.5
2	5	2-23	1.2-7.8
3	8	5-19	2.5-14.5
4	5	10-61	3.2-15
5	8	3-30	1.8-4.5
6	5	4-14	1-8.2
7	5	6.5-12	3-11
8	5	5-24	1.5-4
9	6	7-45	3-14.5
10	7	4-29	2.8-11
11	2	17	7.0-10.7

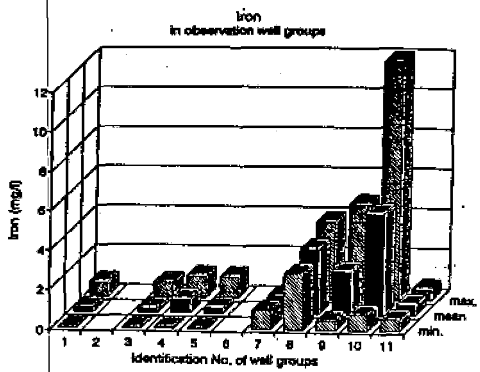


Figure 3.14: Characteristic iron concentrations in the observation well groups (after László, 1994a)

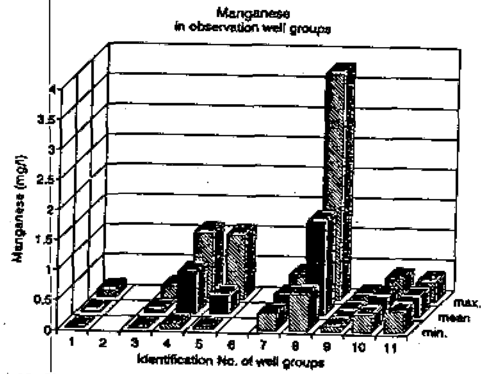


Figure 3.15: Characteristic manganese concentrations in the observation well groups (after László, 1994a)

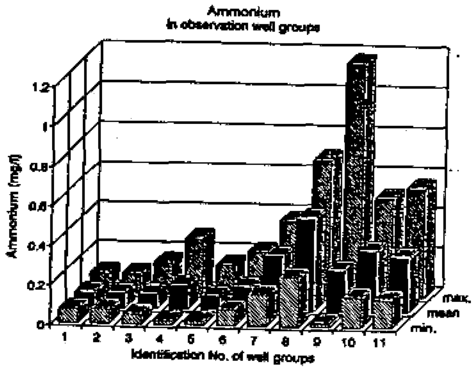


Figure 3.16: Characteristic ammonium concentrations in the observation well groups (after László, 1994a)

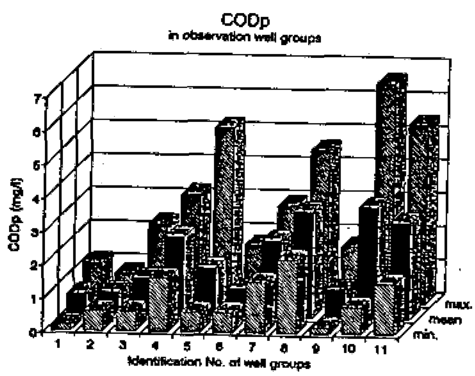


Figure 3.17: Characteristic COD concentrations in the observation well groups (after László, 1994b)

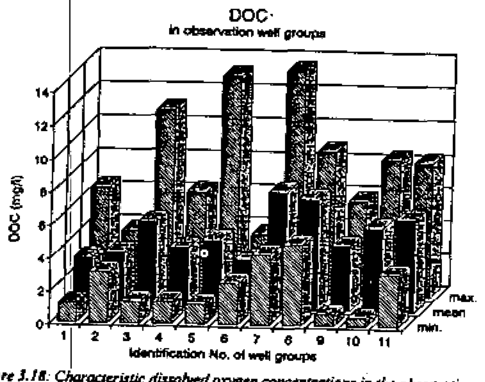


Figure 3.18: Characteristic dissolved oxygen concentrations in the observation well groups (after László, 1994b)

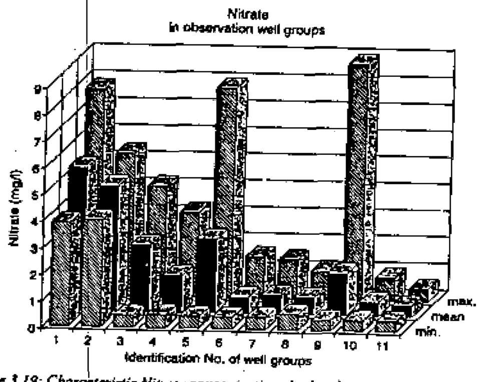


Figure 3.19: Characteristic Nitrate concentrations in the observation well groups (after László, 1994b)

(1) Although subject to uncertainty, calculations indicate that recharge from the reservoir is likely to be of poor quality. Concern over this issue is evident from Slovak activities. It has been demonstrated from Hungarian data that poor water quality has occurred adjacent to the side-arm system. The clear implication is that recharge will result in long-term adverse changes to the quality of this major alluvial aquifer.

Hungary's insistence on "calculations" and on "uncertainty" is wilful and does not serve to present a true picture of Project impacts. The results of the careful monitoring of the actual impacts of the Variant "C" reservoir are not subject to uncertainty and are available for analysis (e.g., by the EC experts). These show that there has been no deterioration of the water entering the aquifer. See, Vol. III, pp. 15, 25-26 and 33-35. See, also, EC Working Group report of 2 November 1993 - HM, Vol. 5, Annex 18 (at pp. 696 and 713).

"Demonstrated from Hungarian data": Such data has simply shown that, as would be expected, Hungary's failure to supply a direct recharge into its side arms has continued a previously negative trend in water quality. There is no "clear implication" to be drawn from this in relation to the impacts on the aquifer of either the reservoir or the Slovak side arms (which impacts, to date, have been beneficial). See, Vol. III, at p. 18. Put simply, there is no link, whether implicit or otherwise, between the poor conditions in the Hungarian side arm system today and conditions in the reservoir or in the Slovak side arms.

3.6 BANK-FILTERED WATER SUPPLIES

by Howard Wheater

3.6.1 EXISTING BANK-FILTERED WELLS

In the river reach from Gönyü to Budapest, bank-filtered wells have been developed to a varying extent to exploit the alluvial aquifer. Between Gönyü and Nagymaros, the reach influenced by backwater effects from the proposed dam at Nagymaros, major well-fields have an existing capacity of approximately 30,000 m^3/d (*Table 3.13* and *Plate 3.8, Volume 5*), and potential resources of 19,000 m^3/d and 75,000 m^3/d have been identified in the Ács-Komárom-Almásneszmély and Esztergom reaches (Hungarian Academy of Sciences, 1994).

Below Nagymaros, 64% of the Budapest Waterworks supply comes from the major well-fields to the North of the city, principally Szentendre Island (see *Plate 3.9, Volume 5*). It is therefore an issue of national importance to evaluate the potential risk to these resources, considering effects both upstream and downstream of the Nagymaros dam. 1

Table 3.13: Existing bank-filtered well fields – Gönyü to Nagymaros

Waterworks	Capacity (m^3/day)
Komárom - Koppánymonostor	5,000-6,000
Nyergesújfalu	5,000-6,000
Tát	2,000-3,000
Esztergom - Prímás	12,000-13,000
Esztergom - Szentkirály	2,000
Szob	<1,000
Zebegény	<1,000
Dömös	<1,000

3.6.2 POTENTIAL RISKS TO BANK-FILTERED WATER SUPPLIES

Bank-filtration is used extensively on the major European rivers. It has been shown to be highly effective in removing contaminants, for example inorganic and organic pollutants, heavy metals, algae and bacteria (e.g. Sontheimer, 1980;

Hermann *et al.*, 1986 and Chorus *et al.*, 1992), although there is a dependence of removal efficiency on the length of the filter pathway. However, the water quality of bank-filtered wells is dependent on the chemical conditions in the filter layer. If chemically-reducing conditions develop, mobilisation of metals such as iron and manganese (and other heavy metal pollutants which may be present in river sediment) may occur, together with the generation of ammonium, and, in addition, serious clogging problems can arise due to bacterial activity (van der Kooij *et al.*, 1985).

The yield in terms of water quantity from bank-filtered wells is dependent on river water levels and the hydraulic connection with the river. This in turn is affected by the geometry and material properties of the riverbed.

The primary concerns for bank-filtered water supplies are associated with a combination of these two factors. Changes to river water levels and riverbed levels will affect yield; changing patterns of sedimentation will cause deposition of organic-rich sediment. Their long-term degradation can change the chemical state of the filter system, with serious adverse consequences.

In addition, it is not uncommon in international experience for adjacent groundwater to have inferior water quality to bank-filtered river water. Reduction in river bed hydraulic connection can lead to increased well capture of poorer quality water.

3.6.3 HUNGARIAN EXPERIENCE OF DEGRADATION OF BANK-FILTERED WATER QUALITY

The extent of dredging of the Danube has been discussed in *Chapter 2*. The Danube reach from Nagymaros to Budapest has been dredged for industrial purposes and also to some extent for navigation. River training works have also included the construction of groynes. Two examples illustrate the consequences of changing sedimentation patterns on groundwater quality. 2

3.6.3.1 The Surány Waterworks

This waterworks was constructed by Budapest Waterworks on Szentendre Island between 1968 and 1971. Following tests in 1965 and 1966 which showed potable quality water with no iron, manganese or ammonium, 20 wells were installed (*Figure 3.20*). Water quality problems emerged, and were initially analysed in the mid-1980s (László *et al.*, 1990). Data from 1984 show particularly high levels of manganese and ammonium in wells 7 to 9 (*Figure 3.21*). The time-series of manganese and ammonium concentrations from 1973 to 1984 is shown in *Figure 3.22* for wells Nos. 4 and 9. Concentrations in well No. 4 peaked in the mid-1970s, and declined thereafter, whereas a significant deterioration in well 9 continued.

The investigation programme extended to the riverbed, and included detailed sediment survey, additional investigation boreholes, and biological and chemical analysis. The field survey in the vicinity of well No. 7 revealed two sediment-filled troughs (*Figure 3.23*), extending also to wells 8 and 9. The processes of sediment degradation outlined above were indeed occurring, and the resulting concentration of manganese and ammonium can be compared with EC (1980) limits of maximum admissible concentrations of 50 μg/l (0.05 g/m^3) and 0.5 mg/l (0.5 g/m^3) respectively and guide levels of 20 μg/l (0.02 g/m^3) and 0.05 mg/l (0.05 g/m^3), respectively. It will be noted that ammonium levels in well 9 in 1984 reached 90 times guide levels, manganese 200 times guide levels.

Investigation of well 4 indicated that problems of sediment degradation had occurred, but that the sediment had been gradually scoured following a change in flow pattern associated with later groyne construction.

The question remained whether the effects observed in wells 7 to 9 were likely to be persistent, or short-lived. More recent data for wells 8 and 9 are presented in *Figures 3.24* to *3.29*, and show that unacceptable levels of manganese, ammonium and iron continue up to the present. The riverbed now appears stable in the vicinity of the wells. Hence the clear implication is that the original sediment deposition does indeed have long term effects.

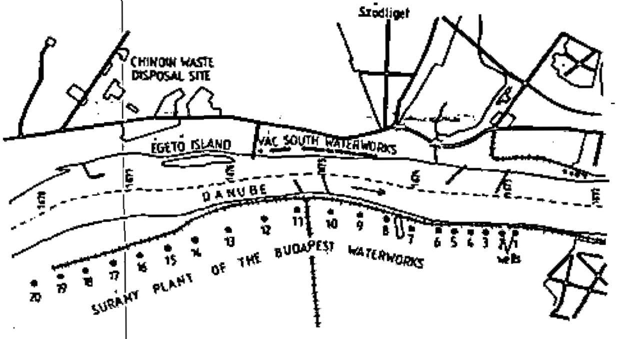


Figure 3.20: Surány bank filtration well field along the Danube rkm 1673-1678

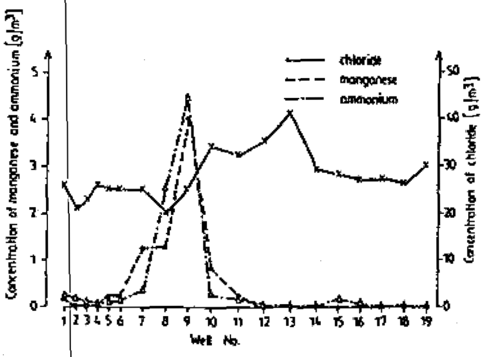


Figure 3.21: Water quality in the Surány well field in 1984

(1) *It is therefore an issue of national importance to evaluate the potential risk to these resources, considering effects both upstream and downstream of the Nagymaros dam.*

"To evaluate": The importance of evaluation is self-evident. But this was known to the Treaty parties at the time of entering into the 1976 Joint Contractual Plan Agreement and figured as part of the parties' further research obligations thereunder- see, SC-M, para. 7.68. The evaluation has already been carried out - in a 5 year research and development program carried out by Budapest Waterworks and in the 1985 EIA (amongst others). See, SC-M, para. 7.70 et seq.

Assuming adequate flow rates are maintained in the Čunovo reservoir, the water quality downstream of Gabčíkovo should improve as compared to its pre-dam state. See, Vol. III, at p. 24:

"On the basis of the overall comparison of monitoring results from the period prior and after the putting of the Gabčíkovo section into operation, it may be stated that no significant changes in water quality occurred. The recorded trend has shown a slight improvement in some parameters."

Upstream of Nagymaros not only will more good quality Danube water infiltrate into the bank filtered wells because of increased water levels and water pressure, but also this water will be of a slightly improved quality and will have been aerated after passing through the Gabčíkovo barrage.

Nonethless, the need remains for waste water treatment in Hungarian cities like Györ in order to maintain this good water quality. See, Comment 3 to "Scientific Evaluation", p. 68.

(2) *Two examples illustrate the consequences of changing sedimentation patterns on groundwater quality.*

It is important to stress that the examples that follow have nothing whatsoever to do with the G/N Project. They simply serve to show that random commercial dredging can be harmful if it takes place too close to drinking water wells, which is largely self-evident. It is scientifically invalid to try in this way to establish a link between a random dredging event that happens to fit Hungary's theses and the expected impacts of the G/N Project.

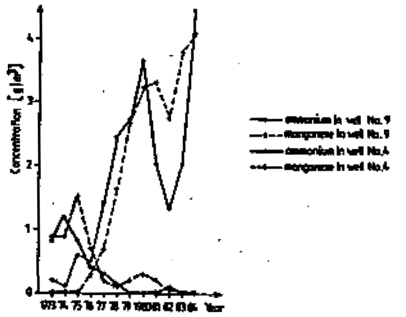


Figure 3.22: Annual highest manganese and ammonium ion concentrations in the well No. 4 and No. 9 between 1973-1984

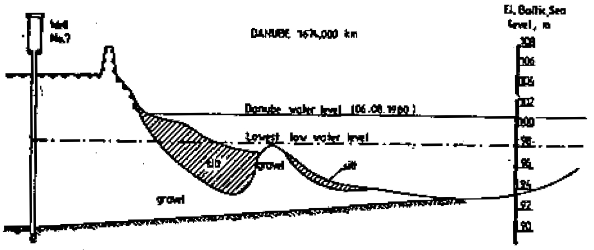
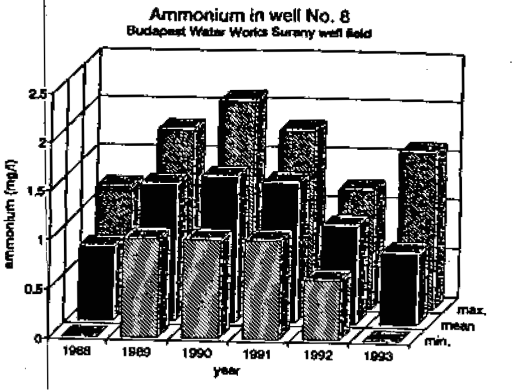
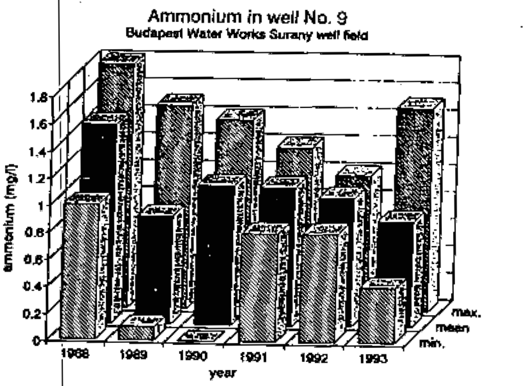


Figure 3.23: Danube cross section through well No. 7


Ammonium in well No. 8

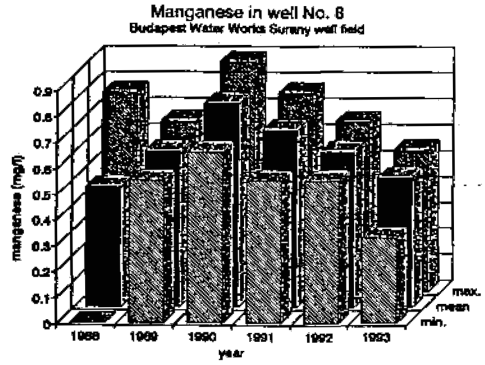
Budapest Water Works Surany well field

Figure 3.24: Annual maximum, minimum and mean ammonium concentrations in well No. 8 between 1988 and 1993


Ammonium in well No. 9

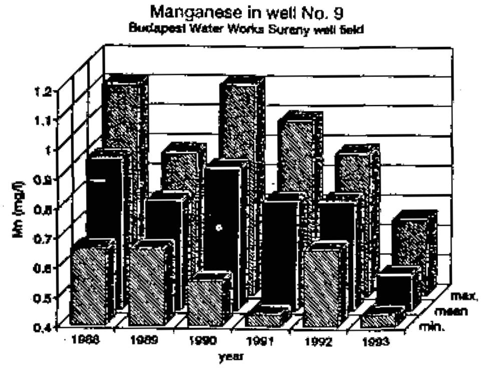
Budapest Water Works Surany well field

Figure 3.25: Annual maximum, minimum and mean ammonium concentrations in well No. 9 between 1988 and 1993


Manganese in well No. 8

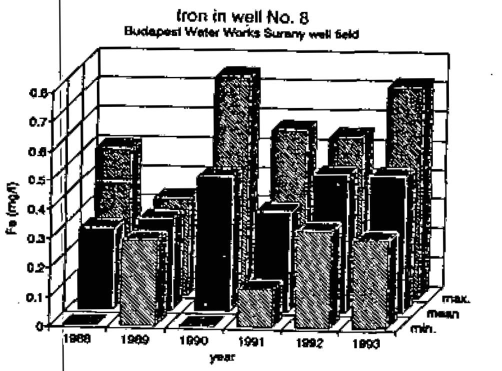
Budapest Water Works Surany well field

Figure 3.26: Annual maximum, minimum and mean manganese concentrations in well No. 8 between 1988 and 1993


Manganese in well No. 9

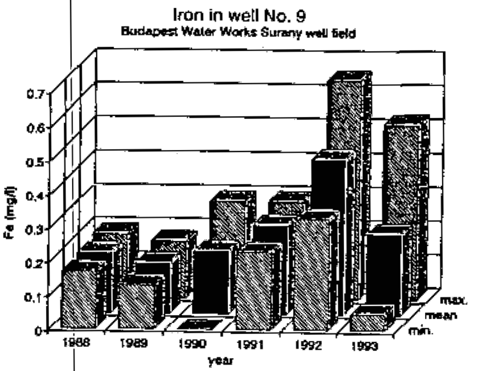
Budapest Water Works Sureny well field

Figure 3.27: Annual maximum, minimum and mean manganese concentrations in well No. 9 between 1988 and 1993


Iron in well No. 8

Budapest Water Works Surany well field

Figure 3.28: Annual maximum, minimum and mean iron concentrations in well No. 8 between 1988 and 1993


Iron in well No. 9

Budapest Water Works Surany well field

Figure 3.29: Annual maximum, minimum and mean iron concentrations in well No. 9 between 1988 and 1993

No especial comments.

3.6.3.2 *Nagymaros Waterworks*

Two bank-filtration wells of the Nagymaros Waterworks of the Danube Regional Water Company were operated on the left bank of the Danube at rkm 1693 between 1963 and 1988. Rapid water quality deterioration began in both wells in the early 1980's, as shown in *Figures 3.30* and *3.31*. The manganese and ammonium concentrations exceeded drinking water limits and the operating licences for the wells were withdrawn. A Raney-type well was installed two kilometres downstream in 1986. Within six years the water quality became unacceptable. As can be seen from *Figure 3.32*, the results show a change of redox conditions leading to increased manganese and ammonium and reduced nitrate concentrations.

1

The adverse changes in water quality in these three wells occurred due to bed sediment deposition. It is believed to be a direct result of the Nagymaros coffer dam construction.

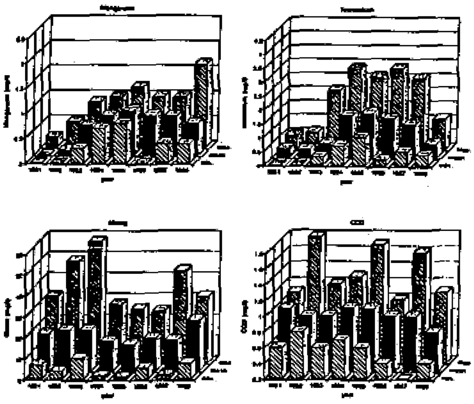


Figure 3.30: Water quality of the bank filtration well No. I, Nagymaros Waterworks

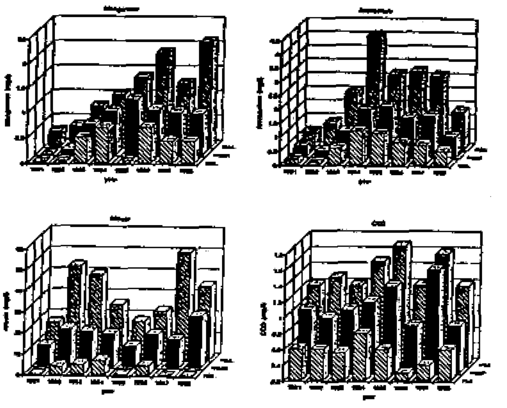


Figure 3.31: Water quality of the bank filtration well No. II., Nagymaros Waterworks

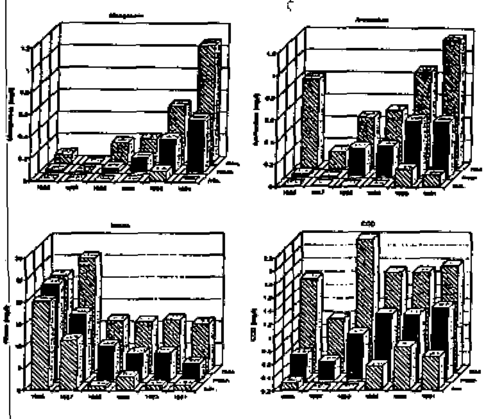


Figure 3.32: Water quality of the bank filtration Raney well, Nagymaros Waterworks

3.6.4 HUNGARIAN EXPERIENCE OF YIELD REDUCTION

2

It has been noted above that extensive dredging has taken place below Nagymaros, in part in preparation for the Original Project. In consequence, the riverbed has dropped by 2.5 metres on average (Budapest Waterworks, 1994). This has led to a reduction in low flow water levels by 0.6 m at Budapest, 1.23 m at Nagymaros, and 1.5 m at Surány since 1960. The channel bed has become uneven, leading to the localised deposition of sediment, with consequences as discussed above. In the Budapest area, the thickness of filter media has decreased in places to 1-2 metres, which in practice means that it cannot perform its function properly. There has also been a decrease in the effective width of riverbed for filtration, by approximately 40-50 m or 30%. The estimated decrease in capacity due to reduced water levels is 100,000 m^3/day and due to decreased filter area is 200,000 m^3/day.

3.6.5 IMPACTS OF THE ORIGINAL PROJECT

3.6.5.1 Impacts of the Nagymaros Dam on bank-filtered wells in the backwater reach (Gönyü to Nagymaros)

The significance of bank-filtered wells in this reach has been discussed above. The existing well capacity is approximately 30,000 m^3/d, and potential additional resources have been estimated as 94,000 m^3/d (*Table 3.13* and *Plate 3.8, Volume 5*).

3

Changes in surface water quality can be expected, as discussed already in *Chapter 3.3*. However, a major concern is the process of sediment deposition, the subsequent degradation of organic matter, and the associated development of reducing conditions. As discussed above, there is ample evidence from international experience, including the Danube, and from Budapest, that these processes occur.

4

The processes of sediment transport are complex, and predictions are inevitably uncertain. In the case of the Nagymaros Reservoir, the influx of suspended sediment load will depend on the discharge from the upstream system of the Dunakiliti Reservoir, power canal and main Danube channel. Rákóczi and Bognár (1985) estimated that most of the upstream load would be transmitted to the Nagymaros Reservoir. More recent simulations (VITUKI, 1988) indicated that between 41 and 73% would be retained upstream, depending on the particular flow regime in a given year.

Apart from this input uncertainty, flows in the Nagymaros Reservoir would be affected by peak power operation, again leading to significant uncertainty in the estimation of the two-dimensional distribution of sediment deposition that could be expected.

The study by Rákóczi and Bognár (1985) suggested that the main section of concern was the 42 km-long section between Lábatlan and Nagymaros, although significant deposition further upstream could not be excluded. Consideration of the settling velocity of the fine sediment fraction, and the distribution of velocity profiles and bed shear stress expected during peak power operation led to the conclusion that fine sediment would mainly settle in a strip of 6.5 m depth below surface water level on each side with a combined width of 80 m at rkm 1708.5 and of 280 m at rkm 1724.4, upstream of Esztergom. The 1985 study estimated an annual rate of sediment deposition of 40-50 mm. Assumptions of a reduced sediment inflow suggest 20 mm/year.

Research by Starosolszky (1966, 1981) on the effect of sediment deposition on the reduction of infiltration rates indicated penetration of fine sediment within the alluvial profile. Hence the effects on reduction of bank-filtered well yields were estimated assuming:

A. a 5 cm. silt layer over the relevant strip

B. a 1 m clogged layer of alluvium underlying the silt

The potential reduction in yield was 2-6% in case A (which represents 1-2.5 years deposition) and 10-40% in case B, depending on well configuration.

To evaluate the groundwater quality impacts, László (1994b) modelled the redox processes in the filtration layer under conditions of organic degradation, i.e.:

– aerobic respiration

$$CH_2O + O_2 \quad \rightarrow \quad CO_2 + H_2O$$

– denitrification

$$CH_2O + {}^4/_5\, NO_3^- + {}^4/_5\, H^+ \quad \rightarrow \quad CO_2 + {}^2/_5\, N_2 + {}^7/_5\, H_2O$$

– manganese (Mn (IV)) reduction

$$CH_2O + 2MnO_2 + 4H^+ \quad \rightarrow \quad 2Mn^{2+} + 3H_2O + CO_2$$

– iron (Fe (III)) reduction

$$CH_2O + 8H^+ + 4Fe(OH)_3 \quad \rightarrow \quad 4Fe^{2+} + 11H_2O + CO_2$$

5

For a biodegradable organic content of settled sediment of 2% (VITUKI, 1988), sedimentation at the conservative rate of 2 cm/year and typical river water quality, it was concluded that reduction would occur, with the likely impact of increased iron and manganese in bank-filtered wells.

(1) *The adverse changes in water quality in these three wells occurred due to bed sediment deposition. It is believed to be a direct result of the Nagymaros coffer dam construction.*

"Direct result": Hungary complains of "rapid water quality deterioration in both wells in the early 1980s". The Nagymaros coffer dam was built in 1987-1988. There is no link. The third well in question is located 5 km downstream of the Nagymaros coffer dam.

The real reasons for the "adverse changes" are summarised by the Hungarian scientists Somlyody, et al., in their 1989 study, which forms Annex 13 to HC-M, Vol. 4 (at pp. 562-563): "To summarise the water quality of the bank filtered wells has recently seriously deteriorated. This has been caused by the coinciding effects of a number of factors: the deterioration of the Danube's ecologically sound water body; inappropriate specification of the water bases' protection area; inappropriate location of water bases; background pollution due to excessive use of agricultural pesticide; waterbed regulation work and dredging (VGI, 1985)."

(2) *It has been noted above that extensive dredging has taken place below Nagymaros, in part in preparation for the Original Project. In consequence, the riverbed has dropped by 2.5 metres on average (Budapest Waterworks, 1994). This has led to a reduction in low flow water levels by 0.6 m at Budapest, 1.23 m at Nagymaros, and 1.5m at Surány since 1960.*

"In preparation for the Original Project": This is simply false. Although Chapter 2 of the "Scientific Evaluation" conveniently omits any real examination of the Nagymaros-Budapest stretch, it is nonetheless "noted above" (at "Scientific Evaluation" p. 11) that in this stretch "excessive dredging was carried out for industrial purposes". See, also, HM, p. 428, where it is admitted that in this stretch the riverbed has been lowered by up to 1.5 m "due to the effects of commercial gravel dredging".

See, also, HC-M, Vol. 4, Annex 6 (at p. 378): "Between Nagymaros and Budapest excessive dredging was carried out for industrial purposes .... ."

This dredging was done by Hungary unilaterally, without consultation with Czechoslovakia, many years before the dredging planned for the Project.

(3) *Changes in surface water quality can be expected, as discussed already in Chapter 3.3.*

Chapter 3.3 predicts no changes in surface water quality in this stretch: it does not even mention the impact of the Nagymaros dam on the backwater stretch. As to the actual impacts of Variant "C", Chapter 3.3 notes that "bacteriological quality for 1993 suggests an improvement" in the main channel (at p. 75). Slovak monitoring shows either an improvement or no change in surface water quality - see, Vol. III, at pp. 15 and 24.

(4) *The processes of sediment transport are complex, and predictions are inevitably uncertain.*

There is no real evidence to suggest a problem connected with sediment transport due to the G/N Project - Hungary therefore resorts to a claim of "uncertainty". By contrast, there is evidence - from two years of monitoring the impact of the Variant "C" reservoir - that sediments are not significantly polluted and therefore cannot pollute groundwater or waters tapped by bank-filtered wells. See, Vol. III, at p. 35.

(5) *For a biodegradable organic content of settled sediment of 2% (VITUKI, 1988), sedimentation at the conservative rate of 2 cm/year and typical river water quality, it was concluded that reduction would occur, with the likely impact of increased iron and manganese in bank-filtered wells.*

Hungary is happy to rely on pre-1989 studies when these fit its current theories. Its 1985 EIA predicted an <u>improvement</u> in these bank filtered wells due to the increased flow of Danube water eliminating background pollution - <u>see</u>, HM, Vol. 5, Annex 4. As to the actual quality of sediment, <u>see</u>, Vol. III, at pp. 33-37. This does not indicate that waters would be polluted by heavy metals, and it notes that iron and manganese are present due to the composition of upstream rock formations, <u>i.e.</u>, are from natural sources. In the worst case, as the HQI report pointed out: "iron and manganese are easy to recover from water and do not pose a risk to health" - <u>see</u>, HM, Vol. 5, Annex 9.

please turn to next page

3.6.5.2 Impacts of the Nagymaros Dam on bank-filtered wells downstream

1

The national significance of the water supply from this reach *(Plate 3.9, Volume 5)* has already been discussed. It has been shown that dredging for the Original Project has, together with other dredging activities, already led to a dangerous reduction of the riverbed filter layer to 1-2 m in places, and that changing patterns of sediment movement have already given severe water quality problems, with certain parameters exceeding drinking water standards in excess of 2 orders of magnitude. In particular, construction of the Nagymaros coffer dam appears to have been responsible for the closure of wells due to unacceptable water quality. According to the Joint Contractual Plan, additional dredging was planned to lower the Nagymaros tailwater by 0.6-1.2 m.

The uncertainty in sediment transport calculations has already been referred to. A numerical modelling study of bed degradation downstream of the Nagymaros Dam used two alternative approaches, each well-founded on relevant Hungarian experience of the Danube (Bakonyi, 1994). Order of magnitude differences were obtained in the predicted bed changes, with local rates of degradation and aggradation of 1.5 m/year in the worst case.

2

The effects of the planned dredging were estimated to give a reduction in the yield of the bank-filtered wells of 75,740 m^3/d (Budapest Waterworks, 1994).

3

It is therefore evident that, although uncertain, predictions indicate a potentially serious threat to the Budapest water supply, and that adverse changes associated with the project have already occurred.

(1) It has been shown that dredging for the Original Project has, together with other dredging activities, already led to a dangerous reduction of the riverbed filter layer to 1-2 m in places, and that changing patterns of sediment movement have already given severe water quality problems, with certain parameters exceeding drinking water standards in excess of 2 orders of magnitude. In particular, construction of the Nagymaros coffer dam appears to have been responsible for the closure of wells due to unacceptable water quality.

This is seriously misleading. Hungary admits that its own commercial dredging (of 20 million m^3) led to the drop in the riverbed. The dredging downstream of Nagymaros provided for in the Project (of 6 million m^3) never took place. See, "Scientific Evaluation", p. 11, and HM, p. 428. The Nagymaros coffer dam, constructed in 1987-1988, could not have been responsible for the "rapid deterioration" of wells "in the early 1980s". See, Comment 1 to "Scientific Evaluation", p. 113.

(2) The effects of the planned dredging were estimated to give a reduction in the yield of the bank-filtered wells of 75,740 m^3/d (Budapest Waterworks, 1994).

This after-the-event assessment, which Slovakia has no means of verifying, is wholly irrelevant. As noted above, the Project anticipated dredging of 6 million m^3 of gravel. Hungary has already dredged 20 million m^3 for commercial reasons. There is no need for further dredging, as admitted in Hungary's own annexes: "As a result of intensive dredging over the past decades, the water level of the present section complies with that planned for the [G/N Project] system (VIZITERV 1985)." See, HC-M, Vol. 4, Annex 13 (at p. 576).

(3) It is therefore evident that, although uncertain, predictions indicate a potentially serious threat to the Budapest water supply, and that adverse changes associated with the project have already occurred.

It is not clear how something can be "evident" but "uncertain" at the same time.

It is important to put this particular contention in perspective. The verification of the effects of the Project on Budapest water supplies was Hungary's Treaty responsibility - see, SC-M, para. 7.68. As a result it carried out a 5 year research and development program (1980-1985) and conducted the 1985 EIA, which was specifically aimed at potential impacts to the Budapest water supply - see, SC-M, para. 7.74. The EIA concluded that: "The Barrage System has no effect upon the filter layer of the Budapest Waterworks' water resources ...". HM, Vol. 5, Annex 4.

These findings were reviewed by Hungary in 1989 by Somlyódy, et al. Again, no threat was predicted. Their conclusion was merely that: "Special attention should be paid to water bases in the course of waterbed regulation following start of G/N Project operations in order to maintain the present quantity and quality filtration layer." See, HC-M, Vol. 4, Annex 13 (at p. 576).

The "adverse changes associated with the Project"are a recent invention.

CHAPTER 4

FLORA AND FAUNA

4.1 HISTORICAL DEVELOPMENT

by Gábor Vida

1

The area affected by the Gabčíkovo-Nagymaros project extends to the large area between Bratislava and Budapest. However, by far the largest impact is and will be on the unique inland delta, of which the Hungarian part is called the Szigetköz, and the Slovak part Žitný Ostrov. This area was originally covered with waterbodies, 2 marshes and various kinds of forests ranging from inundated to the driest forest-steppe types. Due to the natural (flood) and artificial (clearing) disturbances, which started mainly in the last century, the diversity of habitats was supplemented by several succession series resulting in an exceptionally high species- and community-diversity. This high biodiversity was further increased by the transitional position of the area. Pannonian, East-Alpine (Noricum) and Carpathian elements of the flora and fauna meet here. The climate is also a mixture of continental, Atlantic and even sub-Mediterranean influences.

Agriculture has long taken over most areas of natural vegetation in the drier, less frequently inundated areas. In the middle of the last century, large scale river regulatory work started, confining the flooded area to the 2-6 km-wide belt (see *Chapter 2*) between the flood protection dykes. This first intervention did not change significantly the groundwater level distribution in the old (former) floodplain. Much more impact resulted, however, from the regulations to improve navigation. The originally braided channel was modified into the recent main channel plus side branches system, increasing up to 90% of the discharge in the main channel at the expense of the side-arms. This launched a series of slow gradual transformations (successions) in the floodplain.

4.1.1 PROTECTIONAL VALUE

In spite of all these anthropogenic actions, biologists have been able to report on an exceptionally rich flora and fauna (see *Plate 4.1, Volume 5*). As Mészáros and contributors (1994a, 1994b) describe, there are 80 different plant communities (associations) comprising one thousand vascular plants in the Szigetköz. Lower plants (mosses, liverworts, lichens, algae), fungi and micro-organisms are only imperfectly known.

3

The fauna is even richer (see Mészáros *et al.*, 1994a, 1994b). The species so far recorded by zoologists (a few thousand taxa) make up only a fraction of the total fauna. In light of the rapid degradation of the habitats, it is questionable that the total fauna of the Szigetköz will ever be assessed.

Natural flooding was (until 1992) a major factor in maintaining high biodiversity. It excluded several otherwise competitive species in the floodplain, therefore supporting the survival of the specially adapted ones.

8% of the vascular flora of the Szigetköz are officially protected. There are 314 protected animals, of which 66 species are listed in the Hungarian Red Book. 9,158 ha belong to the Protected Landscape Area (Mészáros, 1994b).

It is well known that this area and, more generally, the inland delta are of international interest and have a patrimonial value (e.g. Dister, 1994). Until the last few decades, the Danube lowland between Bratislava and Győr represented the largest and most valuable floodplain in Central and Western Europe. The size of this area, namely the Szigetköz and the Žitný Ostrov, surpassed similar areas along the Rhine and Rhône rivers, and the latter were additionally altered by 4 hydroelectric development. Szigetköz and Žitný Ostrov remain "especially important because of their morphodynamics but have been fundamentally destroyed by the construction of the Gabčíkovo-Nagymaros hydroelectric plant" (Dister, 1994). Concerning more precisely the Szigetköz, before the completion of Variant C, it was unique with respect to the diversity of its alluvial habitats, its geographical location, its geomorphic location, its geomorphological and hydrological features, and its sub-Atlantic climate. All these characteristics "lead to the development of combinations of species that partly differ from the usual fauna of European river valleys" (Mészáros *et al.*, 1994b). The international patrimonial value of this area is well known and well documented (cf. Mészáros *et al.*, 1994a).

There has been substantial damage in the flora and fauna as a consequence of the 5 implementation of Variant C (see Mészáros *et al.*, 1994a and *Chapter 4.5*). There can be no doubt for an ecologist that the loss so far recorded is only the first sign of a massive degradation. The whole process can take place over decades, giving the impression to the layman, accustomed to the rapid changes in the human spheres, that there is limited change. Short-sightedness, however, cannot be an excuse. The essential problem is that of gradual but cumulative losses.

According to the Rio Conference's recommendations, the "precautionary principle" should be applied in such a case: in the absence of adequate scientific knowledge large scale interventions should be avoided. This principle accords well with the experience of the ecological sciences.

4.2 THE NATURAL SYSTEM

by Gábor Vida

4.2.1 THE IMPORTANCE OF BIODIVERSITY

Natural terrestrial biotic communities, the interacting assemblage of thousands of living creatures (plants, animals, fungi and micro-organisms) have evolved for 400 million years, incorporating successful innovations and eliminating mistakes in the course of co-evolution. Only recently have we realised that even the present diminishing natural richness is still a rich storehouse. In addition, the natural systems contain invaluable information on principles of efficient organisation for energy utilisation and sustainable material use. Even more importantly, on a global scale we depend on ecosystem services provided mainly by natural ecosystems.

The major contrasting difference between natural and man-made ecosystems is in relative scales of biodiversity (Vida, 1994). Natural systems are rich in species (high species diversity), and each species is rich in gene forms (alleles) giving high genetic diversity, a prerequisite for long-term survival. On the other hand, man-made systems, e.g. an agro-ecosystem, are much more uniform in both species and genetic diversity.

Conservation and understanding of biological diversity therefore became a world-wide major issue the late 1980s in both the scientific and the popular press (Groombridge, 1992 and Wilson, 1988).

One of the most worrying issues confronting modern societies is the massive transformation of the Earth's landscapes taking place today, including changes in soil, water, vegetation, and atmosphere (Solbrig *et al.*, 1992). Present biodiversity changes have a negative influence on the biosphere's functioning. J.W.M. La Riviere from the International Institute for Hydraulic and Environmental Engineering (Delft, The Netherlands) regards biodiversity as "one of the most important problem areas of our time" for three reasons:

> "1) It is the living part of creation, possibly unique in the Universe;
>
> 2) It is a storehouse of economic goods, underexplored and underexploited; and
>
> 3) It is an essential part of the life support system. Its complexity and vulnerability are poorly understood" (La Riviere, 1992).

Hence, as F. di Castri, President of IUBS (International Union of Biological Sciences) claimed, "Biodiversity is likely to become one of the most crucial issues of environmental sciences" (di Castri, 1990). Two years later at the Rio Summit (UNCED, United Nations Conference on the Environment and Development) the Convention on Biological Diversity was signed by more than 150 states, including Hungary.

The Preamble of the Convention on Biological Diversity states as follows:

> "Affirming that the conservation of biological diversity is a common concern of humankind,
>
> Reaffirming that States have sovereign rights over their own biological resources,
>
> Reaffirming also that States are responsible for conserving their biological diversity and for using their biological resources in a sustainable manner,
>
> Concerned that biological diversity is being significantly reduced by certain human activities,
>
> Aware of the general lack of information and knowledge regarding biological diversity and of the urgent need to develop scientific, technical and institutional capacities to provide the basic understanding upon which to plan and implement appropriate measures,
>
> Noting that it is vital to anticipate, prevent and attack the causes of significant reduction or loss of biological diversity at source,
>
> Noting also that where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimise such a threat,
>
> Noting further that the fundamental requirement for the conservation of biological diversity is the in-situ conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings."

Again, this closely reflects the day-to-day experience of biologists and the lessons of their discipline. Consistent with this, the maintenance and safeguarding of the biodiversity in the Szigetköz and other affected areas of the Gabčíkovo-Nagymaros Project is an important national and international concern.

4.2.2. BIODIVERSITY LOSS IS UNAVOIDABLE WITH HYDROPOWER DEVELOPMENT

Natural ecosystems are among the most complicated natural systems. Despite much study, ecologists are still far from a complete understanding of this complexity. Natural ecosystems form an intricately interwoven system of the populations of plants, herbivorous and carnivorous animals, decomposers and the

4. COMMENTS TO HUNGARY'S "SCIENTIFIC EVALUATION", CHAPTER 4: FLORA AND FAUNA

(1) *The area affected by the Gabčikovo-Nagymaros project extends to the large area between Bratislava and Budapest.*

In much of this "large area" the effect of the G/N Project is minimal. Hungary makes no serious attempt to claim otherwise - as is clear from the focus of this Chapter of the "Scientific Evaluation" which is largely on Szigetköz. It is noted that Hungary nowhere provides a useful map showing clearly exactly where the impact it alleges would be felt. The SR has prepared such a map - see, Illus. No. R 4, appearing at the start of Part III.

(2) *Due to the natural (flood) and artifical (clearing) disturbances, which started mainly in the last century, the diversity of habitats was supplemented by several succession series resulting in an exceptionally high species - and community-diversity.*

Hungary seems to make the startling suggestion that human intervention has increased biodiversity - surely, a peculiar conception of what biodiversity is. While, strictly speaking, it is correct that if new species - for example, cultivated poplars - are introduced into a region, biodiversity has increased, this is at the expense of the natural biodiversity that existed beforehand. And cultivated species quickly predominate over the natural species. Put simply, human intervention led last century to the radical reduction of the floodplain area, the large scale cultivation of the region by economically valuable crops and therefore an overall and undeniable loss in the natural, floodplain biodiversity.

As to the flood regime, this was not "natural". The creation of the Danube main channel and the construction of flood dykes led to more frequent and more extreme flooding and water level fluctuation. See, Vol. III, at p. 9:

"The trend towards the increase of the water level fluctuation, registered in previous decades, was related to the closing of the river branches, river regulations and antiflood measures, fortification of river banks and the construction of spurdykes (groynes) to assure navigation depth during lowflow discharge. The fluctuation of the Danube water level and the ground water level fluctuation were much smaller in the time when the Danube merely meandered across the floodplain with its many river branches. In addition, the confining of the Danube to a single channel in the upper reaches (Austria and Germany) resulted in an increase of the flood peak discharge."

As to the "clearing disturbances", presumably this refers to the replacing of indigenous tree species in Hungary with commercial growth species, 64% of which are of one broad type - hybrid poplars. See, "Scientific Evaluation", at p. 183. This has not increased biodiversity in its usual environmental sense.

(3) *The species so far recorded by zoologists (a few thousand taxa) make up only a fraction of the total fauna. In light of the rapid degradation of the habitats, it is questionable that the total fauna of the Szigetköz will ever be assessed.*

This is an admission that Hungary has put little effort into establishing an inventory of species in Szigetköz. This is not so for Slovakia (in relation to Žitný Ostrov). The inventory of aquatic fauna in the Danube was established by the Slovak scientist Brtek J. in 1964. See, Vol. III, p. 106. Inventories as to the floodplain fauna were established from the 1950s to the 1980s and are largely reflected in Országh I. et al., 1994. It is not realistic, however, to expect to have a definitive inventory covering all taxa in a given

region - this is not international practice and nor is it international practice to hold up a given project until such an inventory is established.

"Rapid degradation": Hungary does not specify the causes of this "rapid degradation" which are not necessarily connected with the Project. One of these causes was Hungary's unwillingness to allow the direct supply of water into its side arms as provided for in the G/N Project. A direct supply has been assured on the Slovak side where, according to Slovak scientists, no decrease in the biodiversity of fauna is envisaged. See, Vol. III, at p. 100:

"A significant change of fauna in the branches cannot be expected due to the existence of variable flowing conditions. There is an ongoing progressive regeneration of original species. Different species can, however, have another quantitative occurrence as compared to the pre-dam situation."

Indeed, there has been a positive increase in biodiversity in some areas due to Variant "C" and there are signs that due to the multiple succession of new ecotypes, biodiversity will return to the more natural levels of a century ago. Already, new species that had been considered locally extinct have been recorded again - particularly in the shallow areas of the reservoir, the Čunovo and Rusovce side arms, the Biskupice side arms and in the reservoir seepage canals. See, Ch. 5 and Ch. 7 re. Avifauna.

(4) *Szigetköz and Žitný Ostrov remain "especially important because of their morphodynamics but have been fundamentally destroyed by the construction of the Gabčíkovo-Nagymaros hydroelectric plant" (Dister, 1994).*

This conclusion is very inaccurate. Of course, there was some "fundamental destruction" due to Project construction. This occurred primarily on the Slovak side of the Danube. The loss of forest consisted largely of the harvesting of cultivated poplars that would anyway have been harvested at some stage.

Moreover, without the G/N Project, the floodplain forest would have disappeared (as demonstrated by data relating to the Slovak side of the Danube) - see, Vol. III, at p. 87.

As the EC Working Group of Experts commented, Project implementation allows the floodplain to "develop more naturally" - see, EC report of 23 November 1992, HM, Vol. 5, Annex 14 (at p. 418). This is confirmed by recorded impacts to the biodiversity of flora to date. See, Vol. III, p. 87:

"As to plant biodiversity, there is no proof as to the lowering of the phytogenofund from the experience of two or more years since the damming. To the contrary, new biotopes may appear as a result of the water recharge into the side arm system in the inundation area (Dobrohošť - Palkovičovo) and in the huge limozic and littoral zone around the Hrušov reservoir, leading to a presumption in the favour of increased biodiversity."

(5) *There can be no doubt for an ecologist that the loss so far recorded is only the first sign of a massive degradation.*

This is an emotional conclusion having no basis in fact; it is refuted by the monitoring of the actual status on the Slovak side of the Danube. See, Vol. III, Chapters 4, 5, 6 and 7 and Comment 3 above.

As to the words "no doubt", this is noticeably at odds with Hungary's finding (at "Scientific Evaluation", p. 3) that: "The abundance of issues and data on the one hand and

the lack of knowledge and information in certain fields on the other leaves a great deal of uncertainty over the extent to which the environment will be affected in the short and long term by the Project, and whether or not these changes can be considered acceptable."

non-living environment. Most of the living creatures of an ecosystem are invisible; in the gallery-forests of the Szigetköz there are several thousand species of which the conspicuous trees, game-animals, fishes and birds altogether represent only 1-2% at most. In the case of the floodplain ecosystems the river forms the core of the system. Its physical, chemical and biological parameters influence directly or indirectly every other part of the system. 1 It is inconceivable to suppose that riverine ecosystems can be maintained by diverting substantial proportions of the water discharge from the main channel into an isolated power canal. Yet Miroslav Liška, a senior Slovak engineer, said in a recent report to New Scientist (Pearce, 1994): "We have separated the navigational and commercial function of the river from its ecological function. This gives us a unique opportunity to develop this section of the river in its natural form".

This artificially engineered "natural form" of the former river can at best be an artificial lacustrine ecosystem, if weirs are built, or an artificial small river if not. In any event, it would be far from performing the eupotamon functions described below (*Chapter 4.3.2.2*). What kind of ecological function of the river is left, if the flux is missing? The quoted scenario could be more or less valid only if 95% of the discharge remains in the main channel.

In the case of the implementation of the Gabčíkovo-Nagymaros Barrage System, the substantial loss of flora and fauna is inevitable for several reasons: 2

– Certain habitats are no longer available. Species adapted to these conditions (main channel with high water flow velocity) will disappear;

– With the changing water level and flow conditions many species find themselves in the wrong place, forced to move and recolonise to the nearest right place. Such has often been the case in an actively developing natural river system. The present Čunovo Dam situation, however, is quite different, for the magnitude of change was abnormally large (e.g. a 2-3 m drop in water level), and the natural and semi-natural spots now are mostly fragmented, separated by long distances, allowing little chance for many species to reach the suitable place;

– Even if they can find the correct place to colonise they have to compete with weedy species from the disturbed environment, and, having lost substantial genetic diversity through the "bottle-neck effect" of migration, they fail to establish themselves. Genetic diversity is necessary to adjust the population into the multi-species community's food web system (Vrijenhoek, 1994); 3

– Peak operation with huge daily fluctuation of the water level and flow velocity creates an additional burden and subsequent loss to the aquatic and littoral ecosystems (see *Chapter 4.4*).

4.2.3. PREDICTABILITY AND REVERSIBILITY

All these are basically stochastic processes: their time requirement and concrete realisation is highly unpredictable. A limited amount of disturbance can actually increase local biodiversity but usually only at the expense of regional biodiversity. In other words, new weedy species with ubiquitous distribution will enter the biotic communities and out-compete the unique local species or genotypes. 4

Thus, the final outcome, a loss of local biodiversity, is unavoidable. This has already been demonstrated by every single water regulation, including the Upper Rhine barrage system or the Rhône barrage system. P. Petermann (1987), an authority on Upper Rhine ecological impacts, concludes on the results of the two centuries of river transformations. "Altogether each intervention had adverse effects that made further measures necessary" (cf. Lösing, 1994). 5 The most regrettable fact of biodiversity losses is that they are to some extent irreversible, particularly if they are induced by physical modifications of the habitat. As opposed to chemical disturbances or pollution, physical disturbances like dams are irreversible. Even if a locally lost species can be reintroduced from other places, the specific genetic composition will not be the same. Provided the colonisation was successful, hundreds of generations are needed to develop an adaptive gene pool comparable to that of the extinct, original population (Frankel and Soule, 1981).

4.3 ECOLOGY OF FLOODPLAINS

by Joachim Lösing and Albert Roux

4.3.1 INTRODUCTION

In the past ten years, the view of rivers as one-dimensional structures, primarily determined by the environmental parameters upstream and downstream, has progressively been enlarged to encompass other functional dimensions: the lateral dimension (riverine-floodplain interactions), the vertical dimension (surface water-groundwater interactions), and the time dimension of the interfering multi-scaled ecological to geohistorical processes (Amaros *et al.*, 1987). We will focus here on the lateral dimension of river-floodplain systems.

The determining ecological factor of floodplains is the cycle of flooding and drying. Otherwise, the whole ecosystem with its typical floodplain forests and other types of biotopes could not exist. Floodplains are extensive amphibic ecosystems in contrast to other types of wetlands.

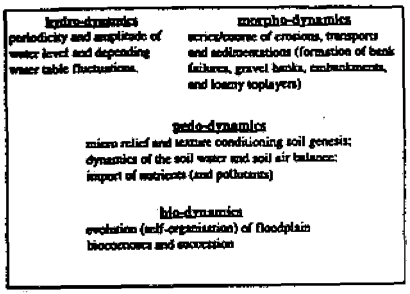


Figure 4.1: Processes of natural floodplain dynamics responsible for the variety of structures (Henrichfreise, 1988, modified in Lösing, 1994)

The periodicity and the amplitude of water level fluctuations in the reaches and the inundation area are determined by hydrodynamics, the specific water discharge regime of a river (*Figure 4.1*). Running water produces erosion, transport, and deposition, i.e., morphodynamics. Morphodynamics result in soil genesis, soil-water dynamics and soil-air diffusion, known as pedo-dynamics (including dynamics of other substances like oxygen, nutrients and pollutants; see *Chapter 3*). Lastly, hydrodynamics and morphodynamics are controlling all ecological processes. In addition, the topography of the inundation area and the conductivity of all stretches for irrigation and drifting biota are of particular importance.

4.3.2 THE ECOLOGICAL ZONATION

4.3.2.1 Landscape ecological zonation

A mosaic of structures, typical in a floodplain, arises from the combination of all processes, with varying impact from place to place. Nevertheless, the structures may be differentiated following the generally acknowledged ecological zonation (Henrichfreise, 1988):

a) Surface waters of the floodplain and river banks

Surface waters of the floodplain are subdivided according to the period of water discharge (permanently to episodically filled with water), the intensity of the current (fast flowing to stagnant) and the morphology, or form, of surface (narrow, broad and deep, shallow). River banks are subdivided by inclination (steep to

gentle slope), substratum (silt to gravel), and duration of the terrestrial and amphibian phases.

Lower zones of the floodplain (wet to moist)

b) Softwood and lower hardwood floodplain

The softwood floodplain is subdivided according to the intensity of hydro- and morphodynamics. *Dynamic* softwood exists in areas near the river with strong erosion and deposition. *Wet* softwood exists in areas distant from the river, situated on a higher level with little influence of erosion and deposition). The *lower* hardwood floodplain is differentiated by shorter duration of flooding, depending on the relief and granular fine soils.

Upper zones of the floodplain (fresh to moderate dry)

c) Upper hardwood floodplain and transition zone

The zones are differentiated first by the duration of floods, which depends on the relief. Second, the combination of fine deposits and the depth of the upper soil layer characterise the upper zones. Inundation is relatively brief but periodical in the upper hardwood floodplain. In the transition zone, inundation is brief and episodic. Due to human impact, such as embankments and dams, another zonation has to be introduced:

Active floodplains

Today, human activities divide the floodplain into two ecologically distinct areas. The sections of the original inundated areas which are situated within the embankments are the active recent floodplains. Floods, corresponding groundwater-table fluctuations, and the four dynamic processes (hydro-, morpho-, pedo- and biodynamics; see *Figure 4.1*) are responsible for their existence and variable changes, though river regulation and bed degradation, the latter mainly caused by dredging (see *Chapter 2.2*), have already altered the dynamics of the system to a certain extent.

Old floodplains (protected side of the floodplain)

The sections of the original inundated areas which are protected from floods by levees or dams are called old floodplains. They originate from natural floodplains but lack the determining factor. The influence of a fluctuating groundwater-table which corresponds to the water level of the river, although reduced, is the only one remaining. Side branch systems with stagnant water belong to this category. Geographically, these side-arms are still part of the floodplain; ecologically, they

(1) *It is inconceivable to suppose that riverine ecosystems can be maintained by diverting substantial proportions of the water discharge from the main channel into an isolated power canal. Yet Miroslav Liška, a senior Slovak engineer, said in a recent report to New Scientist (Pearce, 1994): "We have separated the navigational and commercial function of the river from its ecological function. This gives us a unique opportunity to develop this section of the river in its natural form".*

Mr. Liška simply referred to the findings of the EC Working Group of Experts in their report of 23 November 1992. See, HM, Vol. 5, Annex 14 (at p. 418).

(2) *Certain habitats are no longer available. Species adapted to these conditions (main channel with high water flow velocity) will disappear;*

"Main channel with high velocity flow": This was a specifically non-natural situation. Prior to regulation works in the 19th century, the Danube had no main channel in this region. Excessive velocity has led to bed degradation and a reduction in fauna, in particular, with regard to ichthyofauna. The limiting value for riverbed stability was the velocity of 1.3 m^3/s and pre-damming, the main channel velocity was greater than 1 m^3/s; This prevented the flourishing of macrozoobenthos (a primary source of food for fish) which, in turn, created unfavourable conditions for fish communities. See, Vol. III, p. 110:

"On the basis of studies performed during a period of 30 years by the former Institute of Fishery Research and Hydrobiology in Bratislava, reliable data on the number and biomass and partial data on fish production in this section of the Danube have been collected. In stationary, periodic waters, the ichthyomass reached an average of 260 kg per hectare, in the branches of the parapotamal type, it reached 400 kg per hectare and in the branches of plesiopotomal type, following a reduction in water area, up to 1200 kg. In similar branches near the source of pollution, there were only 60 kg and in the main channel only 35 kg of ichthyomass per hectare. The low ichthyomass of the main channel was caused by high flow velocity, shifting bottom, high turbidity and low density of food organisms."

In any event, velocity is not merely a function of discharge rates but depends on riverbed configuration and, in particular, gradient. The decrease in the velocity in the main channel has not been excessive: there has been only a decrease of around 30%.

(3) *Peak operation with huge daily fluctuation of the water level and flow velocity creates an additional burden and subsequent loss to the aquatic and littoral ecosystems (see Chapter 4.4).*

"Peak operation": Hungary once again focuses on an aspect of the Project as to which no agreed peak mode had been agreed and where Czechoslovakia had offered its pledge to limit or exclude as required by environmental considerations. These predictions of loss are in any eventnot supported by evidence.

(4) *Thus, the final outcome, a loss of local biodiversity, is unavoidable. This has already been demonstrated by every single water regulation, including the Upper Rhine barrage system or the Rhône barrage system.*

"A loss of local biodiversity": This is simply not correct. Comprehensive monitoring in the Žitný Ostrov floodplain shows no loss in biodiversity and, indeed, a gain in some areas. See, Vol. III, pp. 87 and 100. See, also, Ch. 7 re. Avifauna. Slovakia has sought to learn from the damage caused by other barrage systems.

(5) *The most regrettable fact of biodiversity losses is that they are to some extent irreversible, particularly if they are induced by physical modifications of the habitat. As opposed to chemical disturbances or pollution, physical disturbances like dams are irreversible.*

The building of the Gabčíkovo section of the Project led to an irreversible loss of some floodplain forest (although for the most part, merely areas of cultivated poplars) and agricultural land. This loss was anticipated and agreed to by the Treaty parties. There is simply no evidence to suggest that Project implementation through Variant "C" has led to losses in biodiversity - see, Vol. III, at pp. 87 and 105.

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are no longer an integral part of the floodplain system. Instead, they resemble a lacustrine environment with stagnant waters, such as lakes, marshes, and other types of wetlands.

4.3.2.2 The floodplain waterbodies

The typology of floodplain waterbodies in the Szigetköz can be summarised as follows, recognising 4 main types of functional sets (*Figures 4.2* and *4.3*):

- Eupotamon: the main channel of the river, the meandering sections and its anabranches (braided zone) with a permanent unidirectional flow. The bottom is composed of stones and gravel. There is no stratification in temperature or oxygen. There is an absence of macrophytes. Zoobenthos is dominated by rheophilic species with limited abundance and low biomass. Fish community is characterised by rheophilic species, open substratum spawning species, and little ichthyomass;
- Parapotamon: the side-arms of the braided zone are permanently connected with the main channel at their downstream ends. The flow, which is fed by both surface and groundwater, may reverse due to water level fluctuations in the main channel. The bottom is composed of gravel mixed with sand and silt. Vertical stratification of temperature and oxygen content may appear. Macrophytes are scarce but phytoplankton is abundant and rich in biomass. The fish community is rather diversified and the ichthyomass moderate;
- Plesiopotamon: permanently or temporarily stagnant waterbodies that were formerly side-arms in the braided belt. They are sometimes fed by groundwater. Their size increases or decreases according to the hydrological conditions. The bottom is silt and clay. Vertical stratification in temperature and oxygen content exists. Dense groups of macrophytes and phytoplankton are diversified and very abundant. Zoobenthos and zooplankton have a high biomass. Fish communities are mildly diversified, and ichthyomass varies from very low to very high;
- Paleopotamon: permanently stagnant waterbodies, oxbow lakes, very rarely inundated by flood. The bottom is silt and clay. There is important stratification of temperature and oxygen content. Macrophytes are very dense, and phytoplankton very sparse. The biomass of the zoobenthos is low. Fish communities have few species, and ichthyomass is rather high.

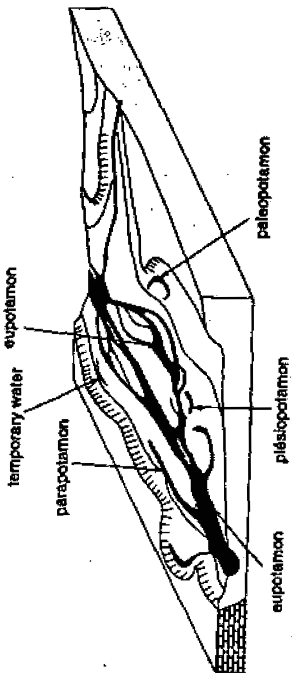

Figure 4.2: Main types of waterbodies in a natural system (schematic figure)

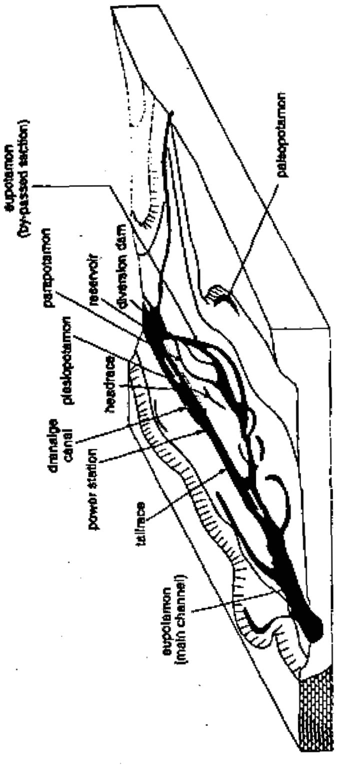

Figure 4.3: Main types of floodplain waterbodies in a regulated system

4.3.2.3 The various biocoenoses of floodplains

The following description is based on the natural morphological formations and follows *Figure 4.4*.

In surface waters, flowering plants and aquatic macrophytes, submerged or with swimming leaves, represent the vegetation. Here, the continual existence of open water is required. During average fluctuations of water levels, pioneer communities (algae and lichen) coexist with reeds on non-wooded, amphibian shores (ecotones). The water level fluctuates frequently and periodically.

On the bars and islands, bushy willow stands grow, eventually followed by willow trees and poplars, grouped in dynamic softwood riparian forests. Under typical conditions, they exist on a low level, only slightly above the average water level. The vegetation is submerged by flood water up to 5 months a year on average (in Central Europe). Under extreme climatic events, inundation occurs only 3 weeks or up to 9 months. Ashes and alders are the main species of the wet varieties of softwood and lower hardwood riparian forests. Elms and oaks dominate the more common dynamic parts of the hardwood forests. These dynamic parts are connected to the upper hardwood riparian forests on higher ground, which consist of a large variety of species, especially elms and oaks. A transition zone , usually containing deciduous forests with elms, oaks and hornbeams, is flooded only episodically or exceptionally during a few days per year. The highest elevations of the floodplains consist of a gravel substratum which carries specific vegetation communities adapted to a very dry and rather hot environment. They are called "steppe forests and meadows" along the Danube and "Heisslaende" ("hot lands") in Austria and "Brennen" ("burners") in Germany.

The most important determining factors for the vegetation are duration of inundations and the elevation of the groundwater-table during the vegetation period. It should be remarked that the zonation is not an absolute, but only a relative division based on the altitudinal levels. It is subtly diversified by the different levels, frequencies, and durations of floods; by the soil texture; and by the current. The fluvial processes of erosion and deposition interrupting the genesis of soil is responsible for the existence of softwood riparian forests on the same level as old hardwood forestlands. The appearance of many formations side by side in immediate vicinity and in different steps of succession is typical.

No especial comments.

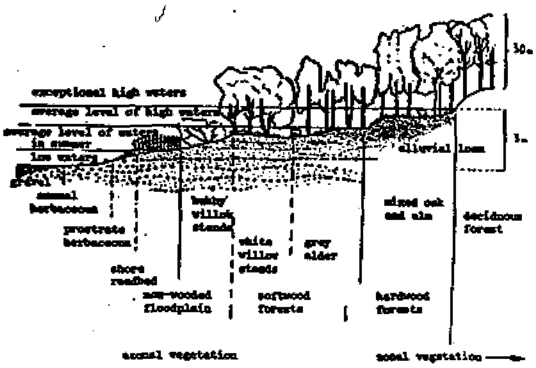

Figure 4.4: *Distribution of plant formations on a cross-section of the middle reaches of an alpine foreland river (from Ellenberg, 1976, modified in Yon and Tendron, 1981)*

In addition, rare, catastrophic events, such as ice drifts blocking the channel and causing extraordinary floods, create further formations of bare soils and rough pioneer areas on all altitudinal levels.

Furthermore, activities of animals such as beavers and ruminants (herds of wild cattle, horses and deer) create and maintain open land, leaving meadows, pastures, forest edges and brushes or beaver ponds. Man has also been part of the ecosystem since the glacial epoch, cutting trees to gain arable land, pastures and wood. Due to the large number of biotopes, the dynamics related to inundations, and the resulting various stages of plant and animal composition, the floodplain ecosystem contains the largest variety of species outside the sea and mountains (see *Chapter 4.1*). Accordingly the species have adapted uniquely to the various sections of the floodplain.

Highly specialised species are to be found in the lower zones where an excellent adaptation to extreme factors is necessary to survive. Environmental conditions

change more quickly and more often than in other systems. Thus, organisms must use pioneer strategies to settle new sites. They can reach new sites, passing large distances, either actively or passively, such as seeds which are transported by water. Many species need special sites. For instance, tamarisks and wading birds need gravel bars, and kingfishers or sand martins need the native, steep slopes of bank failures for breeding. Many willows, on the other hand, have a large spectrum of sites on which they may proliferate, if they manage to compete successfully against other woody species. Only in floodplains do they prevail since they endure long-term inundations up to 300 days/year (100-190 days/year on average). The beaver and many birds, such as the black stork and osprey, have long-range habitat demands and prefer undisturbed places for nesting on islands or in natural forests.

Fish and invertebrates depend on permeable and undisturbed migration routes to their spawning grounds, which for many may only be found in the floodplain.

4.3.3 BIOLOGICAL FUNCTIONS OF FLOODPLAINS AND RIVER-FLOODPLAIN INTERACTIONS

We try here to summarise the main biological functions of floodplains and floodplain-river interactions in order to identify the losses that are caused by alterations of river systems and to provide a scientific rationale for conservation. Four main biological functions can be identified:

- the nutrient cycle and water quality;
- the organic matter cycle and the biomass production;
- the life-cycles of aquatic species and the maintenance of communities;
- the biodiversity.

4.3.3.1 The nutrient cycle and water quality

The complexity of the processes interacting in the floodplain makes the identification of its role as source or sink for mineral nutrients difficult. Flood waters bring substantial amounts of nutrients to the floodplain. They fuel plant growth and are responsible in part for the high nutrient level of alluvial ecosystems. The uptake of these nutrients by floodplain vegetation provides a purification mechanism for the surface water of the river.

Regulation of a river and its floodplain affects the water quality mainly by changing the water temperature and the ions correlated with primary production. Reservoirs in the main channel act as thermal regulators due to the great quantity of water and the decrease in short-term and seasonal fluctuations. These reservoirs also trap nutrients and sediment, including suspended, particular organic matter.

1

The transport of nutrients, especially nitrogen and phosphorus, is often blocked in reservoirs. The physio-chemical dynamics of a regulated river are essentially controlled by the parameters of the reservoir, such as storage capacity and the position of the water outflow and by its function, such as a deep release (hypolimnial) outflow or underflow mechanism. In the Mississippi river, during low flow, some authors note autochtonous nitrogen and phosphorus inputs from side-arms and former channels to the main channel (Fremling *et al.*, 1989). During floods, the physio-chemical composition of the dead side-arms and the main channel are similar. Regulation directly influences the chemical composition of the main channel, but, according to the exchanges between this channel and the other floodplain waterbodies, the water quality of the floodplain environments will also be affected. These floodplain waterbodies will nevertheless act as refuges for the fauna of the river during disturbing events, such as chemical and toxic pollutions.

4.3.3.2 The organic matter cycle and the biomass production

Fluvial wetlands appear to be among the most productive ecosystems. Two conditions can explain this productivity. First, abundance of land-water interfaces characterise these systems; such interfaces prove to be the most productive zone along land-to-water gradients. Second, the fluctuating nature of these boundaries ("moving littoral") promote a very active mineralisation and recycling of the organic matter, resulting in a higher productivity than in more stable aquatic or terrestrial conditions (Junk *et al.*, 1989). Preliminary data on floodplain forests of the South-East coast of the United States show (Cuffney, 1988):

- the processes of the organic matter cycle enriches the riverine-floodplain environments. The floodplain introduces organic matter to the river. These inputs outweigh the primary production of the river and are of the same order as inputs from the upstream watershed. They are important because they provide a substantial food source sustaining the riverine communities;
- The floodplain also regulates the organic matter cycle. The coarse organic particles are retained by snags, slowing the losses by downstream exportation. The major release of organic matter to the river (i.e., the autumn litter) is usually postponed until the spring flood.

Research carried out on the Slovak side of the Danube floodplain also provides useful information. Numerous measurements of the phyto- and zooplankton productions in the Danube side-arms provide evidence of the very high productivity of these biotopes and their contribution to the productivity of the main channel. The biomass and primary production of the main channel are greatly influenced by the fauna (plankton, macroinvertebrates, fish juveniles) and nutrients inputted from the side-arms and former channels (Ertl, 1985 and

Vranovsky, 1974, 1985). Studies of the Upper Mississippi river and the Rhône river elaborate their roles as producers and subsequent distributors by their drift.

The fish production of the floodplain waterbodies is highly correlated to the periodic flooding. Numerous studies carried out in the braided side-arms of the Danube give figures and estimations concerning this subject. These studies show the importance of dispersion from the side-arms to the river during high waters and the subsequent shelter in former channels and lentic waterbodies for fish which did not drift (Holčik and Bastl, 1973; Holčik *et al.*, 1981 and Holčik, 1988, 1991). Parapotamic and, to a lesser extent, pleisopotamic waterbodies are of special interest in this respect. Maintaining the connection with the river is very important for production. If waterbodies are excessively isolated and sporadically flooded, their biomass and production are low. Studies of waterbodies in the Rhine and Rhône floodplains which are permanently or only temporarily connected with the river prove that higher biomass and diversity occur in permanently connected bodies (Lelek, 1989).

4.3.3.3 The life-cycles of aquatic species and the maintenance of communities

As in the case of fish, the known migration patterns of two mayfly species (*Leptophlebia cupida* in Canada and *Parameletus chelifer* in Sweden) provide clues that floodplain water in bodies connected to the main channel are vital stages in the life cycle of some invertebrate species. For these mayflies, the aquatic floodplain biotopes provide a temporary shelter from severe flow conditions in the main channel and better temperature and food which accelerates growth (Hayden and Clifford, 1974 and Olsson and Söderstrom, 1978). When the main channel returns to normal after a severe disturbance (such as floods shifting the bed sediment), side channels and temporarily inundated areas provide potential sources of organisms for the recolonisation of the main channel. This phenomenon is documented by a study of post-flood invertebrate drift in a side channel of the Durance river in France (Prevot and Prevot, 1986).

The diversity of aquatic and semi-aquatic habitats is necessary for the life cycle of numerous fish species and for refuge during disturbing events such as floods, reductions of discharge, or polluting inputs. The example of a toxic pollution of the Rhine in November 1986 can be given (Müller and Meng, 1990). The recolonisation (resettling) of the main channel by fishes was quicker than expected because many fish found shelter in the few remaining or rejuvenated side-arms and in the tributaries still connected with the channel. The periodic phenomena such as floods, low flows, or physio-chemical cycles are essential to normal, productive biological functioning of the floodplain. The necessity of these conditions can be exemplified by the migration of fish in a sector of the Morava river's floodplain.

(1) *The transport of nutrients, especially nitrogen and phosphorus, is often blocked in reservoirs. The physio-chemical dynamics of a regulated river are essentially controlled by the parameters of the reservoir, such as storage capacity and the position of the water outflow and by its function, such as a deep release (hypolimnial) outflow or underflow mechanism. In the Mississippi river, during low flow, some authors note autochtonous nitrogen and phosphorus inputs from side-arms and former channels to the main channel (Fremling et al., 1989).*

"Nitrogen and phosphorus": These elements remain suspended in the water, i.e., they cannot be blocked in the reservoir. Hungary's starting point is therefore incorrect. See, Vol. III, Ch. 2, Figs. 2.10 and 2.11, which show the absence of a deteriorating trend in the presence of nitrogen and phosporus downstream of the reservoir (at Medvedov) in comparison with the upstream section at Bratislava.

As to the retention of fine sediment that would otherwise carry nutrients into the floodplain, the impact of this in terms of the G/N Project stretch of the Danube may not be great. Data from the 1950s, that is before the isolation of the side arms and when the flooding regime was closer to natural conditions, shows only a minimal difference between supplies of humus in flooded and unflooded areas of forest. In other words, the transport of nutrients by flood waters was not overly significant in the 1950s and there is no reason to suppose that it is today.

4.3.3.4 The biodiversity

Biodiversity of benthic invertebrates in different aquatic environments

Floodplain aquatic and semi-aquatic ecosystems support rich and diverse communities. They encompass the whole range of aquatic conditions from flowing to stagnant to semi-aqustic waters. Two cases can be exemplified from the Rhône floodplain. In the first one, a parapotamic side-arm, two opposing flows enter a former channel. Upstream, water seeps into the channel from the river. Downstream, the side-arm is directly connected with the main channel, and therefore feeds the channel during low flow, whereas during floods the channel feeds the side-arm. Thus, within a two kilometre stretch of the former channel, a clear gradient from a spring to fluvial condition exists. This results in a strong gradient structure of benthic *Oligochaetes* communities with local overlapping of phreatophilous, rheophilous and lenitophilous species (Juget and Roux, 1982).

In the second case, the large amplitude of hydrological fluctuation in a set of former meanders of the Ain river, France, provides the optimal conditions for the short-term coexistence of ecologically distinct aquatic beetle assemblages (Richoux and Castella, 1986). This type of diversity can be described by the "intermediate disturbance hypothesis" (Ward and Stanford, 1983), which states that the productivity of the system and the coexistence of otherwise competitive species is enhanced by the diversity of ecosystems undergoing intermediate levels of disturbances (in this case, floods or drought conditions). A traditional example can be given of the diversity of former channel types in a floodplain sector supporting a large range of invertebrate communities in the surface water and the groundwater (Dole and Chessel, 1986). The lack of objective and comparative methods to evaluate the biological and functional diversity of floodplain systems should be emphasised. It is especially difficult to relate this parameter to different taxonomic characters or to make comparisons for different wetlands undergoing various types of human alterations. The physical factors of a regulated hydrosystem determine the ecology according to the quality, quantity, and stability of the benthic invertebrate communities. Different studies in the Missouri (Morris *et al.*, 1968 and Hesse *et al.*, 1989a, 1989b), Mississippi (Becket *et al.*, 1989), Rhône (Cogerino, 1989 and Fruget, 1991) and Volga (Mordukhai-Boltovskoi, 1979) rivers show that species diversity is greater in unembanked parts of these rivers than in embanked ones. Embankments lead to a reduced diversity of substrates (habitats), limiting biodiversity. The banks, ecotones between terrestrial and aquatic (interstitial and potamic) environments, play a very important role in the processes of colonisation. The vegetal and mineral habitats of eroding environments which are connected permanently to the river (lotic side channels, wing dykes and embankments of the main channel) have more individuals than mineral habitats of silting environments and vegetal semi-terrestrial habitats. This indicates the evolution of the waterbodies towards terrestrial stages by siltation.

Biodiversity of fish in different aquatic environments

The taxonomic diversity of fish increases from upstream to downstream as a function of the diversity of habitats, i.e., as the floodplain increases. The positive correlation between structure of fish communities and an increase in stream order is used to indicate geomorphological and hydrological changes along the longitudinal continuum. The structure of fish communities can also reflect disruptions in the hydrosystem (disappearance of backwaters and former channels, disappearance of islands and shingle-shores). This is demonstrated by examples from highly regulated rivers in the United States, such as the Missouri (Hesse *et al.*, 1989a, 1989b), Colorado (Stanford and Ward, 1986), and Tennessee (Krenkel *et al.*, 1979) rivers. In these rivers, numerous native original species have been replaced by exotic species as well as littoral and pelagic planktonophage species which usually constitute a minor part of fish assemblages in unmodified reaches. In European regulated rivers, such as the Rhône (Persat, 1988 and Fruget, 1992), Rhine (Lelek, 1989) and German-Austrian Danube (Balon *et al.*, 1986), the fish communities are dominated by some species which represent 80% or more of the absolute abundance. The structure of these communities has shifted from phytophilic (floodplain) spawners to mainly lithophilic (main channel) spawners and limnophilic *Cyprinids*, clearly indicating a lower value with respect to nature conservancy. Thus, the species diversity of fish is closely correlated to habitat complexity. The more diversified and accessible the aquatic and semi-aquatic areas are, the more variable is the structure of communities and the more diverse the species. The same principle applies to the benthic invertebrates.

4.3.4 CONCLUSION

Fluvial wetlands and floodplain waterbodies are generally more productive than the running water of the main channel. When floodplain habitats are connected to the river, a major part of the organic matter is washed out into the running water, providing food for the benthic invertebrates and the river fish. These connected habitats are also used as spawning areas and nurseries as well as a refuge during high spates or accidental pollutions of the main river by numerous fish species from the river.

However, floodplain waterbodies and wetlands are processed by natural phenomena (ecological successions, eutrophication, siltation) which transform them into terrestrial habitats in a more or less short term sense (from several decades to a few centuries). The connections between floodplain environments and the main river also experience temporal changes. Seasonal and annual fluctuations on the connection with the main channel depend on the water level of the river as well as the morphology of the channels, alluvial plugs and bank levees. On longer time-scales, changes of the degree of connection result from human impacts as well as natural processes (ecological successions, siltation). Some of these processes are reversible, naturally or artificially. The process would be naturally

reversed if the fluvial dynamics (lateral erosion) can reset the ecological successions and reconnect the former channels to the river. The connections could also be artificially restored (restoration concept). Considering the functional dependency of the diverse habitats of river floodplains and their ability to restore themselves, any environmental management scheme should take into account the different spatial dimensions of the fluvial hydrosystem (running to stagnant waterbodies, wetlands, terrestrial biotopes, underground alluvial biotopes) as well as the temporal dimension (genesis of the diverse biotopes, successional processes, changes in connectivity). To be applied, these dimensions must be quantified.

4.4 IMPACTS OF THE ORIGINAL PROJECT

by Joachim Lösing and Albert Roux

4.4.1 CONSTRUCTION

In order to avoid repetition, the effects will be separated into short-term and long-term impacts, the latter being evaluated in the operation section. Nevertheless, all impacts will be discussed in *Chapter 4.4.2.*

4.4.1.1 Dunakiliti-Hrušov Reservoir

The Dunakiliti-Hrušov Reservoir was envisaged with a size of approximately 60 square kilometres, including the head race canal. This element of the Original Project has already been realised. All the aquatic and floodplain structures except the main channel have been destroyed by gravel excavation, construction of the dyke and the canal or by other measures; all forests have been cleared, and all other vegetation has been removed within about 6,000 hectares.

The Original Plans had counted on taking about 6 months to fill the Dunakiliti Reservoir, while the waters on the floodplain and on the protected side branches downstream in the Szigetköz would have received a continuous water supply. However the riverine and floodplain ecosystem needs much more time to adapt, despite the fact that this type of ecosystem is able to react faster than other types (like beech forests and other zonal systems; cf. Lösing, 1994), utilising inherent means of reproduction after catastrophic events.

4.4.1.2 The Szigetköz

1

Under natural conditions those catastrophic events, mentioned above, are very rare and do not affect a complete ecosystem, such as the Szigetköz with about 375 square kilometres, not to mention the area of the Slovak Žitný Ostrov. In addition,

there are usually undisturbed areas upstream and downstream where any form of re-population can start from. In this case, however, the section of the Szigetköz would have been locked as an isolated island between the impoundments of Dunakiliti and Nagymaros, developing lacustrine rather than riverine biotopes.

2

Because of the long history of river training and works in advance of the project, some of the anticipated damage has already occurred. Due to extensive gravel dredging around Bratislava the riverbed of the main channel had degraded drastically (see *Chapter 2.2*). The corresponding groundwater-table had dropped as well.

3

As a result of the relatively fast filling of the upper reservoir which was envisaged, all the vegetation types in the Szigetköz, influenced by the groundwater, would have been damaged by the extraordinary water shortage. For the vegetation as well as the fauna depending on it, the water regime of the surface soil-layer in combination with the floods is the most fundamental factor (Lösing, 1994). The drop of groundwater-tables together with reduced inundations would have caused severe problems in the water balance of the plants. Specifically, these changes would have threatened the softwood riparian forests of willow and poplar in this area (Mészáros *et al.*, 1993). Willow woods "used to give a nearly continuous cover on the islands of the Szigetköz-Danube labyrinth until the 1920s" (Simon *et al.*, 1993). Partially they had to give way to the timber plantations, mainly in the central parts of the islands. Nevertheless, the remaining woods indicated in 1991 were still in "better conditions than indicated by data collected by Kárpáti in the 1950s from willow woods outside the Szigetköz" (Simon *et al.*, 1993).

4

4.4.1.3 The Nagymaros Reservoir and its downstream section

5

The 123 km-long reservoir, including the Danube Valley upstream of Nagymaros, would have radically changed ecological conditions. This section of the Original Project would have required the reinforcement and extension of dykes along both banks of the Danube to contain the water fluctuations resulting from peak power operation. The construction of the reservoir levees would have wiped out the dry meadows on top of the previous dykes as well as parts of the narrow strip of recent, active floodplains within the embankment.

6

The intended lowering of the riverbed downstream of Nagymaros would have degraded the riverbed by 0.60-1.20 m on average (see *Chapter 2.3*). Considering the findings of the MaB[1] ecosystem study at Altenwörth, Austria (Hary and Nachtnebel, 1989 and Lösing, 1994), the corresponding drop of water levels by only about 0.50 m caused already negative effects to the vegetation of that particular stretch of the Austrian Danube. Similar impacts are to be expected at this section of the project.

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[1] Man-and-Biosphere program of the UNESCO

(1) *Under natural conditions those catastrophic events, mentioned above, are very rare and do not affect a complete ecosystem, such as the Szigetköz with about 375 square kilometres, not to mention the area of the Slovak Žitný Ostrov.*

"Catastrophic events": The planned diversion of the Danube's waters at Dunakiliti cannot be considered a catastrophic event. Flow was to be maintained in the old Danube and, if the offtake in the Dunakiliti weir were correctly utilised, there would be no drops in groundwater levels in Szigetkőz and no irremediable impact, let alone catastrophe.

The manner in which the damming of the Danube actually occurred (in putting into operation Variant "C") was the result of Hungary's refusal to cooperate.

"A complete ecosystem": The Szigetkőz does not constitute a complete ecosystem, but rather contains multiple ecosystems - from floodplain to cultivated woodland to heavily agricultural.

(2) *Because of the long history of river training and works in advance of the project, some of the anticipated damage has already occurred. Due to extensive gravel dredging around Bratislava the riverbed of the main channel had degraded drastically (see Chapter 2.2). The corresponding groundwater-table had dropped as well.*

"Extensive gravel dredging around Bratislava": Bed degradation has many causes, of which dredging at Bratislava for flood protection, navigation and commercial reasons is only one. Hungary is also responsible for gravel dredging in the Szigetkőz stretch, of course. See, Comments to "Scientific Evaluation", Ch. 2, above. The most extensive gravel dredging, with the most adverse effects, has been around Budapest - carried out solely by Hungary.

(3) *As a result of the relatively fast filling of the upper reservoir which was envisaged, all the vegetation types in the Szigetköz, influenced by the groundwater, would have been damaged by the extraordinary water shortage.*

This conclusion totally ignores the facts concerning the putting into operation of the Gabčíkovo section. The filling of the reservoir was to take six months - an amount of time that allowed the implementation of the Dunakiliti offtake. This was both well known and agreed in advance. No extraordinary water shortage would exist. The flow into the old Danube was to be reduced, not stopped, and flow into the Szigetkőz side arms was to be increased, in relation to the pre-dam conditions, through utilisation of the Dunakiliti offtake.

(4) *Specifically, these changes would have threatened the softwood riparian forests of willow and poplar in this area (Mészáros et al., 1993). Willow woods "used to give a nearly continuous cover on the islands of the Szigetköz-Danube labyrinth until the 1920s" (Simon et al., 1993). Partially they had to give way to the timber plantations, mainly in the central parts of the islands. Nevertheless, the remaining woods indicated in 1991 were still in "better conditions than indicated by data collected by Kárpáti in the 1950s from willow woods outside the Szigetköz" (Simon et al., 1993).*

"Softwood riparian forests of willow": References to the abundant willow woods in the 1920s are totally misleading. Hungary admits (at "Scientific Evaluation", p. 183) that 64% of the trees in the active floodplain are now a cultivated hybrid poplar, replacing the former floodplain species. There is little willow forest left as a result of Hungary's

forestation policy, aimed at commercial production, that had its impact long before the inception of the G/N Project.

In this respect, Hungary's use of the word "partially" disguises an important ecological fact. In addition, due to the increase of flows into the Mosoni Danube and the Zatonyi Danube (exclusively on Hungarian territory and exclusively due to Variant "C"), conditions for riparian willows have greatly improved in the areas nourished by these branches.

(5) The 123 km-long reservoir, including the Danube Valley upstream of Nagymaros, would have radically changed ecological conditions.

This is a reference to the upstream "reservoir" that the Nagymaros weir would have credited in the Danube. Here, ecological conditions would have "radically changed" only in a very narrow strip within the existing flood dykes - from 1-100 metres wide - alongside the Danube - a strip of minimal importance, not affecting the Danube Valley ecologically or aesthetically. There would have been some changes in groundwater levels outside the floodplain dykes, but protection measures were designed (and largely built) to counter this. Simply, waters would be restricted within the <u>existing</u> dykes: impact would therefore have been far less than the construction of a major road, for example.

(6) The intended lowering of the riverbed downstream of Nagymaros would have degraded the riverbed by 0.60-1.20 m on average (see Chapter 2.3). Considering the findings of the MaB [Man-and-Biosphere program of the UNESCO] ecosystem study at Altenwörth, Austria (Hary and Nachtnebel, 1989 and Lösing, 1994), the corresponding drop of water levels by only about 0.50 m caused already negative effects to the vegetation of that particular stretch of the Austrian Danube. Similar impacts are to be expected at this section of the project.

It makes no sense to refer to the "intended lowering". Hungary has already caused the lowering of the riverbed below Nagymaros by its excessive commercial dredging (dredging more than 3 times what was intended for the Project). No further lowering would have resulted from the G/N Project.

please turn to next page

4.4.2 OPERATION

4.4.2.1 General impacts on the aquatic biotopes

According to Holčik *et al.* (1981), the waters in the entire section affected by the scheme covered about 7,937 hectares prior to the construction.[2] The bands, delimited by the water-level variations (the ecotone of the littoral zone), extended over approximately 671 hectares. The surfaces between the littoral zones (the medial zones) covered 7,266 hectares. None of these areas would have remained in their previous condition since hydrologic parameters would have changed everywhere.

1 The benthos communities of the riverbed would have been destroyed in all the sections where the bed would had been deepened by dredging or other measures, such as the construction of dams, coffer dams, dykes or "underwater weirs". The reduced discharge by the upper reservoir during the filling would have caused further damage to the other aquatic biotopes suffering from water shortage as a result of the induced riverbed erosion.

2 Those detrimental effects have been mentioned by the Slovak hydrobiologist Holčik and contributors (1981):

> "We may now conclude by stating that after the completion of the GNRBS project, the entire Danube section stretching between Bratislava and Nagymaros will have only a minimum biological importance, and moreover the fish populations of both the lower and upper Danube sections can be expected to show considerable decreases. The principal negative influence of the GNRBS is that the conception of the project with a diversion canal eliminates the very floodplain which, together with the arm systems, makes up the productive base of this region and also acts a sort of biocenotic centre as well, which determines to a considerable extent the population of the main channel by all aquatic organisms."

4.4.2.2 Dunakiliti-Hrušov Reservoir

In the upper reservoir the benthic biomass would have been about 30 times higher compared to the previous conditions in the main channel, primarily *Oligochaetes* (Holčik *et al.*, 1981).

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[2] This figure given by Holčik *et al.* (1981) is probably far too low. It would just account for the Danube itself between Bratislava (rkm 1870) and Budapest (rkm 1650) considering an average width of 360 m. Thus the side branches on both sides of the river are not included.

3 Several million tons of sediment per year were expected to be deposited in the reservoir (see *Chapter 2.2*). These sediments play an important role in the functioning of the natural, undisturbed ecosystem by silting up in the floodplain, providing it with nutrients and producing physical stress to the plants. Above that, this sedimentation induces the growth of the typical species, adapted to these conditions, and prevents other species from settling in this area. By retaining the sediment in the reservoir, this abiotic element would be reduced significantly. 4 Similar results would have occurred in the riparian ecotones downstream of the Nagymaros barrage.

4.4.2.3 The Szigetköz

5 The annual average discharge of the Danube was approximately 2,000 m^3/s. Under the Joint Contractual Plan, this was to be reduced to 50 m^3/s. It was envisaged to release up to 200 m^3/s discharge in case of necessity during the growth season without further specifications. Reductions of this order (85-97% of average flow) would have lowered the surface water level, reduced the areal extent of surface water and thus caused a drastic decrease of the groundwater-table. The levels were expected to drop by up to 3 metres, especially in the central part of the Szigetköz. A smaller but still very significant drop in the groundwater level of up to 2 m was forecast for the protected area outside the dyke system.

6 According to the Original Project, which did not entail mitigation measures at its conception, the bed of the Old Danube and the Slovak and Hungarian side-arms would have lost approximately 58% of its aquatic habitats, a total of 1,085 hectares (Holčik *et al.*, 1981).

For the fish fauna three general changes have been predicted (Holčik *et al.*, 1981):

- changes of the species composition;
- disappearance of more sensitive species (like *Salmonids*);
- replacing by species of lower sensitivity (*Cyprinids* like Roach and Chub).

7 Similar developments could be expected for the whole flora and fauna. Hence a considerable deterioration of the natural value of the Szigetköz would occur.

Silty sites and banks

The aquatic macrophytes, the moss cover on the gravel, as well as the riparian plant communities living on silty sites, and the willow brush would become extinct in the entire affected area. Once exposed to the air by the radical drop of the water levels, they would have been completely eliminated within a short period. The

general decline of the water level would have resulted in the rapid expansion of weed communities. This is particularly striking in the main channel in the Szigetköz (Mészáros *et al.*, 1994a).

Interruptions of connections

8 As a result of the diversion into the bypass canal, the connection between the previous main channel and the branch system in the recent, active floodplain would have for the most part ceased to exist. The diversity of this braided zone was the most important conservational factor for the survival of several species in the main channel. Therefore, the diurnal and seasonal migrations between these two parts of the aquatic system in the upper section of the Szigetköz would have stopped. This fact would cause a decline in the populations, particularly in the long term (Mészáros *et al.*, 1994a).

The old floodplain (the protected side) in the Szigetköz

9 The decline or gradual disappearance of the populations in the oxbow lakes, canals and ponds would have been more rapid than in the active floodplain inside the inundation dykes, because the artificial water supply would have been even less effective in these biotopes. As a direct result of the diversion, the water would have practically disappeared in the oxbow lakes. Therefore, their fish fauna would mostly have been killed out. The chance for a natural repopulation would have been minimal (Mészáros *et al.*, 1994a).

Experiences of ecological impacts at the Upper Rhine

Fundamental changes in the area of project would be expected in all the riparian forests and vegetation, except perhaps those small elevations with steppe forests which have not been inundated (at least not in recent decades). 10 Many floodplain ecosystems of other rivers have experienced similar damage and destruction caused by river regulation and waterpower development. The example of the Upper Rhine between Basel, Switzerland, and Rastatt, Germany, is appropriate, especially as it was used to show the environmental benefits of the Gabčikovo-Nagymaros Project.

At the Upper Rhine three steps of river training have been carried out since the beginning of last century (see *Plate 3, Volume 1*). Every stage of the regulation works was accompanied by unexpected, serious, adverse effects which were meant to be corrected with the next measure; nevertheless, other economic and ecological

damage occurred.[3] Therefore, France and Germany decided to break the vicious circle of correcting the negative impacts of a barrage by building another one further downstream and opted for a small-scale solution with the controlled addition of riverbed material (see *Chapter 2.6.1*). Furthermore, about 10 years ago a large programme was started at the Upper Rhine to restore floodplain habitats which were damaged or lost by the implementation of the Upper Rhine barrage system. The programme combines flood protection measures with ecological restoration and is called "Integrated Rhine Program" (LfU, 1994 and RP Karlsruhe and Freiburg, 1990).

11 The impacts of hydropower development at the Upper Rhine were disastrous for flora and fauna. At parts of the 70 km section of the full diversion, 81% of the alluvial forests were devastated or dead. In the section partially diverted only some typical vegetation and their fauna survived within the inundation dykes though with considerable change in composition of species. In the section of river barrages (phase 3 on *Plate 3, Volume 1*), the entire floodplain ecosystem was excluded from floods. Most of the vegetation (85%) changed from being typical and adapted to the ecological conditions of a floodplain to being unadapted and uninfluenced by groundwater. In none of the regulated sections of the Rhine[4] could the natural unique vegetation and wildlife be preserved. The new communities are significantly less valuable from the ecological and conservational point of view (Hügin, 1980, 1981; Dister *et al.*, 1990; Hügin and Henrichfreise, 1992 and Lösing, 1994).

At the Upper Rhine, the predominant plant communities of the lower and upper hardwood riparian forests, belonging to the elm-ash-oak forests (*Querco-Ulmetum minoris* Issl. 24), are replaced by those of the oldest and uppermost levels of the floodplain, belonging to the oak-hornbeam forests (*Carpinion betuli* Issl. 31 em. Oberd. 57) and no longer being influenced by groundwater. The influence of floods has become negligible as well. Due to the long life-cycle of woody species, the conversion of the forests is still in process, but the characteristic species of the herb layer have manifested the change.

Predictable changes in the Szigetköz

12 The impacts of the Original Project on the wetland habitats of the Szigetköz would be quite similar, though their species composition is slightly different (*Figure 4.5*).

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[3] Similar effects have been observed for example at the Rhône river (Fruget, 1992).

[4] (the sections of full and partial diversion as well as the section of barrages)

(1) *The benthos communities of the riverbed would have been destroyed in all the sections where the bed would had been deepened by dredging or other measures, such as the construction of dams, coffer dams, dykes or "underwater weirs". The reduced discharge by the upper reservoir during the filling would have caused further damage to the other aquatic biotopes suffering from water shortage as a result of the induced riverbed erosion.*

It is confusing to write of destruction in relation to short term impacts. Clearly, as for any development, actual construction work will cause disruption and some destruction of individual communities. But these impacts are temporary, as destroyed communities would very soon be replaced. It is in any event futile to write as if dredging was not a regular activity for both Hungary and Czechoslovakia and as if construction work had not actually been carried out.

The underwater weirs would improve conditions for benthos communities and ichthyofauna. See, Vol. III, Chs. 5 and 6.

The reference to reduced discharge by the reservoir is not understood. The filling of the reservoir would have had no impact on the supply of the agreed Project discharge to the old Danube.

"Induced riverbed erosion": There is no factual basis for this concept - see, Comments to "Scientific Evaluation" Ch. 2, above and, also, EC Working Group report of 3 November 1993, HM, Vol. 5, Annex 18, which predicted: "No major net erosion and sedimentation in the Old Danube".

(2) *Those detrimental effects have been mentioned by the Slovak hydrobiologist Holčík and contributors (1981):*

Hungary relies heavily on a 1981 report by Holčík. This report had importance in 1981 but its findings are based on an assumed discharge of just 50m^3/s into the old Danube and no direct discharge into the side arms. Thus its conclusions are only of historical relevance because the principal findings have already been taken into account. The Project has been revised - in terms of direct recharge into the side arms, increased flows into the Danube, underwater weirs etc. There is now sufficient water in the side arm system for optimal conditions for fish reproduction and growth to be created.

(3) *Several million tons of sediment per year were expected to be deposited in the reservoir (see Chapter 2.2).*

Chapter 2.2 makes no such prediction (nor any prediction at all). In any event, it is undeniable that very substantial amounts of sediment are caught in the 24 dams upstream of Bratislava and that sediment reaching Bratislava will be further reduced by the completion of the Austrian dam at Freudenau, close to the Slovak border.

(4) *Similar results would have occurred in the riparian ecotones downstream of the Nagymaros barrage.*

There can be no scientific basis to the claim of "similar results" when the "riparian ecotones" downstream of Nagymaros are wholly different from those in Szigetköz - there is an active floodplain in Szigetköz but none below Nagymaros. In fact, insofar as sediment was reduced, this might favour the quality of water in the bank filtered wells supplying Budapest - see, pp. 106-114 of the "Scientific Evaluation" concerning the adverse impact of sediment deposition close to these wells.

Note that there has been a slight <u>increase</u> in the water quality of the Danube since the implementation of Variant "C". <u>See</u>, Vol. III, pp. 15 and 24.

(5) *The annual average discharge of the Danube was approximately 2,000 m^3/s. Under the Joint Contractual Plan, this was to be reduced to 50 m^3/s. It was envisaged to release up to 200 m^3/s discharge in case of necessity during the growth season without further specifications. Reductions of this order (85-97% of average flow) would have lowered the surface water level, reduced the areal extent of surface water and thus caused a drastic decrease of the groundwater-table. The levels were expected to drop by up to 3 metres, especially in the central part of the Szigetköz. A smaller but still very significant drop in the groundwater level of up to 2 m was forecast for the protected area outside the dyke system.*

Hungary relies once more on its formulation of the "Original Project", without taking into account all the remedial measures incorporated to mitigate environmental impact, in order to concoct a scenario of the "drastic" effects of the Project. Hungary's "Original Project" provides no basis for an accurate assessment of Project impact in 1989-1992.

(6) *According to the Original Project, which did not entail mitigation measures at its conception, the bed of the Old Danube and the Slovak and Hungarian side-arms would have lost approximately 58% of its aquatic habitats, a total of 1,085 hectares (Holčík et al., 1981).*

Slovakia fails to see the relevance of this examination of the "Original Project" without the "mitigation measures" that were later conceived - in part as a result of Holčík's 1981 research.

(7) *Similar developments could be expected for the whole flora and fauna. Hence a considerable deterioration of the natural value of the Szigetköz would occur.*

There is absolutely no scientific basis for the application of a 1981 conclusion relating to the impact of the "Original Project" on <u>fish</u> alone, so as to make predictions as to adverse impact to the whole flora and fauna of a particular region.

(8) *As a result of the diversion into the bypass canal, the connection between the previous main channel and the branch system in the recent, active floodplain would have for the most part ceased to exist.*

This is misleading. In the pre-dam state, an almost full interconnection existed between the side arm system and the main channel for only 17 days per year. This was due to two reasons: the physical dyking off of the side arms where they once linked into the main channel; and the sinking of the water level in the main channel. Due to the transfer of navigation into the bypass canal, both these causes may be dealt with. The side arms may be reconnected by excavation of the old dykes; and the water level in the old Danube may be raised by constructing underwater weirs. This would depend on the will of Hungary. But Slovakia aims to see the restoration of the interconnection between the side arms and the main channel.

(9) *The decline or gradual disappearance of the populations in the oxbow lakes, canals and ponds would have been more rapid than in the active floodplain inside the inundation dykes, because the artifical water supply would have been even less effective in these biotopes.*

This is incorrect. The level of ground water in the old floodplain (that is, the area dyked off from flooding since the 19th Century) is linked to the level of groundwater in the active floodplain. Direct water supply into the Slovak side arms has ensured groundwater <u>increase</u> to 1960s levels both within and outside its floodplain dykes. <u>See</u>, Vol. III, at p.

12. This would have occurred on Hungarian territory also, had Hungary not abandoned the Project, aided by the large increase of the flow into the Mosoni Danube under Variant "C", which has had a favourable impact on ground water levels.

(10) Many floodplain ecosystems of other rivers have experienced similar damage and destruction caused by river regulation and waterpower development.

Hungary continually emphasises the difference between the G/N Project and other dam projects - except where it is convenient to draw a parallel. In terms of its capacity to sustain environmental needs, the Gabčíkovo section of the G/N Project is entirely different from other schemes - because of the remedial measures that have been incorporated in the light of advances in knowledge of environmental impacts, but also as a result of the original design. The transfer of international navigation into the bypass canal and away from the floodplain enables the old Danube and its floodplain to be developed more naturally. See, the EC Working Group report of 23 November 1992. HM, Vol. 5 (II), Annex 14 (at p. 418).

(11) The impacts of hydropower development at the Upper Rhine were disastrous for flora and fauna. At parts of the 70 km section of the full diversion, 81% of the alluvial forests were devastated or dead.

The hydropower projects on the Rhine are very different because the canalisation took place in the actual floodplain itself. The situations are very different.

(12) The impacts of the Original Project on the wetland habitats of the Szigetköz would be quite similar, though their species composition is slightly different (Figure 4.5).

Such alleged impacts of the "Original Project", disregarding the remedial measures that were developed, are once again not relevant to Hungary's claims of ecological necessity in 1989 or 1992, made in relation to a developed and developing Project.

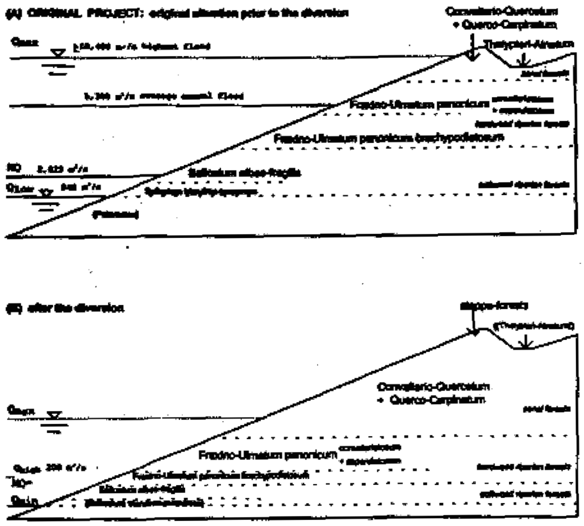

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Figure 4.5: Impacts of the Original Project on the natural vegetation of the Szigetköz.

*The schematic cross-section without scale shows the (simplified) natural potential vegetation (cf. Kárpáti and Kárpáti, 1991) and the predictable reduction of its areas (highest flood 1954 at Bratislava; MQ: average flows; Q_{low}: average low flow; Q_{high}: allowed occasional high discharge = 200 m³/s; Q_{min}: lowest flow = 50 m³/s). The shrubby association of Almond-leaved and Purple Willow (*Salicetum triandrae-purpureae*) on the banks will decrease drastically due to the reduced morphological dynamics in the main channel. All the other associations will shrink to much smaller areas and lower levels due to the reduced inundation. The species composition of all, even of the oak forests (*Convallario-Quercetum*) and the oak-hornbeam forests (*Querco-Carpinetum*) in its lower levels, will modify. However, the latter will not achieve full diversity because the sparse floods will prevent the establishment of their zonal elements, i.e. species which do not endure inundation at all.*

Older forests on small topsoil layers or with previous seasonal groundwater supply would recede, younger ones would reduce their leaf area if the abiotic conditions were not too extreme (cf. Hary and Nachtnebel, 1989). Rejuvenation would stop just as dynamics do. Instead, as a sign of degradation, other communities would

spread out in periodically or permanently wet depressions such as swamp forests of the *Thelypteri-Alnetum* (with black alder) which are typical for areas far away from the main channel at the edge of the floodplain. However, most of their former stands would die. The aquatic macrophytes (class of *Potametea*) would suffer from the vanishing surface waters in the side branches being scarcely scattered in the main channel anyway.

In addition, large parts of the floodplain would lose its occasional contact with groundwater since the maximum level of floods will decrease considerably (see *Chapter 3*).

Another indicator emphasises the degradation. The grey alder (*Alnus incana*) is a typical tree of subalpine rivers preferring initial stages and raw soils, mostly on gravel banks. These pioneer phases had become rare because of the reduced morpho-dynamics and so did *Alnus incana* (Simon *et al.*, 1993). Almost the same happened at the Upper Rhine about 100 years earlier when Tulla's rectification works forced the river to flow in a new straightened bed. The 3,448 islands and the numerous branches of the braided zone between Basel and Strasbourg vanished and the new channel degraded by up to 4 metres until 1900 (cf. Lösing, 1994). Today only a few patches with some specimen of *Alnus incana* are still present in the floodplains of the Upper Rhine. They have been decreasing continuously since the last century. This example shows how slowly the change, especially in the composition of tree species, actually takes place.

2

However, 64% of the vegetation in the active floodplain of the Szigetköz indicated a near-natural status (Simon, 1992) before the real implementation of Variant C and the resulting desiccation of the upper and middle Szigetköz. Regarding the whole Szigetköz area of approximately 37,500 hectares, about 25% was covered by near-natural or semi-cultivated plant associations such as forests, poplar and willow woods, aquatic vegetation, marshes and pastures. Although they were planted on most of the sites, the poplar and willow stands are regarded as near-natural associations because they accommodate floodplain elements and even some montane elements (Mészáros *et al.*, 1993).

3

The anticipated impacts of the Original Project influencing the ecosystem of the Szigetköz can be summarised as follows (cf. Mészáros *et al.*, 1994a):

- a drastic reduction of the discharge in the main channel of the Old Danube;
- significant changes in the groundwater levels (primarily its decline);
- floods fail to enter the floodplain except at a discharge ≥ 6,500-7,500 m³/s (the Old Danube receives additional discharges above 4,000 m³/s only);

- the floods actually entering the floodplain and the almost desiccated main channel arrive in an extremely short time and with high velocity;
- daily fluctuations of several metres in the water level with inverse flow directions, primarily in the middle and lower reaches, as a result of peak-operation at Gabčíkovo.

4.4.2.4 The Nagymaros Reservoir and its downstream section

4

With the implementation of the Original Project, approximately 20 islands, peninsulas and large parts of the shoreline would have been submerged. The narrow but active floodplain would have been destroyed completely.

Peak power operation

The shores being the ecotone of the moving littoral (Junk *et al.*, 1989) would have been attacked by daily water level fluctuation of 1-4 m, depending on the location in the reservoir. Additional rip-rap would also have hindered the settlement of vascular plants. In a word both strips of daily inundation would have been free of vegetation – a devastated belt.

Such bare bands are well-known from the shores of pumped storage lakes, high dams and upland reservoirs although they are usually induced not by daily but by periodical alternations. Peak-power operation at the Greek river, Arachthos, near Arta, resulted in severe damage of the banks and the devastation of the formerly braided, nearly unregulated river bed. 5

General impacts of peak power operation on aquatic habitats

6

Peaking flow operation is the most harmful mode of operation for two main reasons: the initial surge of water released into the tailwater during start up of the turbines, and the highly fluctuating water levels in the tailwater. The surge period is a highly turbulent one. Very rapid changes occur in depth and velocity. The surge scours the rare macrophytes, the periphyton, the invertebrates, juvenile fish, and it disorients adult fish. The sudden changes in flow can exceed the rate of reaction of animals and some are stranded at low flows. Others are entrained by high flows. Highly fluctuating water levels include "fluctuating zones" in the tailwater unsuitable either for terrestrial or (especially) aquatic organisms. Terrestrial or aquatic macrophytes simply cannot develop. Very few specialised benthic invertebrates are able to survive in these zones, particularly *Oligochaetes* and *Chironomids*. Spawning sites and nursery zones for fish cannot exist; embryos and juveniles of fishes cannot survive. Even if they are drifting from side-arms or other tributaries, they will be washed out by the next surge or they will die from desiccation or rapid changes in temperature.

Peaking hydropower also modifies drastically the substrate of the channel; near the dam, erosion increases and further downstream sedimentation rates increase (see *Chapter 2.3.2*). Consequently those processes affect the aquatic habitats and the organisms not only in the immediate zone downstream of the dam but much farther by deposition.

4.5 IMPACTS OF VARIANT C

by Joachim Lösing and Albert Roux

7

In general, the ecological effects of Variant C are expected to be similar to those outlined above for the Original Project. Thus, this section will focus on differences in impact and observed effects while considering the implications of Variant C structures and operation.

4.5.1 ČUNOVO RESERVOIR

8

Approximately 4,500 ha of alluvial forests are seized. The predicted forecasts of what will occur have been discussed in the previous sections and in Chapters 2 and 3.

4.5.2 THE SZIGETKÖZ

9

Shortly after the diversion, the main channel and its side branches were left practically without water. The water level decreased by 3.0 metres at rkm 1850 and by 2.4 metres at rkm 1825 in less than 4 days. The width of the Old Danube narrowed by 55 metres on average. This abrupt change had a severe impact on living communities in this region, especially on fish and other aquatic biota as well as softwood trees.

Aquatic habitats

The diversion of Danube water into the power canal induced not only a lowering of the water level in the main channel but affected all the waterbodies of the floodplain (*Plate 4.2, Volume 5*). Comparing the present situation with pre-dam conditions, the loss of habitat diversity and consequently the loss of biodiversity appears clearly. The most harmful effect is the complete drying of some paleopotamic milieux like the Lipót area. The disappearance of most of the parapotamic waterbodies is to be emphasised. Indeed, these arms which are permanently connected with the main channel and fed by both surface and groundwater present the most important diversity of aquatic habitats and consequently the highest biodiversity. It is not surprising that these parapotamic

(1) *Figure 4.5: Impacts of the Original Project on the natural vegetation of the Szigetköz.*

This discussion of impacts of the "Original Project", i.e., without the remedial measures that developed, is obviously based on incorrect data, as already pointed out. See, also, Comment 2 below.

(2) *However, 64% of the vegetation in the active floodplain of the Szigetköz indicated a near-natural status (Simon, 1992) before the real implementation of Variant C and the resulting desiccation of the upper and middle Szigetköz. Regarding the whole Szigetköz area of approximately 37,500 hectares, about 25% was covered by near-natural or semi-cultivated plant associations such as forests, poplar and willow woods, aquatic vegetation, marshes and pastures. Although they were planted on most of the sites, the poplar and willow stands are regarded as near-natural associations because they accommodate floodplain elements and even some montane elements (Mészáros et al., 1993).*

The "natural vegetation of the Szigetköz", referred to above, is here explained. In the active floodplain, it is claimed by Hungary that 64% of vegetation is "near-natural". Careful attention must be given to what this means in the light of Hungary's reference to "natural vegetation". It means that 36% of vegetation is not natural at all even in the active floodplain. As to the 64% which is "near-natural", this means "planted" by humans i.e., cultivated. According to Hungary, in the whole of Szigetköz, there is no "natural vegetation" but only "near-natural or semi-cultivated", which covers 25% of the area. Again, this appears to mean that the vegetation was planted.

(3) *The anticipated impacts of the Original Project influencing the ecosystem of the Szigetköz can be summarised as follows (cf. Mészáros et al., 1994a):*

Once again, Hungary analyses the impacts of the "Original Project" without its remedial measures. At Vol. III, Ch. 4, Slovak scientists examine the impact of the Project on the flora and vegetation on the Slovak side of the Danube, with particular reference to the actual impacts of Variant "C". Their conclusion (at Vol. III, p. 87) is quoted in full:

"The authors of this study do not deny the negative consequences of the Gabčíkovo-Nagymaros Project, such as the removal of floodplain and other forest to the extent of 3,267 hectares on the Slovak side, the synecological changes in the draining section under the Hrušov reservoir and in the narrow stretch alongside the Danube riverbed. But these may be solved by suitable management (e.g., by plantation of cultivar poplars by depth planting).

As to plant biodiversity, there is no proof as to the lowering of the phytogenofund from the experience of two or more years since the damming. To the contrary, new biotopes may appear as a result of the water recharge into the side arm system in the inundation area (Dobrohošť - Palkovičovo) and in the huge limozic and littoral zone around the Hrušov reservoir, leading to a presumption in the favour of increased biodiversity.

In connection with the prediction of expected changes, it is possible to turn to the past 100 years of the Danube river. For, during this period of construction of the protection dykes, all ecosystems became adapted to the changed conditions. It is therefore possible to predict a similar adaptation to these new conditions.

Our experience since the end of the 1950s leads us to conclude that due to the decrease of water flows in the side arm system following the regulation of the Danube riverbed, the retention of sediments in the Austrian and German stretch of the Danube and the continuing trend of the

Danube riverbed towards erosion, the floodplain forests would eventually have disappeared on the Slovak side of the Danube river. The Gabčíkovo Project and Variant "C" have prevented this regression."

(4) *With the implementation of the Original Project, approximately 20 islands, peninsulas and large parts of the shoreline would have been submerged. The narrow but active floodplain would have been destroyed completely.*

Not only is such a loss small from an environmental stand point, it was understood and agreed by the Treaty parties as an acceptable consequence of the Project. Where water is impounded behind a dam so that its level rises, it is self-evident that certain areas of land will be submerged.

(5) *Peak-power operation at the Greek river, Arachthos, near Arta, resulted in severe damage of the banks and the devastation of the formerly braided, nearly unregulated river bed.*

This is wholly irrelevant. It is regrettable that those preparing Hungary's "Scientific Evaluation" have ignored the available facts concerning the G/N Project and have, instead, gone far afield - here, to a Greek river - in order to find data to bolster its case. No definitive mode of peak operation existed in 1989. Hungary also acknowledges "moderate" peak operation on some other Danube barrages.

(6) *Peaking flow operation is the most harmful mode of operation for two main reasons: the initial surge of water released into the tailwater during start up of the turbines, and the highly fluctuating water levels in the tailwater.*

"Peaking flow operation": the inapposite nature of this discussion has already been explained. The "highly fluctuating water levels" would in any event occur in the tailwater canal, an artificial structure specially designed for this purpose.

(7) *In general, the ecological effects of Variant C are expected to be similar to those outlined above for the Original Project.*

This is obviously wrong. Variant "C" implements the Gabčíkovo section of the Project only - its "ecological effects" have thus no link with the impacts of one half of the Project - the Nagymaros section, "outlined" by Hungary. Also, the Variant "C" reservoir is two-thirds the size of the Project reservoir and accordingly has a reduced impact - <u>see</u>, <u>e.g.</u>, "Scientific Evaluation", p. 74 and at HM, para. 5.108. Variant "C" also benefits from certain flow direction dykes that ensure sediment deposition in the desired areas only - measures that were not designed in 1989.

(8) *Approximately 4,500 ha of alluvial forests are seized.*

This is incorrect and misleading. The figure for the size of the Čunovo reservoir is exaggerated. In fact, a devastated area, already cleared in 1989, was flooded, creating a huge new littoral zone. This area was mostly cultivated forest that would one day have been cleared for commercial purposes.

(9) *Shortly after the diversion, the main channel and its side branches were left practically without water.*

This is incorrect. It is true that the diversion led to the reduction of water in the main channel (agreed to by Hungary in the 1977 Treaty), but it is not true that it was left

"practically without water". This is clear from a site inspection of the old Danube, which can be seen to be a healthy flowing river.

waterbodies containing the most valuable fish are the most dangerously damaged (*Plate 4.3, Volume 5*).

The termination of contact between the branch system and the Old Danube caused severe damage to the benthos, the plankton and the fish fauna. A number of detailed studies has been produced on fish kills occurring as an immediate impact (see in *Mészáros et al.*, 1993, 1994a, 1994b, *Chapter 5.4*).

1

In the branch system of the Upper Szigetköz, the water level was critically low in the spring and early summer up until the beginning of the temporary water supply by pumping in July 1994. The formerly large and uninterrupted reaches were separated into several tiny waterbodies. Inevitably, the number of individuals within the rheophilous[5] species decreased to a greater extent than those favouring stagnant waters. Several rheophilous migratory species reappeared due to the temporary water supply. However, the numbers within non-migratory rheophilous species declined compared to the previous stage. In short, the order and balance among communities was upset by the drastic changes in the biotopes of the active floodplain.

Middle section of the Szigetköz

In the middle reach of the previous main channel, from the end of the Hungarian branch system at Ásvány to the conjunction with the tail-race canal, the surface waters have backed up to rkm 1820-1825, i.e., 9 to 14 kilometres up to the area of Lipót. This section has lost its sub-montane stream character as well. Not only the total number of fish but also the number of fish species has decreased in this stretch. The main channel has lost its function and the rheophilous species are present in small numbers, if at all. Therefore, the most significant immediate change has taken place in this reach from the fish-faunistic aspect. Another chain of barriers would have been built by the "underwater weirs" in the main channel transforming the ecological conditions from those typical for running waters to almost lacustrine conditions in the several impoundments of the small barrages (see *Chapters 2.5* and *4.6*).

The old floodplain (protected side of the floodplain)

As a result of the artificial water supply, the marshy oxbow lake of the Zátony Danube, originally stagnant, became a canal with a flow velocity at some places of 0.4-0.8 m/s. As a result of the provision of supplementary water from the Moson Danube, the fish fauna of the latter was introduced to the Zátony Danube. For this reason, the number of fish species increased significantly, but only one species of the previous fish fauna survived in large numbers (*Cobitidae*). The increase in number of fish species must not divert attention from the fact that the original fish fauna has lost importance. The number of individuals within these eurytropic[6] species became high and their excessive proliferation may lead to the decline of the former (mostly stenotropic[7]) biota *en masse* (Mészáros *et al.*, 1994a).

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[5] (attribute of species which prefer running waters with distinct velocity)

2

Among the oxbow lakes in the old floodplain, the mortlake at Lipót was outstanding in terms of its faunistic value. It dried out completely as a result of the diversion and its fish fauna was destroyed. The provision of supplementary water from the main channel could not restore previous fish fauna. During repeated investigations, none of the species of the original fish fauna could be found.

As another result of the diversion, the water level in the canals fell significantly. The flow slowed down or even stopped. Consequently, the situation for the rheophilous species became critical. The impact of the intervention appeared with some delay due to the now exclusive contact through the groundwater (Mészáros *et al.*, 1994a).

Floodplain vegetation

3

Water-weed communities grew mainly in the oxbow lakes, ponds and canals in the Szigetköz, and as such, they came to the verge of extinction in the upper and middle parts of the Szigetköz. In terms of their prospects for survival, it depends primarily on the efficiency of the provision of supplementary water.

The marsh communities are somewhat more tolerant than the water-weed communities. Their more extensive populations lived only in the active floodplains of the Szigetköz. Nonetheless, the decline in the water-tables seriously threatens these populations in the upper and middle Szigetköz.

The willow forests of "the Szigetköz region [were] fairly close to the natural conditions, especially in the Moson-Danube branch, because of the huge meanders" (Simon *et al.*, 1993, p. 179). This desirable situation has been improved slightly by Variant C in the protected side of the Szigetköz. However, natural floods, as they are characteristic for active floodplains, did not return. Moreover, the situation of the active floodplain of the Szigetköz has been worsened (see *Plate 12, Volume 1*). After June 1993, partial water deficiency could be seen in the forests. Yellow patches occurred on the leaves and branches begin to shrivel. From June onwards, trees started to lose their leaves. By mid-June, 3% of the alluvial forests were classified as dead. At the end of 1993, 5% of the trees were classified as dead. The monitoring shows that reduction of the leaf area did not come to an end in 1994 (Simon, personal communication, publication in prep.).

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[6] (attribute of species which are able to adjust to large fluctuations in environmental factors)

[7] (attribute of species which are inable to tolerate more than slight alternations in ecological conditions)

4

Summarising, the effects of Variant C on the floodplain vegetation do not differ seriously from those predicted for the Original Project (see *Figure 4.5*). The actual increase of the everyday water levels is insufficient for the further existence of the floodplain habitats.

4.6 EVALUATION OF REMEDIAL MEASURES

by Joachim Lösing and Albert Roux

5

Although there was no agreement in the Original Project to build "underwater weirs" in the old riverbed, they were considered in order to maintain the water at a constant level corresponding to the low flow water in pre-dam conditions. In the same manner, the construction of various weirs in the Danube floodplain (side-arm system) was proposed to maintain the height of the local water-table and to obtain a constant flow (SM, para 2.70). This proposal of *constant* water level, of *constant* flow to be maintained or created, is the sign of neglect of the ecological functioning of a river and its floodplain.

6

The biodiversity of the floodplain hydro-system is dependent on the diversity of habitats (mosaic of structures). This diversity derives from the variability both in space and time of the different factors of the biota. The most important factor controlling the floodplain ecosystems is the variation of the water levels (including inundations) induced by fluctuations of the discharge. "The principal driving force responsible for the existence, productivity, and interactions of the major biota in river-floodplain systems is the flood-pulse [...]. The pulse is coupled with a dynamic edge effect, which extends a 'moving littoral' throughout the aquatic/terrestrial transition zone (ATTZ). The moving littoral prevents prolonged stagnation and allows rapid recycling of organic matter and nutrients, thereby resulting in high productivity. Primary production associated with ATTZ is much higher than that of permanent waterbodies in unmodified systems" (Junk *et al.*, 1989).

7

It is evident that all these benefits will be lost when weirs are built either in the Old Danube or in the recent floodplain.

4.6.1 "UNDERWATER WEIRS"

8

The "underwater weirs", which should correctly be called "weirs", would not have the desired effects on the surface- and groundwater levels as pointed out in *Chapter 2.5*. For the ecological impacts on flora and fauna the following findings from *Chapter 2.5* are of primary importance:

– The weirs would dissect the Old Danube into a sequence of small reservoirs, even at higher discharges;

– The groundwater-table would be controlled by the low surface water levels of the upper end of the impoundments;

– The flow velocities would be reduced to about one third of unbacked flow conditions, thus leading to at least temporary siltation;

– The variability of the flow velocity would be considerably reduced;

– The construction of the weirs would lead to rather uniform flow conditions with the consequence of rather uniform riverbed habitats.

9

After the construction of "underwater weirs" the survival of aquatic species in the Old Danube would be restricted to a few species adapted to almost stagnant waterbodies and able to resist rapid rise of discharges.

10

The diversity of aquatic species would be reduced by the physical and chemical parameters directing to eutrophic conditions above silty deposits instead of gravel. Subsequently the benthos coenoses would change considerably. The rare events of flood discharges would wash out the biota just gaining a foothold. Aquatic macrophytes would not be able to settle in this short-term environment although the prevailing conditions would fit very well. Thus the entire habitat would be unsuitable for spawning and juvenile fish. In a few words, the riverbed of the Old Danube would lose almost all its entire biological value.

11

12

The Upper Rhine experience shows that the groundwater-table as one of the vital elements in a floodplain ecosystem could not be sustained to its previous levels, not even at a constant level. So, also the adjacent floodplain itself would profit less than expected.

13

With weirs representing a sequence of small barrages in a small river, the last remaining river continuum in the stretch of the Original Project would be segregated again, transforming the environmental conditions from those typical for running waters of a large river to almost lacustrine conditions with flow velocities of 0.1 m^3/s to 0.6 (-0.7) m^3/s at $Q=350$ m^3/s (see *Chapter 2.5*).

Even though rare flood events may mitigate the effect of segregation, the risks are rising that the small populations in the impoundments will shrink or become extinct due to predators, pests, eutrophication or other inter- and intra-specific effects. Those small rearrangements may even result in total extinction, as can be observed everywhere in the world in recent decades. At least they drastically reduce the genetic pool (bottle neck effect, see *Chapter 4.1*).

(1) *In the branch system of the Upper Szigetköz, the water level was critically low in the spring and early summer up until the beginning of the temporary water supply by pumping in July 1994.*

Hungary acknowledges here that the direct recharge of water into the side arms has a beneficial impact. This is anyway clear from its signature of the Agreement of 19 April 1995, referred to in the Introduction above.

Of course, diversion of water into the Hungarian side arms (as provided for in the Project by means of the Dunakiliti offtake) is far more efficient - both in terms of quantity and cost - than pumping.

(2) *Among the oxbow lakes in the old floodplain, the mortlake at Lipót was outstanding in terms of its faunistic value. It dried out completely as a result of the diversion and its fish fauna was destroyed.*

Lakes in the Hungarian old floodplain were subject to drying out before the implementation of Variant "C". <u>See</u>, <u>e.g.</u>, SC-M, <u>Illus.</u> <u>No.</u> CM-6B (appearing at para. 7.82). As to the negative impact on ecosystems of the sinking groundwater levels from 1960, <u>see</u>, Vol. III, pp. 75-78.

In terms of the water level in Hungary's oxbow lakes, it is wholly irrelevant whether water arrives in Szigetköz by means of flood discharge or whether it is fed through direct recharge. Oxbow lakes would naturally continue to dry out in Szigetköz until Hungary decided to take positive steps to reverse groundwater level decline through the implementation of direct recharge into its side arms.

(3) *Water-weed communities grew mainly in the oxbow lakes, ponds and canals in the Szigetköz, and as such, they came to the verge of extinction in the upper and middle parts of the Szigetköz. In terms of their prospects for survival, it depends primarily on the efficiency of the provision of supplementary water.*

"Supplementary water": Hungary again acknowledges that recharge of water into the sidearms will enable the survival of the water-weed communities. The water has been available - but Hungary made the political decision not to use it - <u>see</u>, SC-M, para. 8.11.

(4) *Summarising, the effects of Variant C on the floodplain vegetation do not differ seriously from those predicted for the Original Project (see Figure 4.5). The actual increase of the everyday water levels is insufficient for the further existence of the floodplain habitats.*

"Everyday water levels" have been determined by Hungary's political decisions, not by Variant "C". Water levels are sufficient on the Slovak side to enable not only the "further existence of the floodplain habitats" but also to enable their rejuvenation. <u>See</u>, Vol. III, pp. 78-86.

(5) *Although there was no agreement in the Original Project to build "underwater weirs" in the old riverbed, they were considered in order to maintain the water at a constant level corresponding to the low flow water in pre-dam conditions. In the same manner, the construction of various weirs in the Danube floodplain (side-arm system) was proposed to maintain the height of the local water-table and to obtain a constant flow (SM, para. 2.70).*

"No agreement": There was indeed such an agreement.

"In the same manner": Weirs in the side arm system are not the same as underwater weirs. They create a cascade effect, rather than merely increasing surface and ground water levels.

"Various weirs in the Danube floodplain": It is misleading to speak of these as merely proposals. Weirs in the side arms have existed for a considerable period in both the Czechoslovak and Hungarian side arms. The weirs in Hungarian territory may be seen in HC-M plate 11 (opposite p. 166). On the Slovak side, where the weirs have been upgraded, they have been proved to have a beneficial impact. <u>See</u>, Vol. III, at p. 84:

"The results of monitoring of reactions of flora to existing situation indicate the following:

- **excellent healthy state of trees in the tree layer, without traces of decline**
- **occurrence of natural reforestation of tree species Fraxinus angustifolia from seed, which was not earlier observed**
- **increase of population of protected humid species Leucojum sativum due to ground water levels increase**
- **almost no changes in the thickness increment of poplar clone "I 214" (the most prevalent tree of the inundation area)."**

(6) The most important factor controlling the floodplain ecosystems is the variation of the water levels (including inundations) induced by fluctuations of the discharge.

"Fluctuations of the discharge" are indeed an important factor. In terms of the Hungarian side arms, fluctuations were allowed for in the Project by means of the large capacity of the offtake in the Dunakiliti weir, providing for a flow of up to 250 m^3/s into the Hungarian side arms. This represents 4-5 times the amount of water considered by the EC Working Group sufficient for "ground water levels on the Hungarian territory ... to be not lower than in pre-dam conditions" and allowed for periodic flooding - <u>see</u>, EC report of 1 December 1993, HM, Vol. 5, Annex 19 (at p. 790).

The intake into the Slovak side arms at Dobrohošť has a similar capacity - 234 m^3/s. Through its use it is possible to create a surface flood of almost all the side arm area - <u>see</u>, Vol. III, at p. 83:

"The decrease of the discharges and the drop of ground water levels in the inundation area (left side of the Danube) have been remedied by means of a managed water supply through the intake structure near Dobrohošť. A system of weirs and permanent water supply from the by-pass canal provides sufficient water level and flow in the branches. It was ascertained (Sumbal and Sikora, 1993) that the level of ground water extrapolated from branches is on the major part of the territory less than 1.5 m under terrain, and thus within the reach of tree roots. This water supply covers about 75% of the inundation area. The increase of the discharge through the intake structure up to 234 m^3/s would enable flooding of the whole inundation area (Sumbal et Sikora, 1993)."

(7) It is evident that all these benefits will be lost when weirs are built either in the Old Danube or in the recent floodplain.

This is entirely wrong. <u>First</u>, weirs have already been built in the side arms within the floodplain both in Hungary and Slovakia. <u>Second</u>, the construction of underwater weirs in the old Danube will allow the interconnection between the main channel and the side arms

to be re-established. It cannot be questioned that this will have a beneficial impact on floodplain ecosystems, with regard to biodiversity.

As to underwater weirs, see, Comment 9 below.

Note: According to the EC Working Group report of 23 November 1992: "The results show that the desired effect of increasing the water levels [by means of underwater weirs] without reducing the velocities too much and of preserving the dynamics with the characteristic fluctuations is possible". See, HM, Vol. 5, Annex 14.

(8) The "underwater weirs", which should correctly be called "weirs", would not have the desired effects on the surface - and groundwater levels as pointed out in Chapter 2.5. For the ecological impacts on flora and fauna the following findings from Chapter 2.5 are of primary importance:

See, Comment 1 to "Scientific Evaluation" p. 36, above. See, also, Vol. III, Chs. 4, 5 and 6.

(9) After the construction of "underwater weirs" the survival of aquatic species in the Old Danube would be restricted to a few species adapted to almost stagnant waterbodies and able to resist rapid rise of discharges.

This hypothesis is not valid. Slovak studies show that, the impact of underwater weirs will be positive. They will not create stagnant areas and will in fact increase habitat diversity by offering an increased variety of flow rates. Obviously, how flow rates are affected will depend on the design of the weirs. In certain areas behind the weirs and close to the banks, velocity will decrease. This provides a favourable habitat for many young fish species, as do the areas behind the groynes that were erected on the old Danube riverbed for navigation purposes. In the centreline of the riverbed, higher velocities will remain. This variety of velocities and potential habitats is far closer to the river's "natural" state than the old high velocity main channel. See, Vol. III, p. 114. A further advantage is that the riverbed bottom will no longer be a smooth, eroded surface. Irregularities may develop that, again, increase habitat diversity.

Note also that the construction of weirs in the side arm system has not led to a reduction in species.

Of course, the "rapid rise of discharges" also occurred in the pre-damming state at times of flooding. It is not understood why species adapted to that situation pre-1992 would suddenly lose their suitability to those conditions.

(10) The diversity of aquatic species would be reduced by the physical and chemical parameters directing to eutrophic conditions above silty deposits instead of gravel.

"Eutrophic conditions": Underwater weirs may lead to increased biomass which is favourable as long as a balance is maintained between dissolved oxygen and organic matter. As there is no problem in the reservoir in relation to eutrophic conditions (see, Comment to "Scientific Evaluation" Ch. 3 above), there would be no such problems in the old Danube where velocities are higher and surface area lower. Slovakia has had extensive experience in terms of monitoring water conditions in its other rivers. In the Váh river, for example, where flow velocities are lower, there is no eutrophication problem although conditions are otherwise comparable.

(11) Thus the entire habitat would be unsuitable for spawning and juvenile fish. In a few words, the riverbed of the Old Danube would lose almost all its entire biological value.

This is entirely untrue. See, Vol. III, Ch. 6.

(12) The Upper Rhine experience shows that the groundwater-table as one of the vital elements in a floodplain ecosystem could not be sustained to its previous levels, not even at a constant level. So, also the adjacent floodplain itself would profit less than expected.

This is, once more, incorrect. Weirs in the Upper Rhine are entirely different in design. <u>See</u>, HC-M, Vol. 4, Annex 14 which focuses on underwater weirs in the old Rhine bed, where the flow is just 15 m^3/s (at p. 657). <u>See</u>, Comment 1 to "Scientific Evaluation" p. 69, above.

(13) With weirs representing a sequence of small barrages in a small river, the last remaining river continuum in the stretch of the Original Project would be segregated again, transforming the environmental conditions from those typical for running waters of a large river to almost lacustrine conditions with flow velocities of 0.1 m^3/s to 0.6 (-0.7) m^3/s at $Q=350$ m^3/s (see Chapter 2.5).

Underwater weirs do <u>not</u> create almost lacustrine (lake like) conditions, nor do they represent "a sequence of small barrages". The planned water velocity behind the underwater weir will be in the range 0.3 m^3/s - 1.0 m^3/s. Underwater weirs can be constructed with lowered sections so that a higher flow velocity in the middle sections is maintained. Furthermore, species that favour high velocity water flows can cross slow flow areas, <u>i.e.</u>, upstream of a weir to rejoin their favoured habitats.

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4.6.2 ARTIFICIAL WATER INPUT IN THE SIDE-ARM SYSTEM

1

The decline of the Danubian inland delta in recent decades was a result of excessive gravel exploitation beginning in the 1960s (see *Chapter 2.2*). Subsequently several side-arms (or parts of them) dried out at times or lost contact with the main channel. The equilibrium of the ecological conditions, achieved in the 1950s and 1960s, was disturbed again (especially since the beginning of the preparations of the Gabčíkovo-Nagymaros Project). But the real incision was made with the implementation of Variant C when the whole stretch of the Szigetköz, including the Slovak side, fell dry at once.

The Slovak watering system (starting in May 1993) was planned to mitigate or even improve the ecological conditions. The Slovak Memorial itself names the technical side of the structures:

> "The Dobrohost intake supplies a regular flow of around 50 m³/s into the side-arm, which is planned to increase to 140 m³/s 1-3 times per year to achieve the inundation of the side-arms as would occasionally occur under natural conditions. The maximum flow through this intake is 234 m³/s...[The] left side-arm system has been divided into 8 distinct zones, each with its own water level. These zones are graded as to form a cascade from Dobrohost to Gabčíkovo..." (SM, para 5.42).

2

It is remarkable that a regular flow of 50 m³/s as the only intake should be enough to supply an area of approximately 4,000 hectares and that 234 m³/s should simulate floods of up to 4,000 m³/s (distributing over both sides of the recent floodplain).

The WWF statement (Dister *et al.*, 1994) goes on to say: 3

> "Even though in 1991 the Slovak Environment Ministry expressively (!) criticises such measures as very detrimental and demanding a solution ensuring a water input in the side-arms from the [Old] Danube and a removal of the closures between the river and the side-arms [...], the Gabčíkovo engineers started to build this scheme in winter 1992/93 destroying parts of the side-arm system, reinforcing the closures with the Danube and starting a permanent inundation of the wetlands in May 1993. [...These] dykes 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 [...] lifted the water level to a higher level than under pre-dam conditions. However, the single-point inflow of water, its stable, significantly reduced volume and its changed water quality [...] in fact result in detrimental effects.
>
> The water level just upstream from each lateral dyke is lifted too high and remains stable over many months. This is damaging for natural floodplain biocenoses. [...] *This measure induces a real threat to the affected floodplain forests.*"

4

Willow trees are having clear physiological problems since their bases are permanently flooded. Large numbers, especially of large old trees, will die or have died already. The lateral dykes (or dams) proved to impede the migration of fish and other aquatic biota, so that the fish biomass dropped drastically. Almost all large fish vanished and only a few species dominate (for instance bleak [*Alburnus a.*]). The originally rich biodiversity is largely changed today (Roux, 1994).

5

Biological investigations at the upper Rhine have also proven the effects of such artificial side-arm systems. Krause and Hügin (1987) emphasise as a result of their analysis that "the planning of management systems of connected side-arms cannot be accepted any more."

(1) *Subsequently several side-arms (or parts of them) dried out at times or lost contact with the main channel.*

The cause of the drying out of side arms from the 1960s is discussed in Vol. III, Chs. 1 and 4. The principal cause was their physical isolation through dyking off from the main channel and erosion of the riverbed. By 1989, almost all branches had any direct connection with the main channel for only 17 days per year - see, "Scientific Evaluation", at p. 52.

(2) *It is remarkable that a regular flow of 50 m^3/s as the only intake should be enough to supply an area of approximately 4,000 hectares and that 234 m^3/s should simulate floods of up to 4,000 m^3/s (distributing over both sides of the recent flood plain).*

This should not be "remarkable" to Hungary. Hungary's 1985 EIA noted that: "After the Barrage System is put into operation the plan provides water supply for the Mosoni-Danube and the tributaries from the infiltration system and from the Dunakiliti reservoir via water intake, far exceeding their present discharge throughout the entire year." Although such a flow may appear relatively small, it has a very substantial impact because it is regular, i.e., not just for 17 days per year. See, HM, Vol. 5(I), Annex 4.

Note, also, the findings of the EC Working Group of Experts. See, reports of 2 November and 1 December 1993, HM, Vol. 5, Annexes 18 and 19. See, also, Vol. III, at p. 83.

(3) *The WWF statement (Dister et al., 1994) goes on to say:*

WWF was heavily critical of the EC reports, but subsequently withdrew its criticisms in the light of monitoring results proving the real impacts of the Project on the environment - see, Prof. Mucha's paper that forms SC-M, Annex 24. Prof. Mucha responded to the criticisms raised by WWF. When WWF later decided to maintain its criticisms, it refused to supply any justification for this recantation. See, SC-M, para. 8.17.

(4) *Willow trees are having clear physiological problems since their bases are permanently flooded. Large numbers, especially of large old trees, will die or have died already. The lateral dykes (or dams) proved to impede the migration of fish and other aquatic biota, so that the fish biomass dropped drastically. Almost all large fish vanished and only a few species dominate (for instance bleak [Alburnus a.]). The originally rich biodiversity is largely changed today (Roux, 1994).*

This account of what is occurring in the Slovak side arms is completely untrue. There, no permanent flooding has occurred. The direct discharge into the sidearms fluctuates from 10-90 m^3/s, as dictated by ecological considerations.

The impact of Variant "C" on forests in the Slovak floodplain is discussed at Vol. III, Ch. 3, Sec. 3 and Ch. 4, on the basis of extensive monitoring. The condition of willow trees has (amongst others) been recorded by means of leaf area index (surface area of leaves per hectare) and leaf loss at four different monitoring plots in the inundated area (MB 10, MB 14-15, L03). There have been no significant changes in leaf area index. Claims that large numbers of trees have died or will die are simply wrong. As to leaf loss, there is no significant change between monitoring results for 1991-1992, (pre-dam) and 1993-1994 (post-dam). See, Vol. III, at pp. 66-67:

"On permanent monitoring plots which represent the majority of the territory (MB10, MB14, MB15, MB18, MB23 - Fig. 3. 1, Pišút 1994, 1994 and L02, L05, L06, L03 - Fig.

3.2, CSölle et al., 1993, 1994, the loss of leaves is relatively small and the differences between the respective years are not significant. The loss of leaves here is 10 - 15 % and only very seldom is higher than 20 % (L11, L12). This parameter documents also the stable, unchanged healthy state of trees on the majority of the permanent monitoring plots, as well as the stable state of trees, physiological activities.

Despite the small number of observations (4 vegetation periods), the positive trend in loss of leaves can be documented on permanent monitoring plots MB02b and MB03 in the years 1993 and 1994. This is without any doubt the result of the better growing conditions in the area caused by the increase of the ground water level in the locality (Pišút, 1994).

Decrease of the loss of leaves, which is, however, still relatively high, can be observed on other permanent monitoring plots in the upper part (where there has been the raising up of the ground water level); especially on MB04 and MB05. Here the values in 1993 and 1994 document the significant improvement of the health state of trees (Fig. 3.3).

Positive changes, i. e., obvious tendency towards the decrease of leaf loss have been registered on the following permanent monitoring plots in the upper part: L14, L15, L16, L18, L19, L20, L21, L23, Fig. 3.4. An exception are lots L24 and L13, where the loss of leaves is still getting higher. Tendency towards the leaves loss increase has been recorded also on MB09 (willow) which lies directly in the neighbourhood of the old riverbank."

Hungary's allegations are wholly without foundation.

As to the impact of Variant "C" on fish in the Slovak side arms, see, Vol. III, Ch. 6. Slovak studies conclude, unambiguously, that conditions for fish will improve (at p. 117) and that the number of predatory, i.e., "large" fish will increase - alongside an overall decrease in fish destruction (at p. 116). These are clearly positive developments (at p. 117):

"The intake structure of the branch system makes it possible to control water levels in the branches, i.e., to control the flow and length of time (according to water temperature), during which the spawning and early development of young specimen and their nutrition can take place. It is important from the point of view of the phylogenetic adaptation of fishes, in that it develops their food basis and reduces mortality of young specimens especially in the winter period. Thus the conditions of fishery will be improved in this section of the river.

The new solution of the system of branches thus offers the possibility of effective investment into fishery and fish production through the controlled application of appropriate fish fries and catch at the end of the season. The value of production and possible catch will increase at least three times due to the change of species composition of ichthyofauna in favour of economically preferred species and they will become comparable with the fish production in ponds of second class."

Lateral dykes do not impede migration due to the construction of fish ladders.

(5) Biological investigations at the upper Rhine have also proven the effects of such artificial side-arm systems. Krause and Hügin (1987) emphasise as a result of their analysis that "the planning of management systems of connected side-arms cannot be accepted any more."

There is nothing "artificial" about the side arm systems - these are real river branches, supplied with real Danube water, generating real ecosystems. The flows into the old Danube are far higher than those into the side arms of the Rhine, and flows into the Danube side arms can be varied widely from 10-250 m^3/s to create the fluctuations favourable to the floodplain ecosystems.

CHAPTER 5

SOILS, AGRICULTURE, FORESTRY, FISHERY

5.1 SOILS

by Howard Wheater
(based on Várallyay, 1993)

5.1.1 INTRODUCTION

The area affected by the Gabčíkovo-Nagymaros Project is, as noted in *Chapter 4*, a large alluvial plain, rich in various valuable natural ecosystems, with high diversity and fine landscapes. At the same time, the area is a traditionally important agricultural region of Hungary, and hence there is abundant information on, and a good understanding of, the soils and associated environmental factors, supported by extensive long-term observations, field experiments, and experience of agricultural production (*Table 5.1;* MTA, 1994 and Várallyay, 1991). 1

The area has a continental climate, with considerable temperature extremes (cold winter, hot summer) and low precipitation. The soils of the Danube alluvial terrace with favourable hydrophysical characteristics and moisture regimes effectively moderate the weather extremes over much of the region. 2 High quality groundwater is drawn up by capillary action to provide an important contribution to the water-use of natural vegetation and cultivated crops. However, this can only occur where the groundwater-table reaches the fine-grained sediment (sand/loam/silt) which overlie the gravel aquifers of the alluvial terrace (see *Plate 3.4*). 3 A high geothermal gradient exists throughout the region, and the availability of good-quality hot waters at moderate depths provides particularly favourable conditions for intensive vegetable production.

The characteristic geological structure of the alluvial terrace has developed in response to the geomorphological effects discussed in *Chapter 2*. The area has high horizontal heterogeneity and vertical stratification, and variable depths of fine sediment. 4 Hence the natural and agricultural ecosystems of the region show high spatial and temporal variability, and, as noted above, are in particular sensitive to capillary moisture supply to the root zone from the underlying groundwater. This moisture supply is primarily dependent on:

1) the profile of the soil above the gravel strata and its associated hydrophysical properties;

2) the depth and fluctuation of the groundwater-table.

Table 5.1: Soil mapping activities in the Bős-Nagymaros Project Area

	Mapping project	Scale	Date	Cartographic basis	Content
1.	OTTK	1:10 000	1957-1959	Gauss-Krüger map sheets	Soil type, subtype, local variety: colour; most important soil properties (texture, pH, carbonate status, depth): signs.
2.	Géczy practical soil maps	1:25 000	1958-1961	settlements	soil type, subtype, local variety: colour; colour diagrams of representative soil profiles; characteristic land use and cropping pattern
3.	Genetic soil maps	1:10 000	1960-1970	farming units (state and cooperative)	soil map; cartograms/thematic maps/ on the most important soil properties and on recommendations for rational land use, cropping pattern and agrotechnics; data of field survey and lab analysis; explanatory text
4.	Soil map of Győr-Sopron County	1:75 000	1959-1960	Győr-Sopron County	soil type, subtype: colour; most important soil properties (texture, pH, carbonate content, depth): signs.
5.	Program of the "Assessment of the agro-ecological potential"	1:100 000	1978-1980	TIEDIT map sheets	soil map indicating 7 characteristics (soil classification unit; parent material; soil reaction and carbonate status; soil texture; hydrophysical properties; organic matter resource; depth of the soil) with an 8-digit code system; explanatory booklet – with territorial data)
6.	Agrotopographical map	1:100 000	1988-1990	EOTR topographical map sheets	9 soil characteristics (the above-mentioned 7+clay mineral associations; and soil productivity index) with a 10-digit code-system; most important meteorological characteristics on small-size maps and diagrams
7.	Soil of Mosonmagyaróvár and its surroundings	1:25 000	1983	Mosonmagyaróvár and its environment	5 most important soil characteristics (soil type, subtype; carbonate-content; texture; depth of the humus horizon; depth of the soil) with a 5-digit code-system; explanatory text
8.	Geological Atlas of Kisalföld	1:100 000	1990-1993	Győr-N., Győr-S., Mosonmagyaróvár, Kapuvár atlases	genetic soil map; map of the limiting factors of soil fertility; small-size thematic maps (pH, $CaCO_3$-content, groundwater conditions); explanatory text

These two sets of factors are not independent. As will be discussed below, the soil physical and chemical properties reflect the origin of the alluvial parent material and the water regime.

Depending on the territorial variability of the above factors, the soils, natural vegetation and biomass productivity of agricultural land vary considerably. A wide spectrum of landscapes results, including periodically inundated floodplains, with fresh sediment supply, and highly productive agricultural areas, dependent on the natural sub-irrigation of the underlying groundwater. 5 This is an environment in a dynamic equilibrium. Any human intervention on a large scale will change this state, possibly irreversibly. It is evident that the complex interrelation of physical, chemical and biological processes must be fully considered before such changes occur.

In this chapter, soil formation processes are described, and existing soils in the area of the old floodplain (flood-protected area) are briefly characterised (see *Plate 5.1, Volume 5*), with particular regard to the soil moisture, soil chemical and plant nutrient regimes. Potential long-term impacts of the proposed GNB Project on soils and soil water are discussed.

5.1.2 SOIL FORMATION PROCESSES

In the alluvial terrace of the Danube, the main parent materials for soil formation are fluvial alluvial deposits. In the higher ground of the Moson Plateau (Mosoni Síkság), to the south-west of the Mosoni Danube, soil development began on loess material, mixed with various alluvial deposits and re-deposited repeatedly by fluvial action; and in the transitional region beyond, towards the Fertő and Hanság depression, it was based on lacustrine sediment (peats) (MTA, 1994 and Várallyay, 1991).

The alluvium is characterised by high carbonate content (reflecting the limestone origin of the Danube sediment) and has a high degree of vertical stratification (layering) and horizontal variability in soil texture. On this "raw" parent material two primary soil processes began: humus formation and soil structure development. Depending on the history of fluvial deposition, and the development of the humus horizon and other features of the soil structure, a time sequence of soils can be clearly distinguished in the alluvial terrace region (Stefanovits, 1992.):

alluvium→ alluvial soils→ humous alluvial soils (The latter refer to alluvial soils with a humus horizon)

The rate of soil development (soil formation) depends on the moisture conditions; on the particle-size distribution, carbonate content and original organic matter content of the alluvium; on the character of natural vegetation; and on land use and/or agricultural development. It occurs on a time-scale of hundreds of years.

The further development of the humous alluvial soils is primarily determined by the moisture regime, which in turn is dependent on rainfall, groundwater conditions and soil hydrophysical properties. As rainfall is relatively uniform over the region, groundwater conditions have been a dominant influence in determining the spatial distribution of soils. As the depth to the groundwater-table is closely related to relief, a general topographic sequence (catena) of soils can be observed:

chernozem→ meadow chernozem→ meadow soils→ peaty meadow soils→ peat (bog)

In this sequence, the influence of groundwater is minimal for chernozem soils, but is progressively more important moving through the sequence. Thus in the case of peat soils, the impact of periodic or permanent water-logging is the dominant factor of soil formation.

The influence of groundwater depends on the location of the water-table in the vertical profile. If the groundwater remains wholly within the gravel strata, capillary rise is prevented, and its effect on soil processes is negligible. In such cases the sequence can be reversed, for example with humous alluvial soils developing in the direction of "terrace chernozems".

On the extensive alluvial terrace of the Danube and the Mosoni Danube, in the Szigetköz region and its surroundings, the three cases described above can all be found, i.e.:

1) alluvium – alluvial soils – humous alluvial soils

2) humous alluvial soils (topographic and hydromorphic sequence) mostly meadow soils and meadow chernozems

3) humous alluvial soil – terrace chernozems

The consequence is the mosaic-like spatial variability of slightly alkaline soils (pH 7.3-8.3), with heterogeneity in stratification, $CaCO_3$-content, depth of humous horizon and its organic matter content, texture, hydrophysical properties, depth of gravel strata and groundwater conditions.

On the Moson Plateau, soil development began on loess or loess-like deposits, without any groundwater influence, hence tending to chernozem soils. The other soil types of the hydromorphic sequence (meadow chernozems – chernozem meadow soils – meadow soils) occur only in the deeper parts and microdepressions of this area.

In the transitional areas towards the Lake Fertő and Hanság depression, the wetter members of the toposequence predominate, i.e.:

meadow soils → peaty meadow soils → peat soils.

5. COMMENTS TO HUNGARY'S "SCIENTIFIC EVALUATION", CHAPTER 5: SOILS, AGRICULTURE, FORESTRY, FISHERY

(1) *The area affected by the Gabčíkovo-Nagymaros Project is, as noted in Chapter 4, a large alluvial plain, rich in various valuable natural ecosystems, with high diversity and fine landscapes. At the same time, the area is a traditionally important agricultural region of Hungary, and hence there is abundant information on, and a good understanding of, the soils and associated environmental factors, supported by extensive long-term observations, field experiments, and experience of agricultural production (Table 5.1; MTA, 1994 and Várallyay, 1991).*

"A large alluvial plain": Both the HM (at paras. 5.16-5.26) and the HC-M (at para. 1.55) divide the G/N Project area into three distinct regions: Szigetköz, the Danube Valley and the Danube Bend. Only the first of these can be described as "a large alluvial plain". The topography of the other areas is quite different in that the Danube does not (at least on the Hungarian side) tend to dominate the surrounding terrain. As Hungary notes: "Downstream from the Szigetköz ... the topography is hilly" - <u>see</u>, HM, para. 1.13; "over time the Danube has curved and shaped the landscape of steep hills, cliffs and gorges of the Danube Bend" - <u>see</u>, HM, para. 5.26. This is crucial because it means that in the downstream sectors in Hungary the Danube does not define groundwater levels in the surrounding terrain to the same extent.

In fact, as becomes clear in this sub-Chapter, Hungary is only examining alleged Project impact on Szigetköz, while giving the impression that this impact extends to the whole Project area. This is incorrect and misleading.

(2) *High quality groundwater is drawn up by capillary action to provide an important contribution to the water-use of natural vegetation and cultivated crops.*

"Capillary action": Again, as to the "important contribution" of ground water, this depends on where. Hungary's statement is too general to have any real meaning. For example, the "Scientific Evaluation" estimates (at p. 173) that groundwater makes no contribution at all to crop water use in "about 30% of the impact area" (which is presumably Szigetköz). According to HC-M, Vol. 4, Annex 20, this figure appears to be as high as 47% (at p. 769). In fact this annex explains that the "key factors" in relation to crop yield are the "amount and periodicity of rainfall" (at p. 768). Note also that in many areas the Project allowed for increased irrigation to those areas where ground water supply was limited in the pre-Project state. This was a clear project benefit.

(3) *A high geothermal gradient exists throughout the region, and the availability of good-quality hot waters at moderate depths provides particularly favourable conditions for intensive vegetable production.*

It is once more not wholly clear what "region" Hungary is referring to. The statement is anyway wholly irrelevant to this case. The hot waters exist at great depths (underneath the aquifer) and could in no way be affected.

(4) *Hence the natural and agricultural ecosystems of the region show high spatial and temporal variability, and, as noted above, are in particular sensitive to capillary moisture supply to the root zone from the underlying groundwater.*

This "sensitivity" depends on the areas in question. It cannot exist where the underlying ground water remains always within the gravel layer. The statement also appears to contradict HC-M, Vol. 4, Annex 20 (at p. 768) as quoted at Comment 2 above.

(5) *This is an environment in a dynamic equilibrium. Any human intervention on a large scale will change this state, possibly irreversibly. It is evident that the complex interrelation of physical, chemical and biological processes must be fully considered before such changes occur.*

"Dynamic equilibrium": This has long since been disturbed - by a series of random human interventions whose impacts were neither planned nor foreseen. The G/N Project is a planned and very well researched intervention.

"Any human intervention on a large scale": Once again, Hungary speaks as if large scale human intervention had not already totally changed the environment of the Szigetköz over the past centuries: (i) in cultivating the land, (ii) by building an anti-flood dyke system, (iii) through the construction of the main Danube channel and (iv) by the isolation of the side arm system. For a discussion of these changes, see, Vol. III, at pp. 74-80 . Some of the impacts recorded in the pre-dam period (1960-1992) may be listed as follows:

- **"Loss of communication between the side arms and the Danube in the uppper part of Žitný Ostrov (stretch between Bratislava-Čunovo).**
- **Seasonal reduction of flow through the side arm system in the inter-dyke area in the stretch Hrušov-Palkovičov (Sap).**
- **Drying off of dead arms bed and their gradual settlement by shrub, often even by xero-thermophillous vegetation (Cornus sanguinea, Crataegus oxyacantha, Salix purpurea, Salix alba). Typical examples were mainly in the stretch Bratislava - Hrušov.**
- **Areal destruction of water and marsh vegetation in favour of a littoral one due to loss of communication between the water in the side arms and in the main channel, in particular in the second half of the vegetation season. This was typical for the side arm system in the inter-dyke area.**
- **Re-building of soft floodplain forests by means of regressive succession from the most humid and humid types (Salicipopuletum myosotidetosum and typicum) towards more xerophyllous types (Salici-Populetum variant with Cornus sanguinea) in the upper part of the territory.**
- **Re-building of elm-ash (Ulmo-Fraxinetum) and ash-poplar (Fraxino angustifoliae-Populetum albae) phytocoenoses into climax types of elm-oak forests (Ulmo-Quercetum), sometimes even into forest steppe shrub communities (Crataegetum danubiale) on the whole territory but mainly in the upper part of Žitný Ostrov.**
- **Drying off of upper part of crowns of Populus alsba, Fraxinus angustifolia, Quercus robur on elevated places of soft but even hard floodplain forest, gradual destruction of the tree layer and rise of shrub blocking stadia with Cornus sanguinea and Cornus mas. between Hrušov end Bratislava.**
- **Decrease of circumference increment of timber, mainly of Populus nigra, Populus alba, Salix alba in the upper part of Žitný Ostrov.**
- **Loss of leaves of willows on aggregated gravel and sandy ramparts along the whole Danube, ending with dying off of trees."**

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5.1.3 SOIL TYPES

The most important characteristics of the main soil types of the region (see *Plate 5.1, Volume 5*) are summarised below (MÁFI, 1989, 1991a, 1991b, 1993 and Várallyay, 1983):

Weakly developed humous sandy soils

Occurrence is limited. Main characteristics are a weakly developed humus horizon, low organic matter content, low water storage capacity and retention properties, no capillary water supply, high drought-sensitivity.

Alluvial soils

The various alluvial soils in the region, developed from different Danube deposits, are light textured (mostly sand, sandy loam, sandy silt, partly silt, loam, silty loam), are slightly alkaline (pH 7.3-8.3), and are calcareous in the upper profile ($CaCO_3$ content 10-25%) in most cases.

The vertical profile of alluvial soils shows the typical alluvial deposition sequence of various particle-size fractions: silt – sandy silt – silty sand – fine sand – coarse sand – fine gravel-gravel, with the texture becoming coarser with depth. The gravel strata occur within the upper 1.5 m of the soil profile in many cases. The moisture regime of alluvial soils depends primarily on three factors:

1) the water retention characteristics of the topsoil;

2) the depth of the gravel strata;

3) the presence of a groundwater-table within the fine sediment of the profile.

The capillary moisture supply can be as high as 150 mm/year under favourable circumstances, for example a sandy silt/loam/loamy silt texture and water-table at 1.5-2 m depth, located within the finer sediment. However, if the water-table only occurs in the underlying gravel, the capillary transport becomes negligible, which results in drought sensitivity, particularly for shallow soils.

Alluvial meadow soils

The alluvial meadow soils of the region are characterised by slightly alkaline reaction (pH 7.3-8.3) and highly variable $CaCO_3$ content (0-25%). In comparison with the alluvial soils, their texture is relatively heavier (loam, clay loam, clay), and their humus horizon deeper (>40 cm), with 2.5-4.0% organic matter content. The well developed soil profile is evidence of the long-term soil formation processes on the Danube and Lajta alluvia. The groundwater influence on the soil formation processes is clearly reflected by the hydromorphic features within the soil profile (especially in the deeper horizons): for example, iron mottling, and the development of carbonate accumulation or even petrocalcic horizons. The capillary moisture supply from the groundwater is highly significant in these soils (except for shallow soils with gravel occurrence near the surface. It can reach 200 mm/year from a 1.5m deep groundwater-table (Várallyay, 1974a and Várallyay and Rajkai, 1989).

Chernozems formed on loess or on loess-like materials

The chernozems of the Moson Plateau are medium-textured (loam, sandy loam, silty loam), with slightly alkaline reaction (pH 7.3-7.9), a favourable carbonate status ($CaCO_3$ content 1-15%), and 2-3% organic matter content. The depth of their humus horizon greatly varies (20-70 cm), mostly due to the influence of lateral soil erosion. They have favourable hydrophysical properties. Their capillary moisture supply from deep groundwater generally is not significant, but, because of the favourable capillary conductivity of the subsoil and the loess parent material, cannot be neglected, particularly in dry years.

Terrace chernozems on alluvial material

These soils can be characterised by slightly alkaline reaction (pH 7.5-8.1), medium organic matter content (2.0-2.8%), variable 1-25% carbonate content ($CaCO_3$), medium texture (loam, sandy loam), good structure and favourable hydrophysical properties. The groundwater is located in the gravel strata underlying these soils, consequently the influence of groundwater on the soil processes and the capillary moisture supply from the groundwater to the root zone are negligible, even in the case of a shallow groundwater-table. Their shallow varieties (with the near-surface occurrence of the gravel strata) are particularly drought-sensitive.

Meadow chernozems

These soils have limited occurrence within the project area. The periodical wetting of the deeper horizons from a moderately deep groundwater-table permanently located in or, at least, temporarily rising into fine-textured sediment, results in the moderate development of hydromorphic features within the profiles of these soils, especially in their deeper horizons: $CaCO_3$-accumulation horizons, iron mottlings, lime concretions, etc. The capillary moisture transport from the groundwater to the overlying horizons may reach 50-150 mm/year (Várallyay and Rajkai, 1989).

Meadow soils

Meadow soils can be found in the low-lying areas, micro- and mezo-depressions of the area and in the transition belts towards the Fertő Lake and Hanság depression. They are under the permanent influence of the shallow groundwater-table. The consequences are hydromorphic features within the whole soil profile, a deep humus horizon (60-80 cm) with relatively high (3-5%) organic matter content, and the formation of lime accumulation horizons ($CaCO_3$-accumulation – petrocalcic horizon – lime-pan) which may reduce the effective soil depth because of their impermeable (non-penetrable) character. The meadow soils of the region are slightly alkaline (pH 7.8-8.3) with high (15-30%) $CaCO_3$-content and medium texture (loam). Because of their occurrence in low-lying areas with shallow groundwater-table conditions (<100-150 cm) they are particularly sensitive to over-moistening and even water-logging.

Peaty meadow soils

These soils occur in the Northern part of the Hanság-Fertő depression. They are highly calcareous in the upper profile ($CaCO_3$ content: 10-25%), have alkaline reaction (pH ≈ 8.0), moderately deep humus horizon (30-50 cm) and widely variable organic matter content (5-20%). Because of the influences of permanent groundwater (and periodic surface water inundation), hydromorphic features are well-developed and strongly expressed within the whole profile.

Peat soils

The peat soils which occur in the Northern part of the Hanság-Fertő depression are alkaline (pH ≈ 8.0) and highly calcareous in the upper profile ($CaCO_3$ content: 10—15%). Their organic top-horizon (usually with more than 20-30% organic matter content) is moderately deep (60-100 cm), and in many cases mixed with the mineral, highly calcareous subsoil and/or with the peat material (organic matter 10-60%).

In summary, it can be noted that soils are dynamic and that soil structure and physical/chemical properties have developed in response to prevailing moisture conditions. In particular, capillary moisture supply is an important feature in the water balance of the region. Additionally, the high concentration of salts, e.g. $CaCO_3$, can have significant effects on the physical characteristics of the soil profile.

5.1.4 SOIL MOISTURE REGIMES

1

As has already been noted, the moisture regime of soils in the flood-protected area of the Szigetköz is determined mainly by:

1) the stratification (layering) of the soils profile: the depth, thickness and sequence of the basewater soil horizons;

2) the hydrophysical properties of the layers (in particular the unsaturated hydraulic conductivity);

3) the depth of the gravel strata from the surface;

4) the depth and fluctuation of the water-table.

For the determination of the quantity of water available to the soils from underlying groundwater, a model has been developed at the Research Institute for Soil Science and Agricultural Chemistry (RISSAC) of the Hungarian Academy of Sciences (Várallyay 1974a, 1974b, 1980; Várallyay and Rajkai, 1989 and Rajkai and Várallyay, 1989).

The model is based on data from an extensive analysis of the hydraulic properties of undisturbed soil columns from the study area. Using an analysis of steady-state evaporation from a near-surface water-table, the maximum contribution under bare soil conditions can be defined, from uniform or layered soil profiles. This is a conservative estimate which neglects the effects of rooting depth, but it provides an effective method for estimation of the optimal depth of the water-table for capillary supply, the critical depth of the water-table to present adverse effects from poor quality groundwater, and the estimates of the contribution from capillary rise to the soil water budget previously referred to.

The practical significance of the capillary rise contribution to the water balance has already been noted. Locally, it can account for one third of crop water use or more. Its contribution is of greatest importance in dry years and in the summer growing season, and it can be noted that the seasonal variation in groundwater levels is determined primarily by Danube flows, which provide maximum supply in the Szigetköz during the period of maximum vegetation water demand (Várallyay, 1980).

5.1.5 NUTRIENT REGIMES OF THE SOIL

The moisture regime directly determines the water-supply of plants, but has a major influence on the air- and heat-regimes of the soil and its biological activity. All of these factors play a considerable role in the plant nutrient regime of soils: the spatial and temporal variabilities of plant nutrients; their changes, transport, abiotic and biotic transformation; their solubility, mobility and "availability" (Várallyay, 1990).

Hence, in the project area the depth and fluctuation of the groundwater-table (as the most important factors of the moisture regime in the root zone) have significant influences on the regime of plant nutrients in the soil (Várallyay *et al.*, 1993; Gergelyné-Gál and Németh, 1989 and Németh, 1994).

(1) As has already been noted, the moisture regime of soils in the flood-protected area of the Szigetköz is determined mainly by ... ."

Hungary admits here that it is only examining soil impacts in Szigetköz, i.e., in just one part of the Project area. As to the ensuing list of determining factors, it is remarkable that no reference is made to precipitation, which is a critical factor for agriculture, and vegetation in the areas of Szigetköz, where no capillary rise exists over a major part of the year (Similar to Žitný Ostrov, see, Vol. III, Ch. 1, Figs. 21-23).

Table 5.2: Main characteristics and nutrient content of the topsoil of the investigated agricultural fields

Soil characteristics	No. of profile (field)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
pH (KCl)	7.55	7.55	6.95	5.80	7.21	6.93	7.27	7.24	7.35	7.48	6.50	7.38	7.45	7.25	7.22	7.19	7.46	7.40
SP	51	45	51	42	40	44	57	57	60	49	50	52	47	59	65	53	61	57
Total salt content%	0.00	0.00	0.02	0.00	0.00	0.06	0.02	0.01	0.04	0.00	0.01	0.05	0.00	0.00	0.00	0.02	0.00	0.01
$CaCO_3$ %	24.2	23.0	9.70	0.00	7.50	2.20	2.3	17.3	21.0	19.2	1.2	22.9	23.3	12.0	18.1	18.4	20.2	8.6
Humus %	1.52	1.76	3.05	3.10	2.62	2.97	2.23	2.61	2.35	2.07	3.31	2.82	1.86	4.30	4.74	2.70	2.80	3.93
NO_3+NO_2 ppm	14.2	16.6	35.0	15.1	9.20	3.90	14.5	36.5	36.9	5.20	8.60	12.8	33.9	18.5	25.9	10.6	17.3	7.36
P_2O_5 ppm	116	183	319	148	216	248	200	262	132	173	73	174	220	292	347	252	290	197
K_2O ppm	151	193	208	315	464	282	192	214	131	163	116	252	272	133	166	174	123	154
Mg ppm	153	173	295	360	127	147	334	251	276	193	352	310	156	315	349	315	201	306
Na ppm	4	60	6	21	37	3.5	8	10	65	5	64	-	52	77	8	-	13	6
Zn ppm	2.1	2.40	4.80	3.0	4.10	2.40	2.10	1.50	2.90	2.10	7.0	2.10	3.2	1.80	3.9	1.8	2.3	2.0
Cu ppm	5.4	5.4	5.30	7.5	2.4	2.0	44.9	3.20	4.70	2.30	9.0	4.00	3.4	4.80	3.1	4.1	3.3	3.8
Mn ppm	66	74	44.4	16	69	99.4	14.4	22.1	13.1	15.3	100	17	17.8	47.3	22	28	17.2	33
SO_4 ppm	26.0	29.0	22.9	25.0	26.0	4.8	8.0	28.0	13.6	11.1	11.6	33.6	15.9	28.4	9.7	29.3	21.9	8.0
Year	86/87	86/87	1986	86/87	86/87	1986	1989	86/87	1989	86/87	1987	86/87	1989	1989	1989	86/87	1985	1981

Characterization of profiles: Alluvial soils (13), Humous alluvial soils (1,2,3,7,9,10,14,15,16,17), Alluvial meadow soil (8,11,12), Meadow chernozem (4,5,18), Terrace chernozem (6)

The nutrient regime of the agricultural soils of the Szigetköz region is summarized in *Table 5.2*, based on 18 representative locations. The studies indicate that:

1) the nutrient supply is in general medium/good in N and P, poor in K;

2) the recorded yields are medium, good and very good;

3) high nitrate accumulation was found at 4 locations, associated with high levels of applied fertiliser.

The issue of nitrate in groundwater was discussed further in *Chapter 3*.

5.1.6 GENERAL IMPLICATIONS OF THE ORIGINAL PROJECT

It will be evident that a central issue underlying the impact on soils, ecology and agriculture is the effect of changes to the groundwater regime. It has been demonstrated that soil moisture is strongly influenced by the availability of groundwater through capillary rise, that this determines the water available for plant-transpiration and also aeration and temperature of the soil. Thus the nutrient status of the soil is affected and, in the long term, soil structure. Indeed, it has been shown that the present distribution of soils has developed in response to the moisture regime.

Three situations can be defined concerning groundwater-soil water interactions, as a consequence of the GNBS Original Project: 1

(1) Case 1 (*Figure 5.1*) The groundwater is and will remain within the gravel strata; its fluctuation is indicated by small arrows. This effect may extent up to about 30% of the impact area. In these areas, there will be no changes to the soil moisture regime as a result of the Original Project. The capillary transport for the groundwater to the soil is practically zero, independent of the depth of water-table in the gravel strata. These shallow soils have low fertility and particularly high drought-sensitivity, and their productivity is highly weather-dependent.

(2) The groundwater is and will remain fluctuating within the finer-textured sediment. (This effect may extent up to about 30% of the impact area.) In these areas

a) lowering of the water-table will be followed by a certain decrease in the capillary transport from the groundwater to the overlying horizons (Case 2 in *Figure 5.1*);

b) a rise of water-table may result in a certain increase in the capillary transport of water (and soluble materials) from the groundwater to the overlying horizons; however waterlogging may occur in certain areas, with a requirement for remedial drainage measures (not demonstrated in *Figure 5.1*);

The average change in the capillary transport is approximately ±50 mm/year.

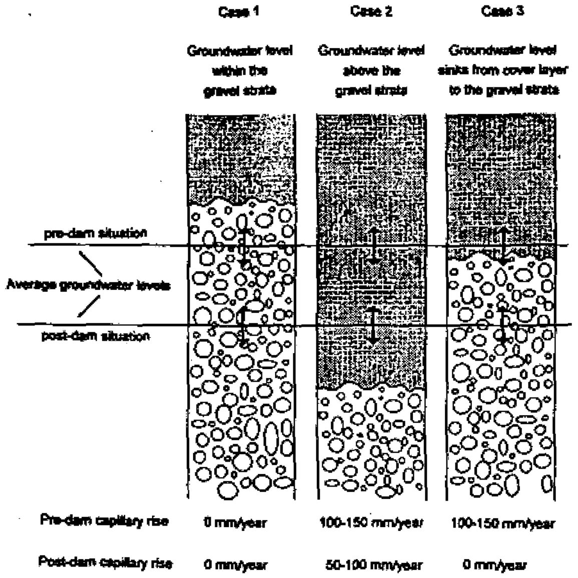

Figure 5.1 The effect of the lowering of the groundwater table on capillary rise

2

(3) Case 3 (*Figure 5.1*). Groundwater is fluctuating at present within finer-textured sediment, but as a consequence of the changes in the hydrology of the Danube-system (e.g. reduction of groundwater-supply from the original riverbed and from the connecting branches and meanders) the groundwater-table will sink to the gravel strata. This effect may extend up to about 30% of the impact area. In these areas the capillary water supply from the groundwater will be radically reduced. This capillary transport reduction may reach 100-150 mm/year or more.

3

Under the given climatic conditions of the area (relatively low atmospheric precipitation and dry vegetation growth period) the relatively favourable (pre-dam) conditions for biomass production (including traditional vegetable production) are based mainly on this capillary water supply from the good-quality groundwater. For agricultural production this ensures high yields and considerably reduces the weather-dependent yield fluctuations (climatic risks). For the natural ecological systems it is essential to their survival. The capillary water-supply is "free of charge", automatic and self-regulating and thus has vital importance in the given region. Consequently, the loss or radical reduction of this moisture supply (50-150 mm/year) can be expected to result in dramatic changes to the soil moisture (and chemical) regimes; in the species spectra and bioproductivity of natural ecosystems; in soil productivity; and in the yields (and yield safety) of cultivated crops.

These consequences for agricultural production cannot in practice be balanced simply with irrigation. Apart from the high cost of irrigation infrastructure, energy and manpower requirements, the potential adverse environmental consequences of irrigation are well known and have occurred extensively world-wide. For the light soils of the region, with poor soil water retention characteristics, frequent irrigation would be necessary, with associated problems of chemical leaching and soil structure degradation, as discussed below. Commonly over-application occurs in practice, with resultant reduction in trafficability and consequent adverse soil structural changes, and also non-uniform irrigation application. In addition, the soils are vulnerable to surface degradation from frequent irrigation application. This is in complete contrast to the naturally occurring processes of subirrigation.

(4) The groundwater remains at present (pre-dam) in the gravel strata, but (as a direct or indirect consequence of hydrological changes in the Danube system) the groundwater-table will rise (at least periodically) to fine-textured sediment. This effect may extend up to about 10% of the impact area. In such cases the moisture-regime consequences are the reverse of the changes mentioned above. In such areas the capillary transport from the groundwater to the overlying horizons may considerably contribute to the moisture supply of the natural vegetation or cultivated crops, a generally beneficial effect.

The estimated territorial distribution of the described cases are in *Chapter 3.4*.

The changes in the moisture regime of soils will be expected to result in important long-term changes to the biogeochemical cycles of various elements, and the chemical regime of the soil. The interrelation between soil water regime and soil structure has been extensively discussed above in the context of soil development. It has been shown that in the long term, soil water regime is a dominant influence on soil structure.

(1) *Three situations can be defined concerning groundwater-soil water interactions, as a consequence of the GNBS Original Project.*

"Three situations": The situations listed are only relevant to Žitný Ostrov and Szigetköz, that is where ground water is influenced by the recharge from the Danube. Where, as downstream in the Danube Valley, the Danube flows along a valley, the river does not have the same influence on "ground water - soil water interaction", as it has a far lower impact on ground water levels (at least on Hungarian territory).

(2) *(3) Case 3 (Figure 5.1). Groundwater is fluctuating at present within finer-textured sediment, but as a consequence of the changes in the hydrology of the Danube-system (e.g. reduction of groundwater-supply from the original riverbed and from the connecting branches and meanders) the groundwater-table will sink to the gravel strata. This effect may extend up to about 30% of the impact area.*

"Reduction of ground water - supply": It is important to stress that this will only occur where Hungary fails to supply water recharge into its side arms as envisaged by the Project. It has not occurred on Slovak territory, which has seen an improvement of water supply to soils via capillary transport in comparison with pre-dam conditions. <u>See</u>, Vol. III, at p. 13, and, also, Ch. 3, Secs. 1 and 2.

Similar geological conditions exist on both sides of the Danube, in the floodplains region, as Hungary accepts, and thus this improvement is equally available to Hungary.

"30% of the impact area": Again, it is stressed that the impact area in Hungary is <u>only</u> Szigetköz. According to HC-M, Vol. 4, Annex 20, the area affected by loss of groundwater is 4,200 hectares (at p. 771) out of the 22,000 hectares used in Szigetköz for agricultural production (at p. 768). This gives a figure of 19%, not 30%.

(3) *Under the given climatic conditions of the area (relatively low atmospheric precipitation and dry vegetation growth period) the relatively favourable (pre-dam) conditions for biomass production (including traditional vegetable production) are based mainly on this capillary water supply from the good-quality groundwater.*

"Dry vegetation growth period": The months May-August, <u>i.e.</u>, the vegetation growth period, are in fact characterised by above average precipitation - <u>see</u>, Vol. III, Ch. 8.

"Based mainly": This is contradicted by Hungary's own technical annexes. In fact, the "key factors" are the "amount and periodicity of rainfall" - <u>see</u>, HC-M, Vol. 4, Annex 20 (at p. 768). This annex estimates that crop yield loss in 1993 was due primarily to weather conditions" (11.9%), second to "technological faults" (4.4%) and only third to groundwater deficiency (4.3%).

The Project may have a beneficial impact on evapotranspiration. <u>See</u>, Vol. III, Ch. 3, Sec. 3 and Ch. 8.

Of particular concern is the effect of carbonate accretion. The high carbonate content of the alluvial soils has been discussed, and reflects their geological origin. The soil structure is sensitive to the development of carbonate accumulation layers, lime concretions and lime coated gravels. These features are commonly observed in their early stages in the region, for example in the Moson Terrace soils (especially in the transition zone with the alluvial terrace and the Hanság Depression) and, of particular interest here, in the soils to the East of Győr. These effects can lead to a hard and impervious petrocalcic horizon or even a solid carbonate hardpan at the boundary of the fine-textured sediment and the gravel strata. (Várallyay, 1983)

The main expected chemical and structural changes are summarized as follows:

1) When groundwater-tables are lowered, the wetting of soils will be reduced, leading to the reduction of their hydromorphic features, and the ratio between the aerobic and anaerobic decomposition of organic material will change. This will lead to increasing mineralisation rates of plant residues as applied organic fertilisers; the consequence will be a loss of soil fertility. Patterns of water and solute transport will change, leading to increased downward fluxes. Downward movement of fine mineral particles from the fine-textured upper horizons can lead to blocking of the large macropores of the gravel strata with, as above, the tendency to develop a cemented gravel layer.

2) Where water-tables rise, increases in soil moisture can be expected. There may be favourable effects of increased sub-irrigation. However, a number of adverse consequences can also be anticipated. These include loss of aeration, leading to unfavourable changes in soil biota, microbiological processes and nutrient regime; problems of tillage and general access by agricultural machines; carbonate accumulation, with implications as described above; secondary salinisation /alkalisation processes under the influences of a stagnant shallow water-table and high groundwater salinity. This last problem is not of major significance for the well drained the Szigetköz area, but is a serious environmental hazard on the Slovak side of the Danube, particularly in the low-lying, poorly-drained areas of the Eastern Žitný Ostrov region. 1

2

3) It must also be recognised that changing groundwater flow paths may lead to pollutant transport, and that changes in groundwater quality may adversely affect soil conditions.

5.2 AGRICULTURE

by Howard Wheater
(based on Palkovits, 1994a-d and
Volume 4, Part II, Annex 20)

5.2.1 EXISTING CONDITIONS PRIOR TO THE PROJECT

3

The Szigetköz is a valuable, fertile agricultural area, with a crop yield 8-12% higher than the regional average. Approximately 30,000 hectares of land are used for agriculture, of which some 22,500 hectares are used for arable production. Historically, the region has been characterised by large agricultural estates, and systematic data collection on agricultural production has been carried out since 1980 for an area of about 20,000 hectares, which includes the production of the 11 most important field crops of the region (some 800-900 fields). Since 1989 major change has taken place to the organisation of agriculture, involving privatisation.

The main factors influencing agricultural productivity are: the precipitation, the groundwater levels and the agricultural management practices

Precipitation

The amount of rainfall and its temporal distribution, especially during the growing season, are key factors influencing soil moisture and, in turn, agricultural productivity.

4

The annual average precipitation (1951-1990) at Mosonmagyaróvár and Győr was 573 and 548 mm, respectively. However, over the last seven years there has been an 11% reduction in annual rainfall at both sites and a 12-14% reduction in rainfall during the growing season.

Groundwater

5

There are over 200 observation wells in the Szigetköz. Hence water-table conditions are well defined and the data have been used to quantify average values over the growing season. These indicate that in the period 1980-1992, 53% of the farmland had sufficient groundwater available for natural sub-irrigation due to capillary rise in the soil profile (see *Chapter 5.1*) to meet crop needs.

For 23% of the monitored arable fields, the water-table was within 2 m of the surface, providing a continuous moisture supply. For 30% the groundwater was between 2 and 3 m below the surface, providing either a constant or a temporary water supply. When the water-table occurred between 3 and 5 m below ground

surface, moisture supply was limited, and for depths greater than 5 m, no moisture supply occurred.

Agricultural management practices

These have a number of elements, for example, crop rotation, cultivation, seed-bed preparation, fertiliser application, weeding, pest-control, irrigation, harvesting, etc. The quality of each element has a direct impact on agricultural productivity, which in turn is linked with environmental conditions. Any defect in a given component will put optimum yield at risk. In the later part of the 1980-1992 period, standard management practice met the basic requirements. However, from 1992 technical problems began to emerge. For example, inadequate application of fertiliser had some effects on average recorded yield.

Data analysis

A multi-factor impact analysis was carried out to understand the effects of the key factors on productivity for the 1980-1992 period. All crop species and soil-types were analysed with respect to water-table conditions and yields for dry, average, and wet years. Management practices, especially fertiliser application, were also included. Crops of less than 1,000 ha/year were excluded as providing an insufficient statistical base.

The conclusions were that for all crop species and soil types, yields were linked to water-table levels. Climatic dependence was illustrated by a 9% yield increase in wet years and 9.5% yield loss in dry years, in comparison with average conditions.

For average rainfall years, areas with water-tables within 2 m of the surface showed a yield increase of 10.8%, and for water-tables between 2 m and 3 m below surface the yield increase was 7.4%. The corresponding figures for dry years were more dramatic, namely a 15-19% yield increase for high water-table conditions and 10-11% increase for 2-3 m water-table depths.

5.2.2 IMPACTS OF THE ORIGINAL PROJECT

6

130 hectares of fields and 260 hectares of grasslands were lost to agricultural production due to construction activities. The effects of groundwater level on crop yields have been discussed, and in *Chapter 3* the areas affected by groundwater level reduction were estimated. Preliminary estimates of associated costs (Palkovits, 1994) were 90-100 million HUF per year due to yield loss. Irrigation costs to replace groundwater supply were similarly estimated to be 66 million HUF on the basis of 1994 prices.

5.2.3 IMPACTS OF VARIANT C

Yield reduction

7

Following the diversion of the Danube, large-scale decreases in groundwater levels in the Szigetköz were observed. Those have been discussed in *Chapter 3*, and illustrated in *Plates 3.13* and *3.14 (Volume 5)*. Considering the area of the Middle Szigetköz for which agricultural survey data are available, 4,200 ha of arable land lost its groundwater moisture supply. Further areas of the Upper and Middle Szigetköz were similarly affected.

8

Impacts on agriculture are complex, as changes in the other factors affecting productivity also occurred. 1993 was the driest and hottest year of the period investigated (from 1980 onwards). In the growing seasons, observed rainfall in the Mosonmagyaróvár-Győr area was 87-118 mm (a 40-year low). Precipitation in the first half of the year was unusually low, and this had a large influence on summer-harvest crops. The situation improved for autumn-harvest crops due to heavy rainfall in late July and rainfall in September and October.

Under these dry conditions, the effects of groundwater were particularly important. However, due to structural changes in the agricultural sector and other factors, fertiliser application was reduced, to only 24.8% of the 1989 value, 23% of wheat growing areas had late sowing, there was some deterioration in the quality of seed, and a reduction in field preparation. It is evident that a simple interpretation of observed data is not possible.

9

The observed data for yield in 1993 in comparison with 1980-1992 are given is *Table 5.3*. The weighted average yield of the 11 main crops was reduced by 20.5%. Using the multi-factor analysis, it is estimated that 22.2% of this reduction is due to reduced groundwater levels as a result of the diversion of the Danube. This table also shows the estimated proportion of crop financial losses due to Variant C, amounting to 49.7 million HUF.

Irrigation

10

Data from 1990 (a relatively dry year) indicate that a total area of 1153 ha of the Middle Szigetköz received irrigation (average application: 106 mm), predominantly (62%) for sugar beet and mainly from groundwater sources. In 1994 significant changes have occurred. 18% of wells are unusable, and 50% of wells are operating at half-capacity. 42 out of 44 dug-wells now provide negligible water yield. Small canals and open drains have either dried up or have minimal water. It is estimated that irrigation supply has been reduced by 40% and costs increased by 60-80%.

(1) *This last problem [salinisation] is not of major significance for the well drained Szigetköz area, but is a serious environmental hazard on the Slovak side of the Danube, particularly in the low-lying, poorly-drained areas of the Eastern Žitný Ostrov region.*

Salinisation is a long-term problem in parts of Žitný Ostrov, but has not been aggravated in any way by the G/N Project - see, Vol. III, p. 55. In fact, the Project provided a partial solution to this problem, allowing for the drainage of the low-lying areas which, coupled with irrigation, would lead to the eventual flushing out of excess salt.

(2) *It must also be recognised that changing groundwater flow paths may lead to pollutant transport, and that changes in groundwater quality may adversely affect soil conditions.*

"Changing groundwater flows": Changes in pollutant transport may in some cases be beneficial. Such a broad reference to "changes in groundwater quality" does not permit scientific analysis; but in any event no adverse changes in quality have been noted or are anticipated on the basis of current monitoring data. See, Vol. III, Chs. 1 and 2.

"Soil conditions": It is useful to refer to the actual impact of Variant "C" in Žitný Ostrov on soil conditions - impacts guaged on the basis of data collected from 20 different monitoring stations. See, Vol. III, Ch. 3, Sec. 2. These show that in comparison with pre-dam conditions there have been no negative changes to the soil water or soil moisture regimes and that the properties of soils have in all respects been preserved.

"The results of the ground water and soil monitoring of Žitný Ostrov confirmed that, after putting the Gabčíkovo Project into operation, no changes of the ground water levels which would cause the negative changes of the soil water regime did occur.

At all monitoring sites the original soil moisture regime was preserved. Due to this the original state of other soil properties and processes is being preserved, too, including their evolution trends. It is confirmed also by the results of the monitoring of soil salting and ground water mineralisation.

The overall conditions for agricultural production on Žitný Ostrov have been preserved and in the area of the reservoir's influence they are even slightly improved."

(3) *The Szigetköz is a valuable, fertile agricultural area, with a crop yield 8-12% higher than the regional average.*

Note again that Hungary only deals with Project impact in one area, i.e., Szigetköz. In other words, Hungary considers that the agricultural impact of the Project in other areas is too minimal to warrant comment.

(4) *However, over the last seven years there has been an 11% reduction in annual rainfall at both sites and a 12-14% reduction in rainfall during the growing season.*

"11% reduction": This is in no way related to the G/N Project. In fact, inadequate rainfall contributed very significantly to crop yield drops in Szigetköz in 1993. According to Hungary's calculations, this accounted for almost three times as much yield loss as did groundwater level falls (due to Hungary's refusal to implement the recharge of its side arms).

(5) *These indicate that in the period 1980-1992, 53% of the farmland had sufficient groundwater available for natural sub-irrigation due to capillary rise in the soil profile (see Chapter 5.1) to meet crop needs.*

For 23% of the monitored arable fields, the water-table was within 2 m of the surface, providing a continuous moisture supply. For 30% the groundwater was between 2 and 3 m below the surface, providing either a constant or a temporary water supply.

This means that some 47% of Szigetköz farmland had insufficient groundwater available for capillary rise during the 1980-1992 period and, hence, could in no way be affected by groundwater level decreases due to Hungary's failure to implement a direct water recharge into its side arms - because the groundwater was already below the soil layer.

As to the Slovak side, see, Vol. III, Ch. 1 and Figs. 21-23.

(6) *130 hectares of fields and 260 hectares of grasslands were lost to agricultural production due to construction activities. The effects of groundwater level on crop yields have been discussed, and in Chapter 3 the areas affected by groundwater level reduction were estimated. Preliminary estimates of associated costs (Palkovits, 1994) were 90-100 million HUF per year due to yield loss. Irrigation costs to replace groundwater supply were similarly estimated to be 66 million HUF on the basis of 1994 prices.*

Hungary's losses "due to construction activities" are minimal compared to those on the Slovak side. The thousands of hectares required for the construction of the reservoir, the bypass canal and Gabčíkovo were understood and agreed by the Treaty parties as a necessary consequence of proceeding with the G/N Project.

It is not understood how "preliminary estimates" can be based on a 1994 study. The "estimates" are clearly based on Hungary's concept of the "Original Project" and so are irrelevant. In any event, they appear exaggerated. The relevance of the estimates is further questioned because the Project provided for irrigation systems construction as part of each parties' national investments.

Conditions for agricultural production in Žitný Ostrov after the implementation of Variant "C" have remained stable and have improved in certain areas. See, Vol. III, p. 13 and, also, Ch. 3, Sec. 1.

(7) *Following the diversion of the Danube, large-scale decreases in groundwater levels in the Szigetköz were observed.*

These decreases were due to Hungary's failure to implement the direct recharge of its side arm system.

On Slovak territory, an increase of groundwater available for capillary rise has been identified by monitoring. See, Vol. III, p. 44.

(8) *Impacts on agriculture are complex, as changes in the other factors affecting productivity also occurred. 1993 was the driest and hottest year of the period investigated (from 1980 onwards).*

Impacts are indeed complex especially as, according to Hungary, "other factors" were far more important to yield reduction in 1993 than the diversion of the Danube. Note, for example, that precipitation in the 1993 growing season was at a 40 year low and that, in comparison with 1989, only 24.8% of fertiliser capacity was applied. See, HC-M, Vol. 4, Annex 20 (at p. 771).

There is no evidence to suggest that Slovakia has suffered yield reduction due to Variant "C". However, like Hungary, Slovakia has experienced loss of productivity due to changes in the management of agricultural production.

(9) The observed data for yield in 1993 in comparison with 1980-1992 are given in Table 5.3. The weighted average yield of the 11 main crops was reduced by 20.5%. Using the multi-factor analysis, it is estimated that 22.2% of this reduction is due to reduced groundwater levels as a result of the diversion of the Danube. This table also shows the estimated proportion of crop financial losses due to Variant C, amounting to 49.7 million HUF.

According to HM, para. 5.121, there is "a major difficulty in interpreting short term effects" of Variant "C" on agriculture. Similarly, the "Scientific Evaluation" (at p. 2) notes that interpretation of observed impacts is "difficult". Hungary is no longer handicapped by such difficulties here when it comes to presenting a precise estimate of the "crop financial losses of Hungary due to Variant C". Such losses were in fact directly due to Hungary's decision not to implement the direct water recharge into its side arms. In any event, it is surprising that they can suddenly be so precisely quantified. This is less than convincing.

(10) In 1994 significant changes have occurred. 18% of wells are unusable, and 50% of wells are operating at half-capacity. 42 out of 44 dug-wells now provide negligible water yield. Small canals and open drains have either dried up or have minimal water. It is estimated that irrigation supply has been reduced by 40% and costs increased by 60-80%.

"Significant changes": These can only be expected. Given the drop in groundwater levels (due to Hungary's failure to implement direct recharge into its side arms), it is evident that certain shallow wells will become "unusable" or less efficient and that surface water conduits will carry less water. But the underlying aquifer has a depth of up to 600 m - see, "Scientific Evaluation", at p. 48. One solution is thus to excavate deeper wells, as Hungary accepts at HC-M, Vol. 4, Annex 20 (at p. 778). A more constructive approach - adopted by Hungary through its signature of the Agreement of 19 April 1995 - is to increase ground water levels by recharging water directly into the Szigetköz side arms.

No similar impacts have been felt in Žitný Ostrov - see, Vol. III, Ch. 1.

Table 5.3: Yield loss and the influential conditioning factors in 1993 compared to the average values of the period between 1980-1992 (cf. Volume 4, Part II, Annex 20)

Species	Yield loss		Total		Weather conditions		Groundwater		Techn. faults	
	tons/ha	%	tons	1,000 HUF	tons	1,000 HUF	tons	1,000 HUF	tons	1,000 HUF
Wheat	1.52	-27.6	9,287	78,940	4,756	40,426	2,449	20,816	2,082	17,968
Winter barley	1.63	-33.7	916	7,328	733	5,864	—	—	183	1,464
Spring barley	1.81	-35.8	3,207	25,656	2,001	16,008	683	5,464	523	4,184
Pea(sowing)	1.07	-38.8	1,582	23,730	1,072	16,080	194	2,910	316	4,740
Pea	1.69	-48.4	187	5,610	152	4,560	—	—	35	1,050
Sunflower	—	+31.3	—	—	—	—	—	—	—	—
Potatoes	4.31	-15.8	879	10,548	578	6,936	125	1,500	176	2,112
Corn	1.51	-22.4	5,483	54,830	3,136	31,360	1,020	10,200	1,327	13,270
Silage corn	0	0	1,217	1,825	395	592	505	757	317	476
Sugar beet	2.86	-7.0	4,959	12,397	2,370	5,925	1,760	4,400	829	2,072
Alfalfa	0.92	-11.3	557	2,785	340	1,700	101	505	116	580
Grass	—	—	2,346	—	—	—	1,064	3,192	—	—
Total			30,620	223,649	15,533	139,451	7,901	49,744	5,904	47,916

It is estimated that to restore lost irrigation capacity to a minimum, required level would cost approximately 10,08 million HUF. To establish optimal irrigation capacity on the previously irrigated area could cost some 12 million HUF.

The use of irrigation to compensate for natural groundwater sub-irrigation has many disadvantages, as discussed in *Chapter 5.1*. However, preliminary estimates of associated costs for the Middle Szigetköz are in the range 19-39 million HUF at 1994 prices for new wells and associated equipment, and 22.1-30.6 million HUF annually for additional water costs.

1 In total, to provide a minimum level of irrigation to mitigate damage would cost 51.2 million HUF; optimal irrigation is estimated to cost 81.6 million HUF.

This is in addition to the 10.08-12.0 million HUF to restore lost irrigation-capacity and excludes the cost of yield reduction defined above as 49.7 million HUF.

5.3 FORESTRY

by László Magas

5.3.1. EXISTING CONDITIONS PRIOR TO THE PROJECT

2 From the point of view of forestry the impact area of the Barrage System on the Hungarian side mainly includes the Szigetköz and the narrow floodplain of the Danube between Gönyű and Szentendre.

The Szigetköz

3 The floodplain of the Szigetköz has been influenced to some extent by flood protection but is still in a semi-natural state (see *Chapter 4*). Its functioning is vulnerable to change because of its dependence on the flow regime of the Danube. This was demonstrated by the unfavourable changes and decline of the forest communities accompanying the changes in the ecological conditions of the natural floodplain downstream of Bratislava (Cifra, 1987). 4 The composition and the productivity of the forest communities of the floodplain in the Szigetköz are basically determined, within the framework of river regulations, by the regime of the Danube (Járó, 1977 and Halupa and Járó, 1987). In addition, timber productivity is determined by the genetic characteristics of the trees and climatic and soil conditions as pointed out in *Chapter 5.1* and *5.2*.

5 The area belongs to the climatic region of Kisalföld. Its macroclimate represents a transitional region with dry, warm and hot summers as well as with moderately dry, moderately warm and mild winters. Within its macroclimate, a specific meso-

climate evolved in the floodplain of the Szigetköz. The numerous branches of the Danube, oxbow lakes, lowland areas without drainage, marshes and reed areas create substantially more humid conditions than the ones characteristic to the macroclimate of the whole Szigetköz.

6 The water regime combined with the morphology of the floodplain shows its effect on forest communities. This is especially true for the Szigetköz, which, without the Danube, would be a wooded steppe, and look like the Great Hungarian Plain, where forests struggle to survive, and forest cover is substantially lower than elsewhere in the country. In the wooded steppe climate, the precipitation is not sufficient to sustain forests, thus forest communities survive and develop only on such habitats where some type of extra water is available to them in addition to rainfall.

The hydrological conditions of the floodplain depend on the elevation of the area above water level, which affects the water-table levels and for how long the area is inundated. The rising of the groundwater-table caused by Danube floods has at least the same significance as actual surface water inundations. Accordingly, before the diversion of the Danube three main types of forested habitats could be distinguished here (proportions calculated from the database of the Forestry Management Planning Service (1988, 1994)):

1) Areas with medium high elevation, flooded 1-3 times a year for short periods only. 20% of the active floodplain (between dykes) belongs to this type;

2) Areas with medium low elevation, flooded 2-5 times a year, the duration of inundated conditions can make up one sixth of the vegetation period. The forest is continuously supported by groundwater supply. This is 71% of the active floodplain;

3) Areas with low and extremely low elevation, submerged under conditions of higher than 430 cm gauge value at Dunaremete, which is characteristically longer than one sixth of the vegetation period (7%);

4) The remaining area belongs to the high and extremely high habitats (2%).

Soils of the forests in the Szigetköz have developed on the gravel deposited by the river. Accordingly all stages of soil-development can be found in the area from the raw to mature alluvial loam (discussed in *Chapter 5.1*). They are usually calcareous, which negatively affects tree growth only in drought stressed conditions.

Characteristic natural forest communities of the Szigetköz are as follows:

1) Bushy willow stands *(Salicetum purpureae)*
These willow stands developed in the deepest sites, representing the pioneer arboreal stage of forest succession.

2) White willow forest *(Salicetum albae)*

This is the dominant, frequently flooded forest-type of the river-bank.

3) Willow-poplar gallery forest *(Populo-Salicetum)*
This mixed forest occupies slightly more elevated places than the previous white willow stands. It is dominated by the black and the grey poplar, white willow and alder. A very productive forest.

4) Oak-ash-elm forest (*Ulmo-Fraxino-Quercetum roboris*)
It covers the elevated areas of the floodplain which are rarely inundated. It is characterised by high diversity of trees and bushes.

5) Grey poplar forest (*Populetum canescensis*)
This forest grows in elevated places, where soil conditions are unfavourable to hardwood forest.

Section between Gönyű and Szentendre

This section, although fairly long, does not represent as significant economic value as that of the Szigetköz. The narrow gallery forest, however, is a very valuable ecological aesthetic and recreational contribution to the landscape.

5.3.2 HISTORICAL DEVELOPMENT

7 Natural forest trees of the Szigetköz have been partly replaced by hybrid-poplar varieties in the last 50 years. Particularly the willow-poplar forest communities of the active floodplain were affected. This change, however, has left the understorey and the animal life more or less intact.

At the same time, new plantations were established in places of pastures and meadows which now represent 20-30% of the forest. The total ratio of the hybrid-poplar is 64% in the active floodplain.

Prior to the onset of construction there were forests on 8,600 ha in the Szigetköz. Out of this, 1,000 ha have been cleared. Actually there are forests on 4,443 ha in the active floodplain and 3,161 ha in the flood-protected area (outside of dykes).

8 The largest proportion of timber production is made up of poplar, ash, willow, and oak. Because of the (formerly) exceptionally favourable habitat conditions this area is recognised as the most productive timber resource of the country. The yearly growth of timber in the active floodplain can reach 25-30 m^3/ha in some islands. The average is 16 m^3/ ha which is more than two times greater than the average of the country (Forestry Management Planning Service, 1994). The yearly timber production was 50-60,000 m^3 before the Project.

(1) *In total, to provide a minimum level of irrigation to mitigate damage would cost 51.2 million HUF; optimal irrigation is estimated to cost 81.6 million HUF.*

The figures are meaningless. Groundwater may be simply and cheaply replenished through direct recharge into the Szigetköz side arms. Note, also, the complaint of Hungarian scientists as to long term inadequate irrigation contained in HC-M, Annex 20 (at p. 778): "The necessity for increased investment in irrigation conditions has constantly been emphasised in our annual reports. That this has not always been realised may be connected with economic factors."

Slovakia has been able to decrease its expenditure on irrigation due to increased groundwater levels in Žitný Ostrov following the putting of Variant "C" into operation.

(2) *From the point of view of forestry the impact area of the Barrage System on the Hungarian side mainly includes the Szigetköz and the narrow floodplain of the Danube between Gönyü and Szentendre.*

"The Szigetköz": The impression is given that forestry is important for the whole of Szigetköz, rather than just selected areas (mainly within the active floodplain).

"The narrow floodplain": The narrow stretch along the Danube is not a floodplain and extends only 1-100 metres inward on each side of the Danube. Its importance in terms of forestry is non-existent and Hungary makes no attempt to assess either its importance or the Project's impact on it in the following sub-chapter.

(3) *The floodplain of the Szigetköz has been influenced to some extent by flood protection but is still in a semi-natural state (see Chapter 4).*

"A semi-natural state": The active floodplain in Szigetköz has been reduced since last Century to a strip along the Danube 1-5 km wide. Because of anti-flood and other measures in the upper reaches of the Danube in Austria and Germany, flooding has become more frequent and more severe - see, Vol. III, p. 9. Alongside this, as Hungary accepts (at "Scientific Evaluation", p. 183), 64% of its floodplain forest consists of one broad species type - a hybrid poplar, planted for commercial harvesting, which is specifically unnatural for the floodplain area.

Hungary's failure to mention the poor conditions for certain trees in the "semi-natural" state is significant. These are summarised at Vol. III, Ch. 4.

(4) *The composition and the productivity of the forest communities of the floodplain in the Szigetköz are basically determined, within the framework of river regulations, by the regime of the Danube (Járó, 1977 and Halupa and Járó 1987).*

It is important not to underestimate the impact of "river regulations" prior to 1992 - an impact that was undoubtedly negative - see, Vol. III, pp. 74-80. In fact, "composition and productivity" are primarily determined by the species that Hungary has chosen to plant as a response to the adverse impacts of river regulation (particularly post 1960), not "the regime of the Danube" as such.

(5) *The area belongs to the climatic region of Kisalföld. Its macroclimate represents a transitional region with dry, warm and hot summers as well as with moderately dry, moderately warm and mild winters.*

Compare, "Scientific Evaluation", p. 164: "The area has a continental climate, with considerable extremes (cold winter, hot summer) ... ." This is quite a different description of the climate of the region. For a detailed evaluation, see, Vol. III, Ch. 8.

(6) *This is especially true for the Szigetköz, which, without the Danube, would be a wooded steppe, and look like the Great Hungarian Plain, where forests struggle to survive, and forest cover is substantially lower than elsewhere in the country.*

This comment is absurdly irrelevant. It is like imagining Switzerland without the Alps.

(7) *Natural forest trees of the Szigetköz have been partly replaced by hybrid-poplar varieties in the last 50 years.*

"Partly" in fact means at least by 64% according to the "Scientific Evaluation" at p. 183.

(8) *Because of the (formerly) exceptionally favourable habitat conditions this area is recognised as the most productive timber resource of the country. The yearly growth of timber in the active floodplain can reach 25-30 m^3/ha in some islands.*

"The most productive timber resource": This economic evaluation of the worth of the floodplain forest can have no relevance to Hungary's legal claims. The forests of the Szigetkõz also represent only a fraction of the Hungarian forests along the Danube between Bratislava and Budapest, which forests are not affected by the Project, as depicted on Plate 1.1, Vol. 2, HM.

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5.3.3 IMPACTS OF THE ORIGINAL PROJECT

1

The average discharge of 2,000 m^3/s would have been reduced to 50-200 m^3/s in the main channel between Dunakiliti and Ásványráró. It was intended to supply 15-25 m^3/s to the Hungarian side branch system (see *Chapter 3.2*). The riparian forest was recommended to be replaced by xerophytic, drought tolerant tree species. These species are unfavourable for valuable timber production and function as "green area" only.

2

In the section between Gönyű and Szentendre altogether 150 ha of forests were cleared in connection with the construction. Forestry started to suffer very substantial impacts in the active floodplain area as well. 1,000 ha of highly productive forests were cleared in the floodplain area. By now, this area could have produced (since 1986) 17,000 m^3 timber a year (Magas *et al*, 1994). The actual production of timber of the Szigetköz area is 40-45,000 m^3 (*Table 5.4*).

Table 5.4: The size and the timber production of the forests of the Szigetköz before the Project and currently

	Before the Project	Actual
Forest area (ha) *	8,600	7,600
Yearly timber production (m^3/year)	50,000-60,000	40,000-45,000

* mainly used for timber production

5.3.4 IMPACTS OF VARIANT C

Two years passed since the unilateral river diversion. All the effects, damage and extra expenditure caused by this action have been registered by researchers and by the affected forest authorities as well. Two years are too short in the life of a forest, consequently the actual observations should be supplemented by sound predictions of the future.

3

Because of the large groundwater level drop caused by the diversion of the Danube and the drought conditions, reduction of circumference increment of the trees occurred especially in drier places. The consequences of the diversion of the Danube can be observed, for example, in the Dunasziget and Dunakiliti sampling area (*Figure 5.2* and Halupa, 1993).

4

Most damage have been demonstrated in the forests of the active floodplain, where 93 percent of the trees (poplar and willow) requires additional water which, could not have been provided due to the 2-3 m decrease of the groundwater level (see *Chapter 3*). The lack of the fertilising effect of the flood also contributed negatively. Accordingly:

1) willows started to decline and die along the banks of the main channel (*Plate 12, Volume I*);

2) reduced growth and impoverished health condition of the trees has been registered;

3) rodents proliferated, secondary pests became abundant.

5

In forestry operation, transportation became more difficult and much more expensive. The former aquatic transport facilities had to be replaced by terrestrial vehicles and machines. The Szigetköz area (hundreds of islands) is not easily accessible any more, the length of road per hectare is less than one metre in the active floodplain. Transportation length also increased, since the wood-working industry is located along the shore-line of the Danube.

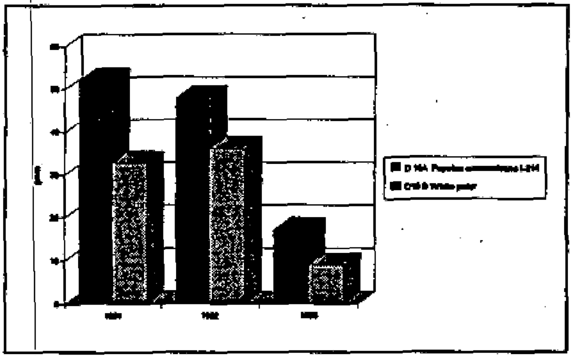

Figure 5.2: Circumference increment of trees in the Dunasziget experimental forest in 1991, 1992 and 1993

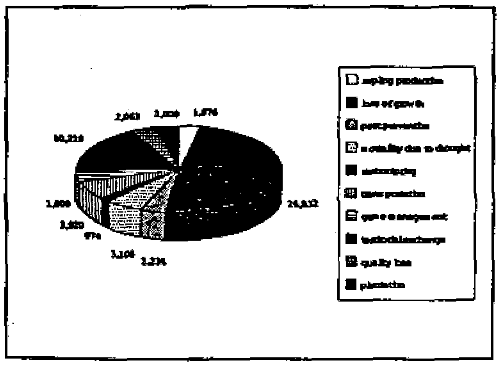

Figure 5.3: Extra costs and losses of the two years following the diversion – units in thousands of HUF (Magas et al., 1994)

6

Figure 5.3 shows the distribution of the estimated cost of damage to the forestry of the two years following the diversion of the Danube. The total volume of extra cost of the two years is 55 million HUF (Magas *et al.*, 1994).

5.3.5 EVALUATION OF REMEDIAL MEASURES

Remedial measures were implemented fairly quickly to supply water to the oxbows and canals of the old floodplain (flood protected area). The "active" floodplain could only get some water (6 m^3/s) first of all in the summer of 1993 (*Chapter 3.2*). These measures provided only negligible effects on the nearby forests.

Regular pumping of 15 m^3/s water from the main channel to the side-arm system started in August 1994. Its effect on the forests could not have been demonstrated so far.

5.3.6 CONCLUSIONS

7

All forests of the Szigetköz require the direct or indirect effect of the Danube water. This had been provided by the relatively high and fluctuating groundwater level, the water of the floods, and the nutrient rich sediment deposited by the regular floods. The floods also eliminated many pests in the soil.

8

These floodplain habitats are exceptionally productive and have been intensively exploited by improved hybrid-poplars in the last decades. This favourable situation was first radically upset by the construction work reducing the valuable forested area and interfering with the aquatic transport of the forestry. Then the deviation of the Danube discharge into Slovak territory created a real catastrophe to the floodplain forests. Substantial damage has been demonstrated and further losses are likely to occur. If the presently well balanced age distribution of the trees cannot be maintained because of general (age independent) decline, the ecological and economical balance of the region will be violated for centuries, independently of any water management optimization.

5.4 FISHERY

by Gábor Guti

SUMMARY

The study evaluates the impact on fish under the Gabčíkovo-Nagymaros Barrage System–the effect of changes in flow and sediment regime in the waters of the floodplain. It reviews the impacts of the Original Project in aspects of fishery and the changes in the fish populations of the Danube predicted by Slovak scientists in 1981. The commercial and recreational fishery statistics presented, as well as some estimated biomass data, verified the detrimental effects of the Gabčíkovo-Nagymaros Project on fish. The most important impacts and the forecast damage in relation to the operation of Variant C, are summarised as a reduction of the fishery potential of the Middle Danube.

5.4.1 THE NATURAL SYSTEM

The great variability of the longitudinal, transversal and vertical dimensions of the fluvial fish hydrosystem in the Little Danubian Plain resulted in the development of a diverse potamic biocoenoses unique in Europe. Before river regulation, the longitudinal variability used to manifest itself in a high gradient, turbulent section upstream of the Little Danubian Plain, a shallow braided stretch, and a low gradient, deeper downstream section. The transverse dimension includes the branches, dead arms and wetlands, that is, all the aquatic, semi-aquatic and terrestrial ecosystems within the alluvial plain, which were interconnected with the lotic environment of the river. The vertical dimension includes the alluvial subterranean waters and their organisms. (see *Chapter 4*).

(1) *The average discharge of 2,000 m³/s would have been reduced to 50-200 m³/s in the main channel between Dunakiliti and Ásványráró. It was intended to supply 15-25 m³/s to the Hungarian side branch system (see Chapter 3.2).*

Throughout its "Scientific Evaluation", Hungary insists on the figure of 15-25 m³/s. But Hungary designed and built, as part of the agreed Project, an offtake into its side arm system at Dunakiliti with a capacity of 250 m³/s. It is therefore not understood why the figure 15-25 m³/s is rigidly adopted as the only possible amount to be supplied to the Hungarian side branch system. Just as with regard to its concept of the "Original Project", Hungary chooses the worst factual scenarios that will fit its case. The Agreement of 19 April 1995 envisages the average discharge into the side arms through Dunakiliti of about 40 m³/s plus 43 m³/s through the Mosoni intake.

(2) *By now, this area could have produced (since 1986) 17,000 m³ timber a year (Magas et al, 1994). The actual production of timber of the Szigetköz area is 40-45,000 m³ (Table 5.4).*

This irrelevant statement as to the potential economic value of forestry cleared by Hungary in 1986 pursuant to the 1977 Treaty is a reflection of what appears to be the underlying purpose of Hungary's "Scientific Evaluation": to invite the Court to question the decision in 1977 of the Treaty parties in approving the G/N Project, rather than the Project's environmental effects in 1989, when Hungary breached the Treaty.

(3) *Because of the large groundwater level drop caused by the diversion of the Danube and the drought conditions, reduction of circumference increment of the trees occurred especially in drier places.*

The measure of the reduction of circumference increment is not a reliable tool for measuring short term impacts. See, Vol. III, p. 67. More accurate measures are the leaf area index (surface area of leaves per hectare of tree stand) and growth season leaf loss (of sample trees at a chosen moment before the autumn fall).

The results of detailed monitoring on the Slovak side of the Danube are contained in Vol. III, Ch. 3, Sec. 3. These results show no significant changes in the leaf area index in the Slovak inundation area since the diversion and no leaf loss (except for in the area just upstream of the Dobrohošť intake, where no recharge into the side arms has yet been effected and which would easily be cured through the construction of an underwater weir in the old riverbed). In some areas, a positive trend in leaf loss has been recorded. See, Vol. III, p.67.

See, also, Vol. III, pp. 81-87.

(4) *Most damage have been demonstrated in the forests of the active floodplain, where 93 percent of the trees (poplar and willow) requires additional water which, could not have been provided due to the 2-3 m decrease of the groundwater level (see Chapter 3).*

There is no evidence of damage occurring in the Slovak floodplain and considerable evidence of improvement, particularly in the floodplains south of Bratislava and close to the Čunovo reservoir. See, Vol. III, at pp. 81-87.

The assertion that additional water "could not have been provided" is wholly incorrect. Additional water could easily have been provided but for the intervention of the Hungarian Parliament preventing the installation of underwater weirs. See, SC-M, para. 8.11.

The figure of 2-3 m is exaggerated as seen from Hungary's own plate (HC-M, Plate 6a). The major decrease was limited to the stretch close to the Danube.

(5) In forestry operation, transportation became more difficult and much more expensive.

This relates to the economics of Hungary's forestry activities. It is not clear how it relates to the Danube damming. It does not appear relevant to Hungary's legal arguments based on environmental risk.

(6) Figure 5.3 shows the distribution of the estimated cost of damage to the forestry of the two years following the diversion of the Danube. The total volume of extra cost of the two years is 55 million HUF (Magas et al., 1994).

This "cost" is self-inflicted. See, SC-M, para. 8.11. No economic losses have been suffered on the Slovak side as a result of Variant "C". See, Vol. III, Ch. 3, Sec. 3 and Ch. 4.

(7) All forests of the Szigetköz require the direct or indirect effect of the Danube water.

Hungary admits that in 30% (and, possibly, 47%) of Szigetköz the groundwater does not reach the soil layer. Hence, the rise there of ground water to tree roots by means of capillary action is not possible.

It is stressed that the Szigetköz forests suffered from the sinking groundwater levels from 1950 onwards due to the sinking water levels in the Danube (see, Vol. III, p. 78) and that the direct recharge of water into the side arms (at Dobrohošť and Dunakiliti) was intended to solve that problem.

Note: in terms of "indirect effect" Hungary now benefits from a greatly increased and regular flow into the Mosoni Danube, which will have a clearly beneficial impact on the forests in the locality.

(8) These floodplain habitats are exceptionally productive and have been intensively exploited by improved hybrid-poplars in the last decades.

Again it is difficult to see the relevance to Hungary's legal arguments of the economic value of "floodplain habitats". Contrast the claim (at "Scientific Evaluation", p. 183) that the floodplain of Szigetköz is still in a "semi-natural state".

Note: the Treaty parties in the Joint Contractual Plan were very much aware that certain species could be affected by changing water regimes, and provided for some species change. This meant the change from one cultivated species to another and is not the unacceptable environmental intervention that Hungary pretends.

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These systems played a prominent part in the regulation processes of fluvial communities. For instance, in the spawning season numerous fishes of the main stream migrated instinctively against the current, sometimes covering a distance of 100-200 km, before they found a suitable habitat for reproduction. Due to the Alpine flood regime of the Danube (see *Figure 3.1*), the low region of the Szigetköz area was flooded during the early summer inundations, where migrating fish could spread out. The slow flowing large branch systems functioned not only as ideal spawning and nursery habitats for the fish species of the Middle Danube, but they were also places where these fishes sought refuge during winter, strong floods or periods of high pollution. Furthermore, the lentic waters of the branches were particularly favourable to the intensive production of plankton and a large part of the planktonic production drifted into the main channel providing an important food source for fish.

5.4.2 HISTORICAL DEVELOPMENT

River regulation since the 19th century impacted on the morphodynamics of the Danube channel as well as its floodplain (see *Chapter 2.2*). Due to the confinement of the inundated area, the closure of the side-arm entrances, the degradation of the main channel, etc. (see *Chapter 2.2*) the ecological conditions have changed considerably, especially in recent decades. This has resulted in detrimental effects on fishery:

> 1) *Temporal changes in flow*: Disruption of spawning patterns through inappropriate stimuli or unnatural short-terms flows resulted in changes in community structure from seasonal spawners to species with more flexible spawning. Reduction of the duration of the inundations reduced phytophil spawners because their juveniles were stranded in isolated pools.
>
> 2) *Prevention of flooding by dykes*: Loss of floodplain area for spawning, loss of habitat variability, changes in species composition with loss of obligate floodplain spawners. General reduction in productivity of the whole system.
>
> 3) *Increased rate of silt deposition in the floodplain* (Dunal, 1992): Reduction of habitat and community diversity, choking of substrates for reproduction leading to failure to reproduce in litophil spawners.

In fishery aspects, the natural waters of the Szigetköz have belonged to the "Előre" Commercial Fishing Company of Győr from 1951 till the present day. The company has a 2,418 ha fishing area on the main stream of the Danube (1850-1770 rkm) and its branch systems, and 730 ha on the Mosoni Danube. As a part of the Danube connected water network another 646 ha is utilised for fishing on the lower section of the tributaries of the Mosoni Danube (*Rába, Marcal, Rábca*) (Jancsó and Tóth, 1987). Besides the commercial company 28 local sport-fishing clubs have fishing rights in the Szigetköz and another 96 ha fishing area belongs only to recreational fishery (Bertalan, 1994).

The catch of the commercial and recreational fisheries has been documented since 1967 and 1968, respectively. The statistical data collected for fishery reasons are not suitable for the scientific analysis on the composition of the fish communities. However, as a result of a continuous and extensive sampling, they provide an opportunity for a moderate evaluation of fish abundance and distribution.

Species composition of commercial and recreational catches from 1968 to 1993 (see *Plate 5.2, Volume 5*) indicate the changes of the fish populations in the Danube section between Rajka and Budapest. The most striking is the moderate decrease in the pike (*Esox lucius*) catch and significant increase in the barbel (*Barbus barbus*) catch. Pike is a seasonal phytophil spawner adapted to laying its eggs on submerged plants or riparian vegetation in early spring. Its spawning habitats were restricted by the decline of inundations of the floodplain, therefore its natural recruitment decreased. Barbel is a litophil spawner, its eggs are attached to stones. For spawning, it requires a clean bottom composed of gravel mixed with sand and pebbles. However, contrasted with pike it is a more flexible spawner in space and time and the human impacts did not cause significant reduction of its population. Although the increased rate of silt deposition in the floodplain waters limited its habitats, this species could find suitable sites for spawning in the main stream and the catch of this species has increased since the beginning of the 1980s.

5.4.3 IMPACTS OF THE ORIGINAL PROJECT ON FISHERY

In the 1980s water engineering works connected with the construction of the Gabčíkovo-Nagymaros River Barrage System caused disadvantageous changes in the aquatic habitats. Structures (cross-dams, ditches, etc.) related to the planned water replenishment system of the branches in the Szigetköz floodplain, made the flushing of the side-arms more difficult and accelerated their siltation.

As a consequence of the coffer-dam at Nagymaros, which surrounds the construction area of the planned barrage, the narrower Danube bed resulted in higher current velocity.

These impacts caused the following damage in aspects of fishery: 1

> 1) *Cross-damming of branches*: Changes in the flushing rate and deposition of organic sediment resulted in anaerobic conditions in the deeper sections of the side-arms leading to fish mortalities. Interruption of migratory pathways by cross-dams eliminated the migratory fish by preventing movement to floodplain breeding sites by adults and slowing the downstream movements of juveniles.

> 2) *Increases in flow velocities at Nagymaros*: The higher velocity created an unsuitable condition for the passage of fish.

Before the operation of the Gabčíkovo-Nagymaros Barrage the statistical data for commercial and recreational fishery indicated a decreasing trend of catch in the Danube section between Rajka and Komárom (see *Plate 5.3a, Volume 5*). The reduction was 53% in the main stream of the Danube and its branches; and 75% in the Mosoni Danube from 1988 to 1992. In this period the number of sport-fishermen increased and number of professional fisherman did not decrease significantly. 2 Fishing intensity was the same or slightly increasing on the basis of proportion of the commercial and recreational catches (see *Plate 5.3b, Volume 5*), therefore the decreasing trend of statistical data indicate a considerable reduction of the fish populations as a consequence of the cross-damming of branches.

Slovak scientists (Holčík, 1981) made a detailed prognosis for completing the Gabčíkovo-Nagymaros River Barrage System from a fishery point of view. They estimated in the region between Dunakiliti and the mouth of the Ipel river including almost 86% of the total area of the Slovak Danube section, that there are almost 97% of all fish and about 99% of all the available fish production and it provides almost 92% of the overall fish yields. The most important section of the entire region lies between Bratislava and Palkovičovo and despite the fact that it makes up only 28% of the total area of the Slovak Danube, it contains about 55% of the overall fish biomass and provides 58% of the overall annual available production.

In the region between the Hrušov and Nagymaros Reservoir the total water area would increase from 11,889 ha to 17,224 ha, i.e., 45%. However, from the view point of fishery potential the hydrological conditions of individual biotopes are more important, than the size of the area. 3

With the Gabčíkovo-Nagymaros Project, the total fish biomass would decrease in the entire region between Bratislava and Nagymaros by 57%, available production by 75%, and the possible yield by 92% (Holčík, 1981). In accordance with an estimate of 1979 these parameters would be 57%, 69% and 89%, respectively (Daubner, 1981). The section which would be the most affected is that adjacent to the Old Danube bed, where the total losses in all parameters exceed 95%. 4

The Danube section between Bratislava and Nagymaros would have only a minimum biological importance, and fish populations of both the upstream and the downstream Danube sections would considerably decrease (Holčík, 1981). This prognosis does not consider the effects of water level fluctuations caused by peak operation of the Gabčíkovo-Nagymaros Project, and any additional increase in pollution whose magnitude and effects can not be predicted.

The riparian ecotones (interface zones between the aquatic and the terrestrial ecosystems in rivers) have an important role in the recruitment of fish populations, as spawning and nursery sites, feeding habitats, etc. 5 The peak operation of the Gabčíkovo-Nagymaros Project would result in very high daily water level fluctuations in the downstream section at Gabčíkovo. The rapid fluctuation would destroy the fluvial communities in the ecotones and diminish the productivity of the whole system.

The huge volume of water flushed down in the bypass canal would dam up the flow in the upstream section of the Old Danube twice a day causing considerable damage to the fish populations as observed in the summer of 1994 (see below). The changes in velocity resulted in the accumulation of silt and toxic wastes leading to fish mortalities. 6 In the hot summer period anaerobic conditions would result in the death of fish.

5.4.4 IMPACTS OF VARIANT C ON FISHERY

Measured damage

After October 1992, when the Danube was diverted to the Gabčíkovo power canal, fish populations which assembled in their winter habitats could not always follow the recession of the water. During the first three weeks of the diversion, according to a governmental expert investigation (FH, 1993), the estimated quantity of fish that perished in the Szigetköz branch system was at least 100 tons (80% small cyprinid fish, 10% zander, 5% carp, 3% pike, 2% catfish). 7 The damage (see *Plate 13, Volume 1*) was estimated at 15-21 million HUF (140,000-196,000 USD) at market prices.

As the side-arms gradually dried out, fish remaining in the crowded muddy pools became easy prey for water birds and wild-boar and an accessible catch for the occasional poacher. In the second half of the winter of 92/93 the shallow pools froze solid because of the extensive, low temperatures, which considerably harmed the opportunity for over wintering of the fish. According to moderate estimates, 50 tons of fish died because of the above mentioned reasons during the winter of 1992-1993. 8 The damage was 7-10 million HUF (65,000-93,000 USD) at market prices.

According to the estimate of the Agricultural Office of Győr-Moson-Sopron County (1993), the reduction of the available fish production could be 75% on the Danube between Bratislava and Komárom, as well as in the rivers of the Little Danubian Plain (*Rába, Rábca, Marcal*), but in the Upper Szigetköz it could be as high as 90%. The potential loss of catch (commercial and recreational fishery) could be 100 tons per year. 9 Its gross value is 15-20 million HUF (140,000-185,000 USD).

The commercial and recreational catch decreased by 19% (from 69 t to 56 t) in the Danube section between Rajka and Komárom in 1993. The supposed reduction of

(1) Cross-damming of branches: Changes in the flushing rate and deposition of organic sediment resulted in anaerobic conditions in the deeper sections of the side-arms leading to fish mortalities.

Cross-damming as such does not cause problems, but rather the closing off of particular branches and the reduction in flow conditions. Where recharge into the side arms is ensured, cross-dams such as constructed in the Slovak side arms (with fish ladders) have had no adverse impact on fish. As is clear from Comment 2 below, the supposed negative impact on fish, due to cross-dams, is a Hungarian invention without factual support.

(2) Fishing intensity was the same or slightly increasing on the basis of proportion of the commercial and recreational catches (see Plate 5.3b, Volume 5), therefore the decreasing trend of statistical data indicate a considerable reduction of the fish populations as a consequence of the cross-damming of branches.

In fact, the cause of reduced fish catches in Hungary is quite different, as is clear from the uncontested findings of the Mixed Commission for the application of the 1958 Danube Fisheries Convention (of which Hungary is a member). Its reports on the fish and fisheries in this sector of the Danube are particularly important, as shown in the following extracts:

As stated in the protocol of the 29th session of the Mixed Commission (3-10 April 1989): "The hydro-meteorological conditions were generally unfavourable in the mentioned period (1987 and 1988). They were characterised by a strong and long winter 1987, short period of inundation with maximum in the last part of April 1988. These unfavourable conditions together with higher pollution influenced negatively reproduction and growth of fish, especially economically important sorts of fishes."

The Mixed Commission stated that less fish were caught in the Panonian basin, especially in the joint Czechoslovak-Hungarian section of the river due to worsened ecological conditions.

The protocol of the 30th session of the Mixed Commission (2-6 April 1991), para. 3 states: "The hydrological conditions were especially unfavourable in the mentioned period (1989 and 1990). They were characterised by low water level and higher pollution, which influenced reproduction and growth of economically important fish species. The Mixed Commission stated that due to [the] ecological situation, the catch substantially decreased in the majority of participating parties". Further, in para. 5.1. it stated: "The Mixed Commission listened to the reports of the Hungarian, Romanian Czecho-Slovak and Yugoslav sides on results of fisheries in the Panonian basin and stated that the catch of [the] majority [of] fishes in 1989 and 1990 decreased due to the low water level in the Danube which caused the isolation of branches which are the main place of spawning and production of fish. The Hungarian side drew attention to the fact that the worsening of conditions for fishes in the Danube was connected not only with the worsening of hydrological conditions, but also with the construction of water works on the Danube in Germany and Austria which limited migration and development of higher number of economically important species."

In para. 2 of the protocol of the 24th session, it is noted that the total catch was in 1987 12,849.5 tonnes and in 1988 13,406.1 tonnes. In comparison with the average catch in the years 1985 - 1986, i.e. 14,219.0 tonnes, the catch in 1987 and 1988 was lower by 1.370,2 tonnes and 813.6 tonnes, respectively. An even greater decrease was recorded in para. 2 of the protocol of the 30th session, the total fish catch in 1989 dropping to 9,983.9 tonnes in 1989 and to 8,850.1 tonnes in 1990.

<u>See</u>, SR Annexes 9 and 10.

(3) *With the Gabčíkovo-Nagymaros Project, the total fish biomass would decrease in the entire region between Bratislava and Nagymaros by 57%, available production by 75%, and the possible yield by 92% (Holčík, 1981).*

See, Comment 2 to "Scientific Evaluation" p. 143, above, concerning the findings of the 1981 Holčík study. Holčík's study was based on a discharge of just 50 m^3/s into the old Danube and no direct recharge into the side arms. In other words, it is outmoded in important respects. The actual impact of the diversion of the Danube in 1993-1994 is a more proper measure of the Project's impact on fish - in terms of both commercial and recreational fishing. <u>See</u>, Vol. III, Ch. 6.

(4) *The Danube section between Bratislava and Nagymaros would have only a minimum biological importance, and fish populations of both the upstream and the downstream Danube sections would considerably decrease (Holčík, 1981).*

<u>See</u>, Comment 3, above.

(5) *The peak operation of the Gabčíkovo-Nagymaros Project would result in very high daily water level fluctuations in the downstream section at Gabčíkovo. The rapid fluctuation would destroy the fluvial communities in the ecotones and diminish the productivity of the whole system.*

The "very high" fluctuations would occur, if at all, in the tailwater section of the bypass canal, which offers a new habitat for fisheries. To date, 24 fish species have been found in this new habitat. <u>See</u>, Reply, Vol. III, p. 113. As to "peak operation", it will be recalled that there was no agreed peak mode in 1989 and, also, that Czechoslovakia offered its pledge in October 1989 to limit or exclude peak mode operation, if so required to protect the environment.

(6) *In the hot summer period anaerobic conditions would result in the death of fish.*

Again, this is a reference to peak mode operation conditions, as to which, <u>see</u>, Comment 5 above. In any event, no evidence is given in support of the existence of "anaerobic conditions". <u>See</u>, Vol. III, Ch. 2, which records no change (and even some increase) in the dissolved oxygen content of the Danube's water since the implementation of Variant "C" (at p. 25).

(7) *The damage (see Plate 13, Volume 1) was estimated at 15-21 million HUF (140,000-196,000 USD) at market prices.*

Hungary does not hesitate to quantify its "losses" in economic terms. Some loss of a very temporary nature in fish numbers in the old main channel was inevitable (and anticipated) when waters were diverted. This must be weighed against the overall beneficial impacts of the Project, including those on fisheries. <u>See</u>, Vol. III, p. 116, which indicates that available fish production could increase from 146 tonnes to 243-320 tonnes and annual catch from 49 to 78-107 tonnes if direct recharge is supplied to the side arms and if some fish restocking is undertaken. <u>See</u>, Vol. III, p. 117.

Hungary's estimates cannot be accepted anyway. A decrease in the density of ichthyocenosis occurred in autumn 1992 (prior to the damming) when waters were at low level. It is untenable to attribute the cause of losses entirely to the Project.

Moreover, on the basis of the official data of the Mixed Commission for application of the Danube Fisheries Convention, the calculations presented by Hungary (at "Scientific Evaluation", pp. 189 - 192) cannot be considered as correct:

- **The total catch of fish in the Danube represented in 1987 90% of the average catch in the years 1985-86, 94% in 1988, 70% in 1989 and only 62% in 1991. This substantial decrease in the fish catch was caused by bad climatic and hydrological conditions and not by local changes of topography of the river in the area of the G/N Project.**

- **The poor fish conditions in the years 1989 and 1990 was the basic cause of the decrease of fish catch in the years 1991 and 1992, and it also influenced the following years. Hungary's estimates of abundance, ichthyomass and available production do not take this fact into consideration for the period after damming of the Danube and therefore they would have to be radically lowered.**

- **Hungarian experts before the Mixed Commission focused their attention on the negative impact of the barrages in Germany and Austria on fishery in the Hungarian-Slovak section of the river.**

(8) The damage was 7-10 million HUF (65,000 - 93,000 USD) at market prices.

See, Comment 7 above. Alleged fish losses in the side arms (that Slovakia cannot verify) were not inevitable - but were caused by Hungary's decision not to implement the direct water recharge into its side arms. Variant "C" has had a positive impact on both commercial and recreational fishing on Slovak territory. It has created new fish habitats (the reservoir, the tailwater canal and the seepage canals) and has enabled the rejuvenation of habitats in the side arm system and in the old Danube. See, Vol. III, Ch. 6.

(9) Its gross value is 15-20 million HUF (140,000-185,000 USD).

As for Comments 7 and 8, above.

fish biomass would have been higher, but in accordance with the general opinion of some experts, fishing was more efficient in the extraordinarily low water level of the Upper Szigetköz than it had been in the previous year.

1

At the end of July 1994 there was considerable fish destruction in the main stream of the Danube between Dunakiliti and Nagybajcs (1842-1802 rkm). Its probable reasons were the very long hot period and the extreme low water level. On 30 July a huge volume of water flushed down into the bypass canal at Gabčíkovo and the discharge dammed up the water in the upstream section of the Danube in the Szigetköz. The flowing of the main stream stopped and triggered the fish deaths. On the basis of the damage survey of the Agricultural Office of Győr-Moson-Sopron County 15 tons of fish perished (0.2 ton zander, 0.3 ton carp, 0.5 ton asp, 4.0 tons of barbel and 10.0 tons of other cyprinid fish). Their value was 1.5-1.7 million HUF (14,000-16,000 USD) at market prices.

After the catastrophic fish mortalities in the Szigetköz, the Fishery Management Fund of the Ministry of Agriculture gave financial support for fish introduction to the local fishery company. The amount of aid was 6 million HUF (56,000 USD) in 1993 and 3 million HUF (28,000 USD) in 1994.

***Table 5.5:** The damage of the fishery in the Szigetköz area since the implementation of Variant C*

DAMAGE	**ESTIMATED VALUE (MIN-MAX)**	
	million HUF	**thousand USD**
Fish killed (November 1992)	15-21	140-195
Fish killed (winter 1992-93)	7-10	65-93
Fish killed (July 1994)	1.5-1.7	14-16
Potential loss of catch (1993)	15-20	140-185
Potential loss of catch (1994)	15-20	140-185
Fish introduction (1993)	6	56
Fish introduction (1994)	3	28
Total	*62.5-81.7*	*583-758*

Forecast of damage

In recent years the ichthyological field studies of the Hungarian Danube Research Station, Hungarian Academy of Sciences concentrated mainly on the Cikola branch system and made quantitative estimates concerning the fish biomass related to the conditions in 1992 and 1994 in the relevant stretch of the Danube: between rkm 1838-1832.

The spatial and temporal distribution of fish communities in the flowing waters is quite heterogeneous, so the quantitative study of fish populations is one of the most difficult questions of ichthyological research in the large rivers. The estimate of fish biomass is more reliable if the calculations are separated in accordance to functional units of the hydrosystem. The functional units of the Szigetköz floodplain were classified by the system of Roux *et al.* (1982) (see *Chapter 4.3.2.2* and *Plate 4.3, Volume 5*). All of the side-arms were categorised on the basis of aerial photographs, field experiments and the results were discussed by water management engineers.

Slovak ichthyologists intensively investigated the quantity of fish stocks in the Danube by the mark and recapture method (Holčík and Bastl, 1976, 1977 and Holčík, 1981). The estimate of the fish biomass related to the conditions in 1992 in the Szigetköz area was based on mean biomass density data determined by Holčík (1991). When the status was described in 1994, the biomass density data were corrected with the catch per unit effort data estimated by the Hungarian Danube Research Station.

In the Cikola branch system the side-arms form a dense network; their length is five times more than the length of main channel. The surface area of the branches and the main arm was 318-390 ha at medium water level in 1992 and in some previous years. On the basis of their morphology the side-arms have the following categories:

1) *eupotamon*, that is large running waters;

2) *parapotamon*, that is semi-stagnant arms, where the downstream end is still connected to the river;

3) *plesiopotamon*, that is temporary standing branches with no permanent connection to the river;

Plate 5.4a (Volume 5) shows the distribution of these functional units and *Table 5.6* summarises the estimate of the fish biomass.

***Table 5.6:** Estimated fish biomass in the Cikola branch system (rkm 1832-1838), before the implementation of Variant C (status prior to 1992)*

Biotope	**Area (ha)**	**Proportion (%)**	**Biomass (kg/ha)**	**Total biomass (tons)**
eupotamon	159-195	45-55	30-40	4.77-7.80
parapotamon	139-171	40-48	200-370	27.80-63.27
plesiopotamon	20-24	6-7	600-1400	12.00-33.60
Total	318-390			44.57-104.67

2

Since the implementation of Variant C, or rather since the diversion of the Danube at Čunovo, the Cikola branch system has been strongly influenced by the reduction of the river discharge, and has had its functional units changed as well. In August 1994, when the major part of water replenishment was provided by pumping, the surface area of the Cikola-branch system was 232-285 ha, this meant that 86-105 ha of the side-arms were dry. In that condition the wet channels have four categories:

1) eupotamon, that is, the main channel of the Danube;

2) lotic parapotamon, that is, slowly flowing arms (0.5-0.6 *m/s*);

3) lentic parapotamon, that is, stagnant waters which have direct contact with the lotic arms;

4) paleo-plesiopotamon, that is, isolated standing waters with no permanent and direct connection to the other arms.

Plate 5.4b (Volume 5) shows the distribution of these functional units and *Table 5.7* summarises the estimate of the fish biomass.

The area of the wet side-arms decreased by 25-30% compared to the situation in 1992 at medium water level. During this period the changes of the hydrological conditions of biotopes resulted in the decrease of the total fish biomass by 56-64% on the basis of calculations.

These calculations indicate the trend and the order of change in the Cikola branch system. The biomass density and proportion of the functional units are different in other sections of the Danube in the Szigetköz, therefore the extrapolations of estimated data would be difficult to the whole floodplain or to the fishing areas.

***Table 5.7:** Estimated fish biomass in the Cikola branch system (rkm 1832-1838), after the implementation of Variant C, when the major share of the water supply was provided by pumping (August 1994)*

Biotope	**Area (ha)**	**Proportion (%)**	**Biomass (kg/ha)**	**Total biomass (tons)**
eupotamon	148-182	58-70	30-60	4.44-11
lotic parapotamon	55-67	21-25	100-300	5.55-20
lentic parapotamon	18-22	7-9	300-600	5.40-13.20
paleo-plesiopotamon	11-14	4-5	50-150	0.55-2.10
Total	232-285			15.94-46.32

3

The medium and long term damage to fisheries is higher than the calculated losses. The structures of the water supply system have blocked of the branch systems in the Szigetköz and there is no direct connection between the floodplain habitats and the main riverbed. The Alpine character of the flood regime does not exist anymore and the hydrology of the side-arms changed. The flow through of the branch systems is only 1.5-2 days annually every 5-10 years and the full inundation is to be expected once in every 10-25 years (see *Chapter 3.2*). Since the operation of the Gabčíkovo Barrage, the water transparency has increased and flow velocity has decreased in the side-arms. This condition is favourable for the high production of submerged aquatic vegetation.

The impacts mentioned have caused the following damage in aspects of fishery:

4

1) *Blocking of the branch systems:* Loss of floodplain habitats for spawning, nursery, feeding and wintering result in a considerable decrease of fish production. Fishery potential of the Szigetköz area will decline. Lack of large-scale fish recruitment has detrimental effects on the fish populations of the Middle Danube for a few hundred kilometres downstream.

5

2) *Changes in flood regime:* Subsequent reduction of habitat diversity, loss of species, diminishing productivity at community level due to the switch from the Alpine character flood regime to stable system dynamics.

6

3) *Decrease of flow rate:* Shifts from rheophilic to limnophilic communities in the side-arms. Changes in flushing rate resulting in accumulation or low dilution of toxic wastes or anaerobic conditions leading to fish mortalities.

7

4) *Decrease in suspended silt load:* Water transparency is higher. Increase in density of submerged aquatic vegetation leads to an increase in the abundance of phytophil fish. Changes in fish community, that is a reduction in number of the non-visual predators and omnivores. Risk of fish mortality due to anaerobic conditions caused by eutrophication.

8

5) *Diversion of water into the bypass canal:* The higher discharge in the tail-race canal directs the shoals of fish during their spawning migration to the tailwater of the Gabčíkovo Barrage, which is an insurmountable barrier and the bypass canal is an unsuitable habitat for spawning.

(1) *At the end of July 1994 there was considerable fish destruction in the main stream of the Danube between Dunakiliti and Nagybajcs (1842-1802 rkm). Its probable reasons were the very long hot period and the extreme low water level. On 30 July a huge volume of water flushed down into the bypass canal at Gabčíkovo and the discharge dammed up the water in the upstream section of the Danube in the Szigetköz. The flowing of the main stream stopped and triggered the fish deaths. On the basis of the damage survey of the Agricultural Office of Győr-Moson-Sopron Country 15 tons of fish perished (0.2 ton zander, 0.3 ton carp, 0.5 ton asp, 4.0 tons of barbel and 10.0 tons of other cyprinid fish). Their value was 1.5-1.7 million HUF (14,000-16,000 USD) at market prices.*

"Considerable fish destruction": There was no such occurrence recorded on the Slovak side of the Danube; nor was any destruction reported by Hungary to the specialised institutions in Slovakia.

"A huge volume of water flushed down into the bypass canal at Gabčíkovo": This did not happen. The water level on 30 July 1994, as for the days immediately before and after, was stabilised in the reservoir at 129.03-129.17 m asl. See, Vol. III, p. 121. No huge volume of water could be "flushed down" without a corresponding reduction in the height of the water in the reservoir. Water discharge into the old riverbed was also stable at 210 m^3/s and water temperature was normal - see, ibid.

"15 tons of fish perished": Hungary offers no explanation as to how it calculates this amount. Furthermore, Slovak scientists carried out a sampling test in January 1995 in the Dunakiliti section of the main riverbed and found groups of thousands of immature (0+ and 1+) fish. This contradicts evidence of large scale fish destruction. All the rheophile species may be observed and were spawned in summer 1994. This indicates favourable conditions.

(2) *Since the implementation of Variant C, or rather since the diversion of the Danube at Čunovo, the Cikola branch system has been strongly influenced by the reduction of the river discharge, and has had its functional units changed as well.*

"Reduction of the river discharge": This could easily be compensated for by implementing the planned recharge into the Cikola branch system.

(3) *The structures of the water supply system have blocked off the branch systems in the Szigetköz and there is no direct connection between the floodplain habitats and the main riverbed. The Alpine character of the flood regime does not exist anymore and the hydrology of the side-arms changed. The flow through of the branch systems is only 1.5-2 days annually every 5-10 years and the full inundation is to be expected once in every 10-25 years (see Chapter 3.2).*

"No direct connection": The isolation of the side arms from the main channel - a step taken primarily for navigational reasons - predated the construction of the G/N Project.

"Flow through": The amount of flow into the Hungarian side arms is controlled by what Hungary will allow. Slovakia does not have a flow at "1.5 - 2 days annually" but, rather, 365 days per year at varying flow rates and velocities.

(4) *1) Blocking of the branch systems: Loss of floodplain habitats for spawning, nursery, feeding and wintering result in a considerable decrease of fish production. Fishery potential of the Szigetköz area will decline. Lack of large-scale fish recruitment has detrimental effects on the fish populations of the Middle Danube for a few hundred kilometres downstream.*

This is directly disproved by the experience in the Slovak side arms, which shows that the diversion of the Danube's waters coupled with the direct supply into the side arms has had an overall beneficial impact on fish populations, which will further improve if further remedial measures dependent on Hungarian cooperation - such as the construction of underwater weirs in the old Danube - are implemented. See, Vol. III, pp. 111-116.

(5) *2) Changes in flood regime: Subsequent reduction of habitat diversity, loss of species, diminishing productivity at community level due to the switch from the Alpine character flood regime to stable system dynamics.*

The flood regime prior to 1992 was far from natural. See, Vol. III, p. 9. Monitoring on the Slovak side of the Danube has shown that there has been an increase in habitat diversity (including the new habitats provided by the reservoir and the tailwater canal), large potential increases in productivity and no loss of species. See, Vol. III, pp. 111-116.

(6) *3) Decrease of flow rate: Shifts from rheophilic to limnophilic communities in the side-arms. Changes in flushing rate resulting in accumulation or low dilution of toxic wastes or anaerobic conditions leading to fish mortalities.*

The direct supply of water into the side arms ensures an increase in flow rates and the disappearance of anaerobic conditions. Fish losses due to eutrophication in the side arms will decrease. Polluted waters (if any) will be more quickly diluted due to the higher flows in the side arms. The previous high flow rate in the main channel was excessive and not conducive to a healthy fish population - see, Vol. III, pp. 110-111. As to anaerobic conditions, see, Vol. III, pp. 24-25.

(7) *4) Decrease in suspended silt load: Water transparency is higher. Increase in density of submerged aquatic vegetation leads to an increase in the abundance of phytophil fish. Changes in fish community, that is a reduction in number of the non-visual predators and omnivores. Risk of fish mortality due to anaerobic conditions caused by eutrophication.*

The prevalence of non-predator species over predator species (which have a higher economic value) long pre-dated the damming of the Danube. See, Vol. III, p. 111. The new habitats provided in the reservoir, the side arms and the tailwater will reverse this situation - see, Vol. III, pp. 111-116. As to eutrophication, see, Vol. III, Ch. 2.

(8) *5) Diversion of water into the bypass canal: The higher discharge in the tailrace canal directs the shoals of fish during their spawning migration to the tailwater of the Gabčikovo Barrage, which is an insurmountable barrier and the bypass canal is an unsuitable habitat for spawning.*

Hungary's criticism would be equally (in fact, more) applicable to all the other hydroelectric projects on the Danube. The criticism makes no sense here as the old Danube, the side arms and the tailwater canal (for species who prefer greater depths) all offer good spawning grounds. For good fish conditions it is far more important to re-establish the inter-connection between the side arms to the old Danube than a migration route which in any event could go no higher than the next dam upstream in Austria.

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CHAPTER 6

SEISMOLOGY AND EARTHQUAKE ENGINEERING

by Anthony Bracegirdle

SUMMARY 1

Seismic design parameters for the Project were decided in 1965. At this time,
design input parameters were based largely on historical data. In the late 1970s
probabilistic methods and, more recently, deterministic methods of assessing
seismic hazard became accepted into current practice. Substantial advances in
design methods have also occurred over this period. It is now widely recognised
that assessments based simply on historical records of earthquakes underestimate
the risks associated with large, critical developments which have the potential for
widespread damage in the event of failure. 1

No systematic re-zoning of the project on the basis of current practice has taken
place since 1965, although a large number of useful background studies have been
undertaken. In terms of global seismology, the region is characterised by 2
moderately low rates of energy release. Simple risk assessments, for example
ICOLD (1989), suggest that the project would fall into a high risk category;
projects in high risk categories are usually designed to avoid an uncontrolled
release of water in the event of a realistic maximum credible ground motion being 3
felt. The selection of maximum credible ground motions should be realistic,
conservatively assessed on a rational basis. For the purpose of review, the effects
of a Richter magnitude, M=6.5, earthquake acting within source zones, identified
by recently assembled macroseismic, geophysical and geological data, have been 4
considered. The water-retaining dykes of the headrace canal and the Dunakiliti-Hrušov/Čunovo Reservoir have been identified as particularly vulnerable;
liquefaction, settlement leading to over-topping, and uncontrolled release of water
are likely to occur under the criteria adopted in this review. 1

It is apparent that the potential problems associated with seismic risk have not
been adequately addressed, either during design or subsequently. It is concluded
that there were significant grounds for concern over seismic design standards and
other unresolved problems at the time when Hungary suspended construction of 4
the project. A potential weakness in the detailing of the Variant C dykes has been
identified. The interface between dykes and structures are often critical in seismic
design, and these have not been checked or commented on in this study. The need
for an immediate full and systematic analysis of risk and dam safety remains,
although background studies have been carried out by Hungary.

6. COMMENTS TO HUNGARY'S "SCIENTIFIC EVALUATION", CHAPTER 6: SEISMOLOGY AND EARTHQUAKE ENGINEERING

(1) *Seismic design parameters for the Project were decided in 1965. At this time, design input parameters were based largely on historical data. In the late 1970s probabilistic methods and, more recently, deterministic methods of assessing seismic hazard became accepted into current practice.*

...

No systematic re-zoning of the project on the basis of current practice has taken place since 1965, although a large number of useful background studies have been undertaken

...

It is apparent that the potential problems associated with seismic risk have not been adequately addressed, either during design or subsequently.

Hungary's contentions here are that the assessment of earthquake risk under the G/N Project: (i) was decided and fixed in 1965, (ii) it was therefore based on outmoded methods and standards, and (iii) was never updated. The Project design is thus allegedly not suitable for the "potential problems". These contentions are simply wrong, Vol. III, Chs. 9 and 10 show:

- **The design of the Project was based on standards for calculating seismic load dated 1963, 1972, 1975 and 1982.**

- **Between 1972 and 1979, a joint geological examination was conducted by the Treaty parties concerning the scope of research drilling and survey methods, resulting in a joint report compiled in 1978.**

- **In 1980, Czechoslovak technical institutions completed the seismic microzoning of the area.**

- **In 1982, an independent assessment was made concerning the Project area by Hydroproject Moscow based on the most recent Russian standards. This was supplemented by an assessment of seismic stability.**

- **Hungarian earthquake specialists participated in the Project from its inception and were directly involved in the design and construction of the Project; for example, the calculation of the key factor of seismic load was reviewed with Hungarian Engineers Polko and Mistéthy.**

- **Deep drilling techniques and other seismic methods of exploration, developed principally by the oil companies, which conducted research throughout the area, led to new views about the structuring of the Danube Basin in which the G/N Project is located. Tectonic maps were constructed with the help of geologists in 1984 (Mahel), in 1985 (Fusan) and a Hungarian map in 1987 (Fillöp-Dank). (See, SC-M, Annex 26, at pp. 386-387). This data was incorporated as appropriate into the Project's safety standards.**

- **In 1990, Hydro-Québec International (HQI) examined, inter alia, the seismological aspects of the Project. The HQI report (i) expressly stated that the preliminary studies of earthquake risk met current international standards and (ii) failed to indicate the slightest reason on account of**

earthquake risk to delay or modify the Project. See, HM, Vol. 5 (Part I), Annex 9 (at pp. 252-274).

Like the environmental protection measures of the G/N Project, modifications were made in design and construction to assure that safety standards reflected the new scientific information and techniques after 1977. In this respect, Czechoslovakia (and now Slovakia) drew on the experience of Germany and Austria on the Rhine and the Danube, as well as its own extensive experience in the design and construction of dams, many of which are located in more active earthquake zones than the G/N Project.

(2) *Simple risk assessments, for example ICOLD (1989), suggest that the project would fall into a high risk category.*

The conclusion that the G/N Project is located in a region of high seismic activity and earthquake risk is completely wrong. Hungary's "Scientific Evaluation" is able to suggest this because of its incorrect, exaggerated calculations. Elsewhere, Hungary contradicts this conclusion when it states:

> **"Despite the difficulties with completeness of the historical record, it is evident that the present rate of energy release is relatively low when compared to more active regions of the world. In regions of low rates of energy release it is extremely difficult to assess a tectonic framework with certainty, and this uncertainty will be carried forward in the assessment of seismic hazard." See, "Scientific Evaluation", p. 207.**

As will be seen below, the Slovak studies in Vol. III identify major mistakes in calculating the three components of earthquake risk in order to determine seismic load: (i) magnitude (M); (ii) intensity (I); and (iii) acceleration (A). Instead of Hungary's assumptions of M = 6.5; I = 9 +; A = 0.38; the assumptions should be: M = 5.7; I = 8.5; A = 0,079g. These are maximum figures. See, Vol. III, Ch. 10.

The differences between the two calculations is very large; in earthquake analysis every decimal point is important; and the mere mathematical comparison of figures does not reflect the enormous differences between the above calculations.

(3) *For the purpose of review, the effects of a Richter magnitude, M=6.5, earthquake acting within source zones, identified by recently assembled macroseismic, geophysical and geological data, have been considered.*

Hungary's assumption of the effects of an earthquake of a magnitude (on the Richter scale) of M = 6.5 is based on studies some 25 years ago concerning the 1763 Komárom earthquake. The current scientific view is that such a magnitude is too high, and the estimate of M = 5.7 for this earthquake set out in the 1991 study by Bune (Russian), Brouček (Czech) and Szeidovitz (Hungarian) is generally accepted. This would correspond to an intensity of I = 8.5 MCS. (Instead of Hungary's I = 9+.) This intensity value would be valid for Komárom, not for Gabčíkovo, 45 km away; and Hungary's ambiguous language "acting within source zones" is scientifically unsupportable. Hungary's analysis of risk is fundamentally flawed from the start through its miscalculation of M and I for the 1763 earthquake, made possible by having completly ignored the widely accepted assessment set out in the 1991 study. See, Vol. III, Ch. 10.

(4) *The water-retaining dykes of the headrace canal and the Dunakiliti-Hrušov/Čunovo Reservoir have been identified as particularly vulnerable; liquefaction, settlement leading to over-topping, and uncontrolled release of water are likely to occur under the criteria adopted in this review.*

...

A potential weakness in the detailing of the Variant C dykes has been identified.

All aspects of dyke safety were extensively studied under the Treaty Project and under Variant "C". <u>See</u>, Comment 6 to "Scientific Evaluation" p. 215, below refuting claims of potential weaknesses.

6.1 INTRODUCTION

6.1.1 EARTHQUAKE RISK

Earthquake risk can, in simple terms, be viewed as the product of damage potential, exposure to hazard and the vulnerability of the structures. 1 The Gabčíkovo-Nagymaros Project, as perceived at the time of the Treaty in 1977, comprised an extensive system of dykes and the construction of three major barrages over a 160 km stretch of the Danube. The dykes provide containment of the impounded waters upstream of the barrages, which were to have been located at Nagymaros (km 1696), Gabčíkovo (adjacent to km 1821) and Dunakiliti (km 1842). Any damage that would occur as a result of a breach of the dyke system (i.e., flooding, economic damage, loss of life, etc.) would vary from location to location and in some areas this could be quite severe.

The rate of release of seismic energy in the region is relatively low when compared to more active areas in Europe, such as Central Italy and Southern Greece. As a consequence, the frequency of large earthquakes is difficult to establish with any certainty. It is apparent from historical records that the region is capable of producing strong shaking, albeit infrequently. 1 The great geographical extent of the project is such that the integrated exposure to seismic hazard for the whole project would be substantially greater than that of a single element of the scheme. 2

The construction of the dykes varies from location to location, although the use of the Danube gravel as bulk fill is relatively widespread throughout the Project. By its nature, the Danube gravel is easily eroded by water and, as a result, a breach would develop quickly if the integrity of the water retaining system were impaired. Under strong earthquake shaking, dykes and embankments may become vulnerable to lateral spreading, settlement and consequent over-topping.

The dykes of the Project are likely to provide the highest risk due to earthquake shaking because they are exposed to hazard over a large area, they are potentially vulnerable, and the consequences of over-topping and failure are likely to be severe in some locations. A full study of risk would normally be required under present-day standards for major projects. Such a study would be extremely complex and is beyond the scope of this report. Design parameters for earthquake shaking were provided in the Joint Contractual Plan. This report discusses the containment dykes and their design in relation to our present understanding of the seismological environment and potential vulnerability of these structures.

6.1.2 PROJECT OUTLINE

6.1.2.1 Nagymaros Reservoir

In the Original Project, barrages would have been provided at Nagymaros, Gabčíkovo and Dunakiliti. The barrage at Nagymaros was to be integrated with power generation facilities and ship locks. Under normal operating conditions the water level upstream of Nagymaros would have been about 6 m above the level of the river under average flow conditions ($Q=2300\ m^3/s$); operating water levels would have been above river bank level for a distance of 30 to 40 km upstream of the barrage, the effects of impoundment extending as far upstream as Gönyü (100 km upstream). Containment dykes would have been provided principally by the raising and strengthening of existing flood protection dykes of the Danube and its tributaries, the Ipoly (Ipel) and Hron Rivers. 3 Substantial geotechnical problems were identified in relation to raising the water level upstream of Nagymaros by Mantuano (1989); these problems were not fully resolved at the time Hungary suspended construction at Nagymaros.

6.1.2.2 Gabčíkovo Structures

The barrage at Gabčíkovo incorporates ship locks and power generation facilities; a 17 km-long headrace canal extends upstream to the Hrušov Reservoir. The water level in the headrace varies between about 7 m and 15 m above the level of the surrounding land, giving an impounded volume for the headrace of about 80 million m^3.

The containment dykes of the headrace are constructed with bulk fill, comprising compacted Danube gravel and an upstream bituminous concrete membrane. A freeboard of 2.0 m is provided between the operating levels of the canal and the crest of the dykes. In order to avoid post-construction settlement, the Joint Contractual Plan called for the removal of 2 to 3 m of clayey and silty soils from the foundation of the dykes. 4 The excavation of about 2 m of soil, extending to up to 5 m where peaty, silty or clayey soils were found was confirmed by Liška (1994). Polko (1993) maintained that an assessment of liquefaction potential of the foundation was made, and unsuitable material removed during the course of construction; no data was presented to illustrate the investigations or the analyses that were carried out. This view was echoed by Hydro-Quebec International (1990), but again no data were provided. 5 This view is strongly contested by Finta (1990), who maintains that considerable difficulty was experienced with the excavations and that insufficient fine-grained material was removed. The allegations made by Finta are of great concern and require investigation.

6.1.2.3 Dunakiliti-Hrušov Reservoir

In the Original Project it was envisaged that the closure of the Old Danube course would be made near Dunakiliti, and a barrage incorporating a spillway, control gates, and a ship lock would be built on the site of the closure. The Dunakiliti-Hrušov Reservoir was intended to have an impounded volume of about 200 million m^3, of which 49 million m^3 is contained over a depth of 1 m below operating level. The containment dykes comprise new gravel-fill structures with upstream blankets of fine-grained soils or asphalt, and strengthened existing flood banks. The greatest retained height of water would have been about 7 m above river bank level, near Dunakiliti. 6 I have no information that an attempt was made to remove liquefiable materials beneath the dykes of the Dunakiliti-Hrušov Reservoir; this is supported by construction drawings provided by OVIBER (1994) and investigations carried out by Eötvös Loránd Geophysical Institute (ELGI, 1991).

6.1.2.4 Čunovo Reservoir and Variant C

Between 1991 and 1992, the Slovak developers constructed the "Variant C" headrace linking Gabčíkovo to a reservoir formed by the closure of the Danube at Čunovo. The Variant C dyke is similar to those forming the headrace constructed under the Joint Contractual Plan, except that water-proofing is provided by a PVC membrane within the retained-water side of the dyke. The membrane is covered by 1.5 m of fill at a slope of 1:3; the fill is protected by a geotextile cover and precast concrete anti-erosion slabs.

The Čunovo Reservoir utilises dykes constructed for the Dunakiliti-Hrušov Reservoir; the resulting impoundment is less than planned under the Joint Contractual Plan, although the length of the critical headrace canal is extended by approximately 9 km.

6.1.3 DAMAGE

The consequences of a breach of the dykes would be most serious at the following locations: immediately upstream of Nagymaros, in the Gabčíkovo Headrace and in the lower reaches of the upstream reservoir. 7 I am not aware of any systematic study of the dyke-breach scenario; it is evident however, that local communities are likely to be inundated (Perczel and Libik,1989).

Although the volume of water impounded by the scheme is large, the relatively low height of the dykes and high flood flows in relation to the impounded volume should be taken into consideration in assessing potential damage. Flood damage that occurred in 1954 and 1965 would provide useful guidance in generating dyke-breach scenarios as part of an assessment of risk. The large volume of water impounded in the headrace canal is, however, of particular concern as this is held

above the level of the surrounding land, and not within the confines of the old river channel. Sound operating procedures, in the event of an earthquake or flood, and contingency plans could substantially mitigate potential damage. 8 It is, however, clear that, at present, there are no risk strategy plans or operating procedures which are mutually agreed between Hungary and Slovakia. 9

A simplistic evaluation of potential damage using the criteria of the International Commission on Large Dams (ICOLD, 1989) would place the scheme in categories III or IV (the classification extends between I and IV in increasing level of severity; categories III and IV are considered high risk categories). In a preliminary analysis of risk, using probabilistic methods, return periods for earthquakes could be taken as 1 in 10,000 years (category III) and 1 in 30,000 years for category IV (for example, see Charles *et al.*, 1991). Critical or high risk structures, even in areas of relatively low seismicity, are preferably designed on the basis of deterministically evaluated ground motions; catastrophic failure as a result of ground motion arising from a Maximum Credible Earthquake (MCE) should be prevented. The MCE is defined as the earthquake that would cause the most severe level of ground motion which appears possible for the prevailing geological and tectonic conditions.

6.2 GEOLOGICAL AND TECTONIC BACKGROUND

6.2.1 BASEMENT STRUCTURE AND CRUSTAL MOVEMENT

10 The most important feature of basement structure of the Little Hungarian Plain is the Rába-Hurbanovo Line. The line separates pre-Tertiary (older than 65 million years) rocks of the Alpine-Carpathian metamorphic series to the NW of the Line from the Transdanubian Range Unit to the SE, and is effectively a boundary between micro-plates. A programme of detailed geological mapping has been undertaken in this area since 1982 (Don *et al.*, 1993), and extensive geophysical mapping as part of the DANREG project carried out since 1989 (Verő and Nemesi, 1994). The Rába-Hurbanovo Line has been identified as running NE from Győr towards Kolárovo in Slovakia and then to the east through Hurbanovo.

A deep (8,000 m) basin is observed in the pre-Tertiary basement rocks between Győr and Dunakiliti to the NW of the Rába Line. The centre of the basin is situated near Gabčíkovo, the principal axis of the basin running NE-SW (see *Plate 6.1, Volume 5*). Very weak Tertiary rocks comprising calcareous clays and weakly cemented sands and gravels fill the basin. This is the result of crustal subsidence, which has been very vigorous in the past and has continued and perhaps accelerated in the Quaternary (i.e. the last 2 million years). Current rates of crustal subsidence are estimated at about 2.0 mm/year within the basement area (Joó, 1994 and Don *et al.*, 1993). The predominant Slovak view is that the basement beneath the Gabčíkovo area is divided by NE-SW and NW-SE oriented faults; blocks of basement rock within this area which are delineated by the faults are

(1) *The Gabčíkovo-Nagymaros Project, as perceived at the time of the treaty in 1977, comprised an extensive system of dykes and the construction of three major barrages over a 160 km stretch of the Danube.*

...

The great geographical extent of the project is such that the integrated exposure to seismic hazard for the whole project would be substantially greater than that of a single element of the scheme..

Earthquake risk in this region is not only relatively low, due to the fact that the region is not seismically active, but also it is a localised risk since the only important recorded earthquake was in 1763 in Komárom. The G/N Project extends over a large area of a relatively inactive region seismically. This should hardly lead to the conclusion suggested in Hungary's "Evaluation" that the "great geographical extent" of the Project created an "integrated exposure to seismic hazard" that would be greater than any single part of the Project. This is meaningless jargon totally lacking in any scientific basis.

(2) *The construction of the dykes varies from location to location, although the use of the Danube gravel as bulk fill is relatively widespread throughout the Project. By its nature, the Danube gravel is easily eroded by water and, as a result, a breach would develop quickly if the integrity of the water retaining system were impaired.*

"Danube gravel is easily eroded by water": There is no risk relating to the use of Danube gravel under the Project (see, Vol. III, Ch. 11). Hungary's conclusion is based on a superficial examination of the problem of dyke safety and incorrect information of the techniques used (see, also, Comment 4, below). In any event, Danube sands not gravel are easily eroded; and here top quality gravel was used to replace the possibly vulnerable soils. Gravel of this kind is the best material to use to ensure dyke stability.

(3) *Substantial geotechnical problems were identified in relation to raising the water level upstream of Nagymaros by Mantuano (1989); these problems were not fully resolved at the time Hungary suspended construction at Nagymaros.*

These alleged problems were not in any way related to earthquake risk and, hence, are misleadingly described as being "geotechnical" in nature, as shown below (see, Comment 2 to "Scientific Evaluation" p. 218). They provided no technical justification for Hungary's suspension of work at Nagymaros.

(4) *The excavation of about 2 m of soil, extending to up to 5 m where peaty, silty or clayey soils were found was confirmed by Liška (1994). Polko (1993) maintained that an assessment of liquefaction potential of the foundation was made, and unsuitable material removed during the course of construction; no data was presented to illustrate the investigations or the analyses that were carried out. This view was echoed by Hydro-Québec International (1990), but again no data were provided.*

"No data were provided": The data may not have been made available by Hungary to the person preparing Chapter 6 of this "Evaluation", but Hydro-Québec International had this information and based their favourable conclusions on it. Hungary knew all of the details of dyke construction under the Project, much of which was in fact performed by Hungary on Hungarian territory, and the proper techniques that were used under Variant "C" were in fact discussed in papers presented at and published by the Proceedings of the International Conference: The Gabčíkovo System (Intentions and Reality), held in Bratislava, 7-9 September 1993.

(5) *This view is strongly contested by Finta (1990), who maintains that considerable difficulty was experienced with the excavations and that insufficient fine-grained material was removed. The allegations made by Finta are of great concern and require investigation.*

Hungary's reliance on Finta (1990) - an allegation unsupported by the slightest evidence - for refusing to believe the evidence of excavation of soils and replacement by gravel is, to say the least, weak. As shown in the references at page 223 of the "Evaluation", this is a reference to a non-scientific piece in the popular press: "Death is lurking at Gabčíkovo", Reflex, Nos. 2-5, Komárom.

(6) *I have no information that an attempt was made to remove liquefiable materials beneath the dykes of the Dunakiliti-Hrušov Reservoir; this is supported by construction drawings provided by OVIBER (1994) and investigations carried out by Eötvös Loránd Geophysical Institute (ELGI, 1991).*

"I have no information ...": As a joint participant in the Project, Hungary had all information. As to the "removal of liquifiable materials", the vast program of material removal in the construction of the dykes is described in Vol. III, Ch. 11. It was an operation of which Hungary was fully aware as a joint participant in this Project: the construction of dykes on Hungarian territory was accomplished by Hungary, using the agreed techniques. Hungary's "Scientific Evaluation" here presupposes dyke instability by conveniently ignoring the evidence concerning measures taken to ensure such stability.

(7) *I am not aware of any systematic study of the dyke-breach scenario; it is evident however that local communities are likely to be inundated (Percel and Libik, 1989).*

The Hungarian side apparently did not provide the author of this Chapter with these studies of dyke-breach scenarios. Hungary as joint participant was fully aware of them.

(8) *It is, however, clear that, at present, there are no risk strategy plans or operating procedures which are mutually agreed between Hungary and Slovakia.*

Up to the time of Hungary's abandonment of the Project (mid-1990), it was a full participant in all risk strategy planning. In this Chapter, Hungary does not attempt to explain how there could have been "mutually agreed" procedures when the Gabčíkovo section was put into operation under Variant "C" - after Hungary had abandoned the Project and had refused to discuss with Czechoslovakia any alternative variants for putting the Project into operation.

(9) *A simplistic evaluation of potential damage using the criteria of the International Commission on Large Dams (ICOLD), 1989) would place the scheme in categories III or IV (the classification extends between I and IV in increasing level of severity; categories III and IV are considered high risk categories).*

There is no proper scientific basis for placing the G/N Project in a high risk category of potential earthquake danger.

(10) *The most important feature of basement structure of the Little Hungarian Plain is the Rába-Hurbanovo Line. The line separates pre-Tertiary (older than 65 million years) rocks of the Alpine-Carpathian metamorphic series to the NW of the Line from the Transdanubian Range Unit to the SE, and is effectively a boundary between micro-plates. A programme of detailed geological mapping has been undertaken in this area since 1982 (Don et al., 1993), and extensive geophysical mapping as part of the DANREG project carried out since 1989 (Verő and*

Nemesi 1994). The Rába-Hurbanovo Line has been identified as running NE from Györ towards Kolárovo in Slovakia and then to the east through Hurbanovo.

These kinds of detail may be important to geologists, who are interested in the history of how the region developed into what it is geographically and geomorphologically, but they are not necessarily indicative of the extent of seismic activity or of earthquake risk.

The existence of a fault line is, in itself, meaningless in terms of earthquake risk. The existence and size of such a risk depends on many factors. The fault line structure in the Little Danube region is such as to indicate that the region may be classified as a low earthquake risk area. No postulated faults near the critical structures of the G/N Project have been shown to be active faults, cabable of causing earthquakes. Slovakia's own study of the seismicity of the region concludes that the G/N Project region in terms of seismic activity is consolidated and that no distinct earthquake centres are located there. See, Vol. III, Ch. 10, Pt. I.

sinking relative to the surrounding rocks. This view is outlined in the Joint Construction Plan, and described in detail by Mantuano (1989). Janaček (1971) describes a major NE-SW fault running sub-parallel to the Rába line through Gabčíkovo. 1 The potential capability for movement of these faults was considered a sufficient hazard by the designers to justify relocation of the Gabčíkovo barrage 700 m upstream to its present location; this decision was made on the basis of investigations made after design, and prior to the commencement of work at Gabčíkovo. 2 A number of studies have been carried out by the Hungarian scientific community (for example, Verő and Nemesi, 1994 and Balla, 1994) in order to examine the potential of faulting in this region to produce shaking. The principal conclusions of these studies are:

1) Faults in the immediate vicinity of Gabčíkovo are unlikely to produce strong motions, and are poorly defined by macroseismic data.

2) A fault line exists between Komárom and Győr , which is well defined by geophysical, geological and macroseismic data. The fault is considered capable of producing strong motion. 3

Excavations for the foundations of the Nagymaros barrage were carried out prior to 1989. The excavations revealed predominantly andesitic rocks that had been greatly distorted by tectonic activity (Bence *et al.*, 1991 and Gálos and Kertész, 1990). Although no direct evidence was found for movement along these faults in the overlying Quaternary deposits during excavations for the Nagymaros facility, geological comparison of the level of gravel terraces of Quaternary age along the Danube in this region show that tectonic movements have taken place in this period. The capability of faults in this area is also supported by macroseismic and geodetic data; their capability cannot be ruled out (Balla, 1994).

6.2.2. SEISMICITY OF THE REGION

Earthquake intensity relates to physical damage observed as a result of an earthquake. Unless otherwise stated, intensity is in this report quoted in terms of the MSK scale; this is a 12 point scale, directly comparable and equivalent to the older MCS scale. Intensity may be related by empirically-based relationships to Richter magnitude, M, which is an instrumental measure of the energy released in a seismic event (see *Chapter 6.3.1.1*).

Considerable research on historical earthquakes in Hungary was carried out by Réthly (1952), who compiled a list of events that occurred between 455 and 1918. Other studies, for example Ribárič (1982), have assisted in assessing historical seismicity for the region. Since the turn of the century a more systematic approach to data collection and retrieval has been in place such that most events of epicentral intensity, I_0, greater than about 3.0 have been recorded. The completeness of the record diminishes with time prior to 1900, particularly in relation to small events.

The Hungarian Earthquake Catalogue (456-1986), prepared by Zsíros *et al.* (1989), lists the historical and more recent instrumental data for the region. It is worth noting that of the 5,000-plus number of earthquakes listed for the Carpathian Basin, only 17 relate to the first 1,000 years of the record; of these, 14 have estimated values of I_0 of 8 or greater. In the subsequent 500 years a total of 49 earthquakes of I_0 of 8 or greater are listed. It is probable, on this basis, that the early historical record is deficient even in respect of large events. 4

Despite the difficulties with completeness of the historical record, it is evident that the present rate of energy release is relatively low when compared to more active regions of the world. In regions of low rates of energy release it is extremely difficult to assess a tectonic framework with certainty, and this uncertainty will be carried forward in the assessment of seismic hazard. Macroseismic data is, however, extremely useful in identifying potential earthquake source zones.

In order to carry out probabilistic analyses on earthquake recurrence, Zsíros (1991) proposed 14 source zones, which were based primarily on macroseismic data (see *Figure 6.1*). Of these source areas, the most active in Hungary is that extending south of Komárom, towards Berhida (Zone 1, *Figure 6.1*). The strongest recorded event within this source was the 1763 Komárom earthquake which is listed as having an epicentral intensity of 9±1 MSK and an estimated Richter magnitude of 6.2 (refer to Zsíros *et al.*, 1989). Other estimates of epicentral intensity range between 8.5 and 9.5 (Szeidovitz and Mónus, 1993 and Szeidovitz, 1986). Zone 11 on *Figure 6.1* represents the relatively active Mur-Mürz Line.

In a recent study, Balla (1994) reviewed potential source zones. He postulates a source zone running east-west between Győr and Becske, sub-parallel to the Hurbanovo Line, as shown on *Figure 6.2*. Evidence for the existence of such a source is found in macroseismic, topographic and geophysical data. 5 The known fault between Győr and Komárom represents the most active section of this source, several hundred earthquakes having occurred on this line since 1754. Balla (1994) maintains that the 1763 Komárom earthquake is not necessarily related solely to the Komárom-Berhida source, but could be related to the Győr -Becske Line. This view is supported by historical research, Szeidovitz (1986), which shows isoseismals for the main shock around an axis lying east-west, parallel to the Győr -Komárom fault. In addition, the main shock was preceded by fore-shocks in the vicinity of Győr . Macroseismic data collected between 1989 and 1993 (Zsíros, 1994) show a small event (I_0=3.5) in Komárom in 1989 and similar sized events near Győr in 1990 and 1993. 5 It should be noted that Dunakiliti lies within 30 km of the Mur-Mürz source, Gabčíkovo within 20 km of the Győr-Becske source, and Nagymaros within the Győr-Becske source.

A few fault plane solutions exist for Hungarian earthquakes. These are predominantly strike-slip mechanisms. 6 There is, however, little data to sensibly assess maximum credible events on the basis of anything other than a probabilistic approach. Kárník (1971), of the Czechoslovakian Academy of Sciences, outlines the

results of a Gumbel analysis of seismicity in the Carpathian region. The analysis utilises data from the whole region and concludes that the largest "possible" event is of Richter magnitude 6.5, having a probability of excedence of 1%. A similar value was obtained independently by Kárník using simple empirical deduction. A refinement of this assessment is embodied in the "Scheme of Earthquake Provinces" produced by Kárník *et al.* (1978), which shows a maximum earthquake strength of Richter magnitude 6.0 (see *Figure 6.3*). 6 At present there is insufficient information to allow a fully deterministic evaluation of the Maximum Credible Earthquake; earthquakes of between 6.0 and 6.5 magnitude (Richter) remain appropriate in light of more recent studies, and it is considered that an event within this range of magnitude could conceivably take place anywhere within the source zones identified.

6.2.3 QUATERNARY DEPOSITS

The Quaternary period extends from 1.64 million years before the present to the present day. The period is sub-divided into the Holocene (0 to 10,000 years before the present) and Pleistocene (10,000 years to 1.64 million years before the present); the division being made on the basis of climatic change. Holocene deposits are often referred to as "recent" and represent a greater risk of liquefaction or cyclic mobility under earthquake shaking than older deposits.

The Quaternary deposits between Nagymaros and Komárom are relatively complex and comprise interbedded clays, gravels and sands, with raised gravel terraces on higher ground to the south of the river. The overburden immediately upstream of Nagymaros is generally about 10 m in thickness, increasing with distance upstream.

A deep basin filled with Quaternary deposits extends beneath the Danube between Bratislava and Komárom. The Pleistocene materials comprise the Gabčíkovo Sand and the overlying Danube gravel, and reach a total thickness of up to about 600 m in the centre of the basin. The relatively permeable Danube gravel is 12-15 m thick at Bratislava, increasing to about 100 m at Dunakiliti, and to about 300 m at Gabčíkovo. The Danube gravels are typically in the fine to medium range, with a variable content of fine and medium sand. These materials are unlikely to be susceptible to liquefaction or settlement during shaking.

The Holocene materials vary in composition and thickness across the Danube alluvial cone. At Dunakiliti they are typically 5 m to 7 m in thickness, and increase to about 30 m in thickness near Gabčíkovo (Don *et al.*, 1993). They comprise clayey silts, silty sands, fine sands, sand/gravel mixtures and can contain layers of peat. The thickness and nature of these materials can vary considerably over a short distance, particularly where in-filled side-arms or channels are met.

I have reviewed cone penetration test data made available by ELGI (1981, 1991) which are considered representative of the Dunakiliti-Hrušov area. Typical traces of cone resistance within the Holocene deposits are shown on *Figure 6.4*. As can

be seen from *Figure 6.4*, cone resistances in fine sands and silty sands are frequently in the range 1-4 MPa, indicating these materials to be extremely loose. Such materials are potentially liquefiable during strong earthquake shaking when present at depths of less than about 15 m: whether or not liquefaction takes place is dependent on the severity of the ground motions, and this is discussed further in *Chapter 6.3.2*. I have not seen data comparable to that provided by ELGI for Slovak territory in the vicinity of Gabčíkovo, or other data that would allow a comprehensive assessment of liquefaction potential in this area. As the depositional environment at Gabčíkovo has been broadly similar to that at Dunakiliti, I would expect similar materials to be present at Gabčíkovo, but in greater thickness.

6.3 EARTHQUAKE ENGINEERING

6.3.1 SEISMIC ZONING OF THE PROJECT

6.3.1.1 Earthquake intensity

The seismicity of the region was discussed by a joint meeting of Czechoslovakian and Hungarian experts in September 1965. During this meeting, levels of earthquake intensity and design levels of acceleration were set for various parts of the project as outlined in *Table 6.1*. The Intensity Scale applied at this time was the twelve-point MCS (Mercalli-Cancani-Sieberg) Scale, which is summarised in *Table 6.2*. The MCS Scale was adopted by the International Seismological Association in 1917. The MCS classification proved to be rather imprecise and made little allowance for local building practice. Levels of ground motion associated with the MCS scale are often those of early building codes. Improvements were made, and the American Modified Mercalli Scale (MM, 1931) and the European Medvedev-Sponheuer-Kárník (MSK, 1964) Scales were introduced. The MSK and MM Scales are twelve-point scales like the original MCS Scale; as outlined by the World Data Centre A for Solid Earth Geophysics (1979), the grades of the three scales are equal and equivalent to each other. In addition, a new European Macroseismic scale (EMS), which is a revision of the MSK scale, has recently been accepted by the European Community (1992).

Use of the MCS Scale has persisted in Italy and Greece, although in neither country is it currently embodied in design codes.

(1) *The potential capability for movement of these faults was considered a sufficient hazard by the designers to justify relocation of the Gabčíkovo barrage 700 m upstream to its present location; this decision was made on the basis of investigations made after design, and prior to the commencement of work at Gabčíkovo.*

There is no proof that any of the postulated faults, sufficiently near the critical structures of the G/N Project to matter, are active faults. It is preposterous to suggest that a move of only 700 m upstream from the location of the Gabčíkovo barrage was due to fears that the Gabčíkovo fault postulated as running through there was active. As any qualified seismologist knows, a move of only 700 m would provide no added safety in such a case.

In this case, Czechoslovakia followed the sound engineering practice of not building the barrage directly over a postulated fault line - not because there was any fear it was an active fault, but because of the possibility of different rates of settling of the subsoil, if indeed a fault lay underneath the surface.

(2) *A number of studies have been carried out by the Hungarian scientific community (for example, Verö and Nemesi, 1994 and Balla, 1994) in order to examine the potential of faulting in this region to produce shaking. The principal conclusions of these studies are:*

1) Faults in the immediate vicinity of Gabčíkovo are unlikely to produce strong motions, and are poorly defined by macroseismic data.

2) A fault line exists between Komárom and Győr, which is well defined by geophysical, geological and macroseismic data. The fault is considered capable of producing strong motion.

There is no proof that a fault line running through Gabčíkovo even exists. It has been hypothesised and, hence, placed on some seismic maps. There is no evidence whatsoever of any such fault being seismically active. Therefore, its possible existence is largely of historical interest from a geological standpoint.

A fault line between Komárom and Györ, the Komárom-Berhida fault line, has been hypothesised and is generally assumed to exist. The possibility of the intersection of such a line with a second fault line near Komárom has been hypothesised as explaining the 1763 Komárom earthquake and other minor ones in this specific region.

There is, no evidence on which to base the conclusion that this fault line is active or is "capable of producing strong motion", to use the ambiguous language of Hungary's "Scientific Evaluation".

(3) *Excavations for the foundations of the Nagymaros barrage were carried out prior to 1989. The excavations revealed predominantly andesitic rocks that had been greatly distorted by tectonic activity (Bence et al., 1991 and Gálos and Kertész, 1990). Although no direct evidence was found for movement along these faults in the underlying Quaternary deposits during excavations for the Nagymaros facility, geological comparison of the level of gravel terraces of Quaternary age along the Danube in this region show that tectonic movements have taken place in this period. The capability of faults in this area is also supported by macroseismic and geodetic data; their capability cannot be ruled out (Balla, 1994).*

Hungary's "assessment" encounters even more difficulty when it comes to Nagymaros - for it must show that in 1989 when Hungary suspended and abandoned Nagymaros there was an earthquake risk that (under Hungary's legal theory) justified this action. This risk

was not perceived at the time, however, according to the "assessment"; only subsequently (in 1990 and 1991) was tectonic activity allegedly found in the extracted "andesitic rocks" - which are some 16 million years old - though, it is admitted, without any "direct evidence" of any movement along "these faults" (not otherwise identified) during the Quaternary period (i.e., in the last 2 million years).

Now, however, in the specially commissioned 1994 Hungarian study, evidence of tectonic movements is said to have been found after further gravel analysis and further study of seismic and geodetic data. This leads Hungary to the remarkable conclusion that "their capability" - presumably of the identified faults in the Nagymaros areas - "cannot be ruled out".

This, then, is the scientific underpinning of Hungary's claim that a lack of earthquake study, in the light of the risks it claimed to exist, justified its actions to suspend and abandon Nagymaros. Hungary's embarrassment is that it is trying to establish the reasonableness of an earthquake risk theory in an area where supporting data is totally missing. Furthermore, Hungary has not made the slightest attempt to show that, even were an earthquake to strike Nagymaros, the results could not be contained with minimum consequential effects.

(4) *Despite the difficulties with completeness of the historical record, it is evident that the present rate of energy release is relatively low when compared to more active regions of the world. In regions of low rates of energy release it is extremely difficult to assess a tectonic framework with certainty, and this uncertainty will be carried forward in the assessment of seismic hazard.*

Here again, it is evident that the "Scientific Evaluation " has great difficulty making the existing scientific facts support a scientific theory in order to bolster Hungary's legal case. The first sentence concedes - in a round about way - that this is an area of low earthquake activity. The second sentence asserts that in such areas of low earthquake activity it is difficult to make an assessment of seismic hazard with any certainty. Surely, these propositions cannot lead to a conclusion that supports Hungary's case. Hungary's difficulty lies in the embarrassing fact that the lack of data stems from the low earthquake activity in the area.

Earlier in this section of the "Scientific Evaluation" (6.2.2), Rebáric (1982) is cited. This study relates to Slovenia not Slovakia as Hungary wrongly supposes.

(5) *The known fault between Györ and Komárom represents the most active section of this source, several hundred earthquakes having occurred on this line since 1754. Balla (1994) maintains that the 1763 Komárom earthquake is not necessarily related solely to the Komárom-Berhida source, but could be related to the Györ-Becske Line.*

...

It should be noted that Dunakiliti lies within 30 km of the Mur-Mürz source, Gabčíkovo within 20 km of the Györ-Becske source, and Nagymaros within the Györ-Becske source.

As already mentioned above, there is no evidence to show that the hypothesised Komárom-Berhida fault line is "active". Only one earthquake of importance, the 1763 Komárom earthquake, occurred near the line.

The 1994 study of Balla commissioned by Hungary for this case has come up with a previously unknown fault line (Györ-Becske); but according to the "Scientific Evaluation" it is only "postulated" - according to Balla it is "supposed". And the Balla study makes clear that the calculations for "supposing" such a line to exist have not been completed. This fortuitous "discovery" moves an alleged fault line closer to Gabčíkovo (20-25 km

rather than 45 km); and Balla then plays down the importance of the postulated Györ-Berhida fault line, further away. All of this is pure theory. Moreover, Balla's supposition is not substantiated by the latest geophysical interpretations, or the latest results of seismological interpretations, or by the latest geologic-tectonic or neotectonic research. See, Vol. III, Ch. 10, Part II.

The aim of the exercise is then made clear: it is to place each barrage near a fault line. Dunakiliti: 30 km from the "Mur-Mürz source"; Gabčíkovo: 20 km from the "Györ-Becske source"; Nagymaros within the "Györ-Becske source". There is absolutely no basis (and none referred to) for the description in the"Scientific Evaluation" of this hypothetical fault as "relatively active". There are no fault lines in Slovakia within a distance of any concern from any of the critical facilities of the G/N Project that can be described on the basis of the scientific data available as "active". Illus. No. R-9 (appearing at SR, para. 12.69) shows the Komárom-Berhida and the Mur-Murz source zones hypothosised by Zsíros (1991) and the new so-called "Györ-Becske" source zone proposed by Balla (1994). It is noted that the earthquake epicentres of any magnitude shown on this map lie far away from the Gabčíkovo section of the Project. It is clear from this Illus. that the "discovery" in 1994 of the so-called "Györ-Becske" fault line and source zone has the effect of reducing the distance from Gabčíkovo to a hypothesised source zone from 45 km to 20-25 km and of almost including Nagymaos within the zone.

The Balla (1994) study was restricted to Hungarian territory; but it is interesting to note that in spite of his postulating a new fault line and various earthquake zones (which he terms "populations"), he merely concludes:

> **"Correlation between the geological structure and earthquake distribution is difficult to find since, due to the moderate seismicity of Hungary, the database ... which covers the last 200 years, is insufficient to trace the seismic actively." HC-M, Vol. 4 (Part 2), Annex 21 (at p. 818 - emphasis added).**

It is evident that in Vol. 2 of its "Scientific Evaluation", Hungary is trying to invent an earthquake risk which is not there.

(6) *There is, however, little data to sensibly assess maximum credible events on the basis of anything other than a probabilistic approach.*

...

At present there is insufficient information to allow a fully deterministic evaluation of the Maximum Credible Earthquake; earthquakes of between 6.0 and 6.5 magnitude (Richter) remain appropriate in light of more recent studies, and it is considered that an event within this range of magnitude could conceivably take place anywhere within the source zones identified.

Having said here that the probabilitistic approach alone is appropriate for assessing a "maximum credible" earthquake, six pages later Hungary suggests instead a "deterministic method", making this statement:

> **"Probabilistic methods suffer a number of drawbacks ... [T]he identification of source zones may be difficult in areas of low rates of energy release [which Hungary has already indicated the region of the G/N Project to be (see, Comment 11 to "Scientific Evaluation", p. 205, above)], particularly when there is little surface expression of the sources ... In addition, it is assumed that earthquakes are uniformly distributed in space and time within the sources zone, which is not necessarily true." See, "Scientific Evaluation", p. 213.**

In the light of the general accepted re-evaluation (ignored by Hungary's "Scientific Evaluation") of the magnitude of the only important known earthquake in the general region - the 1763 Komárom earthquake - to M = 5.7, Hungary's assumed M = 6.5, from which its other calculations proceed, is invalid - see, Comment 3 to "Scientific Evaluation" p. 201, above.

There is no scientific basis for assuming that "an event within this range of magnitude could concurrently take place anywhere within the source zones identified" for these reasons: (i) the fault lines and source zones are only postulated and the so-called Győr-Becske fault line and zone is wholly unsubstantiated; (ii) there is no evidence these faults are active; and (iii) the only appropriate assumption for estimating seismic load is that another earthquake of M = 5.7, I = 8.5, A = 0.0796 g might occur at Komárom. In other words, from these assumed inputs of the seismic load of an earthquake at Komárom, the effect on the critical parts of the Project, over 45 km away, can then be estimated.

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Table 6.1: Seismic Zoning for the Project, September 1965.

River Section (river km)	Design Intensity I_o (MCS)	Design Acceleration (g)
–1861	7	0.025
1861-1823 (Dunakiliti)	6	0.01
1823-1808 (Gabčíkovo)	7	0.025
1808-1797	8	0.05
1797-1770	8.5	0.08
1770-1764 (Komárom)	9	0.10
1764-1752	8.5	0.08
1752-1740	8	0.05
1740-1720	7	0.025
1720-	6	0.01

The instrumental determination of magnitude, for example the Richter Scale, offers a more consistent approach cataloguing earthquake strength. The bulk of historical data was gathered before instrumental determinations were possible, and hence intensity scales continue to be of importance in decision-making. Correlations between epicentral intensity, I_o, and Richter magnitude, M, have been attempted for the Carpathian region by Csomor and Kiss (1959):

$$M = 0.6I_o + 0.3$$

$$M = 0.6I_o + 1.8 \log h - 1.3 \text{ (h: depth of focus),}$$

and more recently by Kárník (1966):

$$M = 0.56I_o + 0.96$$

As can be seen by Kárník's regression analysis, which is shown on *Figure 6.5*, there is considerable scatter in the data. Only broad comparisons are, therefore, advisable; nevertheless, it can be seen from *Figure 6.5* that the "maximum possible" event for the region, M_{max}=6.0-6.5, prescribed by Kárník is broadly consistent with I_o=9 MCS or MSK. 1

Table 6.2: Mercalli Cancani Sieberg (MCS) Intensity Scale.

Class		I_o	Effects
I	"IMPERCEPTIBLE"	1	Can be detected only by instruments
II	"VERY LIGHT"	2	Detected only in the upper floors of buildings by particularly sensitive persons
III	"LIGHT"	3	Detected only by few persons, similar to vibrations produced by a fast car passing nearby
IV	"MODERATE"	4	Detected by many persons inside houses and by a few in open spaces, with vibrations similar to those produced by a heavy lorry. Slight trembling of dishes in cupboards.
V	"QUITE STRONG"	5	Detected by practically everybody; swaying of suspended objects, visible movement of trees and branches.
VI	"STRONG"	6	Detected by everybody with alarm; many run outside. Moving and falling of certain objects; cracks in the mortar of a few houses.
VII	"VERY STRONG"	7	Considerable damage from falling objects; large bells ring in churches. Slight damage to solid houses, localised destruction in old houses.
VIII	"DESTRUCTIVE"	8	Bending and falling of trees. Serious damage to about 25% of buildings. Streams carry sand and mud.
IX	"STRONGLY DESTRUCTIVE"	9	Destruction and severe damage to about 50% of buildings.
X	"RUINOUS"	10	Destruction of about 75% of buildings, of some bridges and dams. Landslides.
XI	"CATASTROPHIC"	11	General destruction of buildings and bridges, including piles. Significant morphological changes and many landslides
XII	"TOTALLY CATASTROPHIC"	12	All works of man are destroyed. Great morphological changes. The course of rivers is changed and lakes disappear.

As can be seen from *Table 6.1*, the highest design intensity, I=9, occurs near Komárom; it is comparable to the 1763 earthquake, and that postulated by Kárník as the "maximum possible" for the region. The seismic zoning proposed in 1965 is very similar to zoning embodied in Czechoslovakian building codes, described by Kárník *et al.* (1988). The zoning applied in the building codes for "standard" buildings is based purely on historical earthquake events. As noted by Kárník *et al.* (1988), this approach is not satisfactory for "critical facilities" for which a "more 2

2 complex hazard assessment must be made". This is particularly true in regions of low rates of energy release where earthquake source zones and recurrence relationships are poorly defined.

6.3.1.2 Design acceleration

The design accelerations given in *Table 6.1* are directly comparable with earthquake coefficients given in Romanian and Yugoslavian (1964) building codes (refer to I.A.E.E., 1984) for the corresponding intensity value. These are compared with peak ground accelerations taken from Spanish, Italian and Soviet practice on *Figure 6.6*. As can be seen from *Figure 6.6*, the design coefficients are approximately 30% of peak ground acceleration.

The design coefficients of the Yugoslav and Romanian codes, and those of the Project, are intended for use in simple pseudo-static design methods. By such methods a "static" force is applied to the structure being analysed, and the stability of the structure tested against simple equilibrium criteria. Because peak ground acceleration refers to the single largest instantaneous acceleration during an earthquake, it would not be appropriate to use peak ground acceleration in such 3 analyses. In the 1970s and 1980s, advances were made in dynamic analyses, which consider the full time-history of earthquake records. Earthquake records are best scaled to meet design requirements according to peak ground acceleration, velocity and duration, which can be measured in the field, and to which the attenuation relationships (ground motion v. distance) can be fitted. Typically, pseudo-static design coefficients are between 20% and 30% of peak ground acceleration. Increasingly, pseudo-static coefficients are not provided directly in building codes 3 but are incorporated into multipliers applied to peak ground acceleration. Dynamic analyses, on the other hand, use peak ground acceleration directly. Relationships between peak ground acceleration and intensity were available at the time the design criteria for the Project were set (for example, see Medvedev, 1962 and *Figure 6.6*). I believe that the acceleration levels embodied in the Joint Contractual Plan were not intended as a measure of peak ground acceleration. Intensity 9 MCS would, for example, have a design coefficient of 0.10 g (see *Table 6.1*), corresponding to a peak ground acceleration of about 0.30 g (see *Figure 6.6*).

6.3.2 METHODS OF EVALUATING EARTHQUAKE HAZARD

6.3.2.1 Probabilistic methods

Probabilistic methods provide a means of evaluating seismic hazard at a specific site. They were introduced by Cornell (1968), and are based on the historical record of earthquakes, applying the following procedure:

1) Earthquake source zones are identified and recurrence relationships (earthquake magnitude v. return period) established for each source.

2) An attenuation relationship (earthquake motion v. distance from the epicentre) is developed or a relationship for a similar tectonic region is adopted. In this case, earthquake motion is characterised by peak ground acceleration.

3) A cumulative probability distribution is constructed from (1) and (2) above, combining the contributions from the various sources.

4) The probability of varying levels of acceleration occurring or being exceeded is calculated assuming an extreme event probability distribution for the expected design life of the facility.

Probabilistic methods suffer a number of drawbacks. As discussed previously, the identification of source zones may be difficult in areas of low rates of energy release, particularly where there is little surface expression of the sources. Recurrence relationships, which are based on a relatively short historical record, become inaccurate when calculating the probability of extreme events with return periods of 10,000 years or more. In addition, it is assumed that earthquakes are uniformly distributed in space and time within the source zones, which is not necessarily true.

A probabilistic analysis was carried out by Zsíros (1991) on the Dunakiliti facility using the source zones shown in *Figure 6.1*. The results of the analysis are shown in *Figure 6.7*. As can be seen from *Figure 6.7*, the design level of intensity (I=7) would be expected to have a return period of about 1,000 years; this corresponds to a 10% probability of excedence over a 100 year period, and I know of no circumstances where this could be shown to be acceptable for large critical structures.

6.3.2.2 Deterministic methods

In the deterministic approach, earthquake sources are identified, and the effects of earthquakes of varying magnitude occurring at the closest point within the various sources to the site are assessed. Because of the difficulties associated with probabilistic analyses, preference is give to deterministic methods in current practice (ICOLD, 1989). Ideally, appropriate real time histories should be used and consideration be given to the local soil conditions in evaluating the site response. Such an analysis has been carried out using strong motion data from the 1976 Friuli earthquake by Bondár (1994). The Friuli earthquake was used because the mechanism is appropriate to the region (i.e., shallow strike-slip), the earthquake recording was made on outcropping basement rock, and the magnitude appropriate to the analysis. The analysis considers the effect of a magnitude 5.6 earthquake at an epicentral distance of 25 km. A soil column 400 m in thickness was used, *(1) It can be seen from Figure 6.5 that the "maximum possible" event for the region, M_{max} = 6.0-6.5, prescribed by Kárník is broadly consistent with I_o=9 MCS or MSK.*

The proposed assumption of M = 6.0 - 6.5 for the magnitude of the 1763 Komárom earthquake was made 25 years ago by Kárník (1971). Hungary ignores the widely accepted 1991 study re-evaluating the magnitude of this event to M = 5.7 as a maximum. Even if the value I = 9 MCS or MSK were valid for Komárom, it would not at all be valid for Gabčíkovo, 45 km away - see, Comment 6 to "Scientific Evaluation" pp. 207-208, above.

However, the key factor in calculating seismic load is acceleration. Here such factors as magnitude, epicentral distance and geological conditions are necessary inputs to be calculated.

(2) The seismic zoning proposed in 1965 is very similar to zoning embodied in Czechoslovakian building codes, described by Kárník et al. (1988). The zoning applied in the building codes for "standard" buildings is based purely on historical earthquake events. As noted by Kárník et al. (1988), this approach is not satisfactory for "critical facilities" for which a "more complex hazard assessment must be made". This is particularly true in regions of low rates of energy release where earthquake source zones and recurrence relationships are poorly defined.

As noted above (see, Comment 1 to the "Scientific Evaluation" p. 201, above), the seismic zoning of the Project was not based on out-dated 1965 standards.

It is noted that Hungary again admits that there are "low rates of energy release" in the region, making it difficult for Hungary to make its risk calculations. But, paradoxically, this fact leads Hungary to assume the presence of greater risks, whereas the lack of data shows the area to be one of low seismic activity.

(3) In the 1970s and 1980s, advances were made in dynamic analyses, which consider the full time-history of earthquake records.

...

Dynamic analyses, on the other hand, use peak ground acceleration directly. Relationships between peak ground acceleration and intensity were available at the time the design criteria for the Project were set (for example, see Medvedev, 1962 and Figure 6.6). I believe that the acceleration levels embodied in the Joint Contractual Plan were not intended as a measure of peak ground acceleration.

While hinting at the availability of the dynamic analysis method at the time when the design criteria for the Project were set out, Hungary hides the fact that meaningful use of this method presupposes the availability of exact information on the geological-tectonic structure of the region (this information was available only later). Hungary in referring to the original state of Project design also ignores the gradual up-dating of the seismicity and stability research.

Thus, the stability of the Project was re-assessed in 1982 when accelerograms of the Friuli earthquake (1976) ("full time history of earthquake record") were used by Gidroproject Moscow (experts Docenko and Vucel to calculate the dynamic response of the Project at acceleration O.2 g at the dyke's foot by the method of finite elements. The duration of the Friuli accelerogram was 20 sec. This calculation was based on the best available information (at that time).

Only after having obtained new information on the structure of the Danube basin in the framework of the DANREG project and seismic reflection research reprocessed by the US oil

company Maxus, was it possible to make full use of the new methods referred to by Hungary. The two studies forming Ch. 10 of Vol. III are based on these methods and the latest information. Without the exact entry data, the use of these methods would be worthless.

When Polko used information gained from the Friuli earthquake in his calculations of acceleration 0.125g at the dyke foot (0.25 at the dyke crown), this testified to the cautions approach of the designer. By contrast, should the Friuli mechanism be used for calculations in the 1990s, when much more advanced data on source accelerograms and the geological structure of the region are available, then the results of such calculations would be irrelevant.

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having properties appropriate to the Danube gravel and overlying Holocene materials. The properties are estimated rather than measured; future work should, where possible, be based on measured data. The analysis is, however, regarded as sufficient for present review purposes. The calculated ground response showed a peak ground acceleration of about 0.25 g. 1

The study by Bondár (1994) forms a useful basis for comparison, as the event size approaches that of the "maximum possible" given by Kárník (1971) and the epicentral distance is comparable to both the distance of Gabčíkovo to the Győr-Becske Line (Balla, 1994) and the distance of Dunakiliti from the Mur-Mürz Line. 2

The concept of designing critical facilities to maximum credible ground motions evolved during the 1970s and 1980s, and was embodied in ICOLD recommendations in Bulletin 72 in 1989. Bulletin 72 states: *"For dams whose failure would present a great social hazard, the maximum design earthquake will normally be characterised by a level of motion equal to that expected at the dam site from the occurrence of a deterministically evaluated maximum credible earthquake....It will be required at least that the impounding capacity of the dam be maintained when subjected to that seismic load."* 2 A detailed risk analysis is, however, required to determine whether this level of design is justified. Such an analysis, using present "state-of-the-art" techniques, has not to my knowledge been carried out. The decision concerning seismic design input parameters should be made jointly by the owners, their consultants and involved regulatory or review agencies, with a strong consideration of public sentiment. When considering the physical size of the project and the number of communities close by, and since the project occupies an international border, it is likely that the use of a Maximum Credible Earthquake would be shown to be appropriate.

In this particular case, a sensible basis for review would be to apply an agreed "maximum possible" earthquake anywhere within the potential source zones (Mur-Mürz and Győr-Becske Lines). 3 The study by Bondár (1992) indicated a peak ground acceleration of about 0.25 g for a magnitude 5.6 earthquake at an epicentral distance of 25 km; a similar exercise using a magnitude 6.5 earthquake is likely to show a higher level of acceleration, probably of the order of 0.3 g, to be applicable to the majority of the project. 4

I have not seen the results of the investigations of the fault line in the immediate vicinity of Gabčíkovo, which were carried out by the Slovak side. I am therefore unable to comment on the capability of this fault and it is possible that this fault should also be considered as an earthquake source. If included, levels of peak ground acceleration greater than 0.3 g may be applicable to Gabčíkovo.

6.3.3 ENGINEERING DESIGN

6.3.3.1 Containment dykes

Experience has shown that compacted granular embankments are usually inherently stable during earthquake shaking, providing the foundation materials are sound. The use of a rolled asphaltic membrane on the retained-water side, such as constructed in the headrace canal under the Joint Contractual Plan, means that the bulk fill of the dykes remain dry and, hence, less susceptible to settlement during strong shaking. Loss of freeboard due to internal deformation and settlement within the headrace dykes is unlikely to exceed 1% of the height of the dyke at levels of shaking consistent with the Maximum Credible Earthquake (see *Chapter 6.3.2.2*). Settlements of less than 0.2 m can therefore be expected from the internal compaction of a 20 m-high dyke. 5

The bulk fill of the headrace canal dykes comprises Danube gravel. As described in the Joint Contractual Plan (1978) and by Mantuano (1989), the particle size distribution of the Danube gravel is well-graded and stepped; the gravel content is typically in the range of fine to medium, with significant proportions of fine sands. Medium and coarse-grained sands are virtually absent. 5 Such materials when re-compacted tend to be easily eroded by water and are potentially internally unstable when subject to through-flow of water. Gradings of the Danube gravel that I have examined fail the criteria of Kenney and Lau (1985), which has been shown to reasonably predict internal instability observed both in the laboratory and in the field. In the 1960s and 1970s, such materials were generally considered as stable. The potential vulnerability of these materials is of concern, and increases the risk of a breach of the dykes occurring in the event of damage to water-proofing membranes or over-topping.

The careful detailing of interfaces between concrete structures, such as weirs, and earth structures is essential in ensuring good performance during earthquakes. 6 I have not had access to such details on the Slovak side and recommend that such a review be carried out by an independent review board. I have some concern over the performance in the retained-water membrane detailed for the Variant C dykes. This comprises a 0.6 mm thick PVC membrane covered by a 1.5 m thickness of bulk fill and pre-cast concrete wave protection units. My chief concern is that strong shaking would be accompanied by down-slope sliding of the fill overlying the membrane. This would cause cracking and settlement at the crest of the dyke, and possibly rupture of the membrane; in this case, the membrane supplies a low-strength surface for the overlying fill to slide on.

6.3.3.2 Liquefaction of dyke foundation materials

Granular materials, for example silts, sands and gravels, that are saturated with water and in a loose condition may be subject to liquefaction. Soils undergoing liquefaction lose their strength, and this is marked by phenomena such as "sand boils" appearing at the surface and flow-slides. Liquefaction phenomena have been associated with earthquakes in historical data extending back to the 16th century. Technical reports on damage to embankment fills due to liquefaction began to emerge in the 1960s (e.g., Duke and Leeds, 1963). It was not until 1971, with the failure of the Lower San Fernando Dam, that designers began to realise the limitations of pseudo-static design methods which made no allowance for complete or even partial liquefaction of soils. A method of evaluating liquefaction potential was first made by Seed and Idriss (1971). The method, which is based on case histories and the results of standard penetration tests, is still used in current practice. Modifications have since been made to make allowance for earthquake magnitude, the presence of fine materials or gravels and the use of cone penetration tests in place of standard penetration tests (for example, Tokimatsu and Seed, 1987 and Tokimatsu, 1988).

Technical developments in laboratory testing and the dynamic modelling of soils have proceeded concurrently with empirical methods. Sophisticated dynamic finite element modelling is now possible in which pore pressure generation can be assessed, and predictions made of displacement and loss of strength of foundation materials as a result of earthquake shaking.

Liquefaction phenomena have been documented on four occasions in Hungarian history:

1) Komárom (1763)	I_o=9.
2) Mór (1810)	I_o=7
3) Érmellék (1834)	I_o=9
4) Kecskemét (1911)	I_o= 8 to 9

In practice, such phenomena are not observed at Richter magnitudes of less than 5.0. Although comparatively large (M=7.2), the 1977 earthquake in Vrancea, Romania, is illustrative of the potential problems. The earthquake epicentre was relatively deep (≈100 km), and the effects spread over a wide area. A maximum horizontal ground acceleration of about 0.2 g and intensity, I=8, were measured in Bucharest. As can be seen from *Figure 6.8a*, liquefaction phenomena were widespread, extending up to 200 km from the epicentre. Lateral spreading and loss of freeboard of dykes due to liquefaction were observed, and are shown schematically on *Figure 6.8b*.

As discussed in *Chapter 6.2.3*, the very low penetration resistance of the recent fine sands and silts in the region indicate these materials to be susceptible to liquefaction. 7

The simple evaluation procedures developed by Seed and Idriss (1971) and Tokimatsu (1988) are based on measured or assumed peak ground acceleration. Bondár (1992) showed that peak ground accelerations of about 0.25 g could be expected about 25 km from an M=5.6 event. Accelerations of 0.3 g probably represent the maximum credible case; liquefaction of the loose sands and silts can be expected when applying the above evaluation methods with this level of acceleration. 8 In the worst credible scenarios, therefore, facilities at Dunakiliti, Čunovo and Gabčíkovo would be just within areas of potential liquefaction surrounding the source zones. Furthermore, the raising of water levels upstream of Nagymaros would have increased the potential for liquefactions in this area as well.

6.3.3.3 Settlement in foundation materials

Granular materials may undergo volume change as a result of earthquake shaking. The degree of volume change is dependent on the dynamic shear strain to which the soils are subject, and the density and grain size of the soils. The volume change results in settlement at the ground surface. Where the degree of shaking is sufficient to cause liquefaction, settlements may be in excess of 1% of the thickness of the liquefiable soil. Liquefaction is, however, not strictly necessary for settlements to take place; settlements of up to about 1% of the thickness of the deposit are possible, without liquefaction taking place.

There have been a number of case studies, the most dramatic of which occurred at the Homer Split during the 1964 Alaskan Earthquake (M=8.5). Measurements showed that settlements amounting to 0.5% (0.76 m) of the 140 m-thick layer of sands and gravels at the site were due to compaction within these materials. In addition, 0.6 m of regional subsidence took place, bringing the total settlement to 1.36 m. Another illustrative case study is the smaller, M=6.3, earthquake in Edgecumbe, New Zealand, in 1987. The earthquake, which had an epicentral intensity of 9, was accompanied by widespread liquefaction over a 200 km^2 area (Smith and Wood, 1989). 9

There are similarities between ground conditions at Edgecumbe and those in the Szigetköz. Both areas are thought to be located in zones of crustal sinking; rates of sinking around Edgecumbe were about 1-2 mm/year prior to the earthquake (Blick and Flaherty, 1989), which is comparable to that of the Szigetköz. In both areas there are deep basins filled with Quaternary materials. In addition to widespread liquefaction, settlements of up to 2 m were recorded. The fault-plane solution for the main shock has indicated both strike-slip and normal components of shaking, and it is clear from field observations that movements have taken place on several faults, not necessarily within the earthquake hypocentre. The settlement observed was the result of both compaction of the Quaternary soils, and tectonic movement.

Simple methods of estimating compaction settlements have been developed by Lee and Albaisa (1974), Tokimatsu and Seed (1987) and Watabe *et al.* (1993). At

(1) *The study by Bondár (1994) forms a useful basis for comparison, as the event size approaches that of the "maximum possible" given by Kárnik (1971) and the epicentral distance is comparable to both the distance of Gabčíkovo to the Györ-Becske Line (Balla, 1994) and the distance of Dunakiliti form the Mur-Mürz Line.*

<u>See</u>, <u>inter</u> <u>alia</u>, Comment 3 to "Scientific Evaluation" p. 201, above.

(2) *The concept of designing critical facilities to maximum credible ground motions evolved during the 1970s and 1980s, and was embodied in ICOLD recommendations in Bulletin 72 in 1989.*

...

A detailed risk analysis is, however, required to determine whether this level of design is justified. Such an analysis, using present "state-of-the-art" techniques, has not to my knowledge been carried out.

All the customary methods of assessment of risk have been used for the G/N Project and brought up to date to reflect advances in science and technology (<u>see</u>, Comment 1 to the "Scientific Evaluation" p. 201). But, of course, any such assessment is hampered by the lack of data, as this Chapter of Hungary's "Evaluation" repeatedly points out, for the Project is not located in an active seismic region and hence there is not much earthquake data.

(3) *The study by Bondár (1992) indicated a peak ground acceleration of about 0.215 g for a magnitude 5.6 earthquake at an epicentral distance of 25 km; a similar exercise using a magnitude 6.5 earthquake is likely to show a higher level of acceleration, probably of the order of 0.3 g, to be applicable to the majority of the project.*

Hungary's calculation of the most important component of earthquake risk, acceleration, is greatly exaggerated. And the reference to Bondár (1992) is a mistake of some significance: the reference at the end of this Chapter of the "Evaluation" includes only Bondár (1994), clearly tied to the 1994 "Scientific Evaluation" of Hungary.

In contrast to Bondár (1994), Slovak experts have calculated the accelerograms of expected earthquakes, using established techniques, from which 500 different models were constructed for different sites within the G/N Project. In the locality of the Gabčíkovo step, the accelerograms could be very accurately calculated since there is situated there a geothermal well of a depth of 2,582 metres, revealing the details of the subsoil. They also had at their disposal seismic reflection sections. These measurements were reprocessed by the United States company Maxus "for the sake of better legibility of integrated geologic environments". Slovakia's calculations so rendered show Hungary's calculations of accelerations to be in error by a wide margin. <u>See</u>, Vol. III, Ch. 10. The following extracts are taken from the conclusion to Part I of Ch. 10:

"We present herewith the results of a complex analysis of accelerations and spectral parameters of wave motion, carried out within the whole area of the Gabčíkovo Project, using in the calculations a variety of parameters, epicentral areas and real geologic environments."

The Slovak scientific analysis indicates the huge difference in the calculations of acceleration resulting from Hungary's errors and incorrect assumptions:

> **"These results have shown that the maximum calculated acceleration applicable for the Gabčíkovo Project and obtained by the means of calculation of the MCE equals the value 0.0796g, and not 0.3g, as asserted in the HC-M."**

(4) *I have not seen the results of the investigations of the fault line in the immediate vicinity of Gabčíkovo, which were carried out by the Slovak side. I am therefore unable to comment on the capability of this fault and it is possible that this fault should also be considered as an earthquake source. If included, levels of peak ground acceleration greater than 0.3 g may be applicable to Gabčíkovo.*

There is no proof that a fault line runs through Gabčíkovo; on the basis of various hypotheses, its existence has been assumed. If such a fault line exists, <u>there is not the slightest evidence that it is an active fault</u>. In fact, nowhere on the Slovak side of the Danube in the region of the G/N Project have any of the fault lines identified been shown to be seismically active.

On the basis of the geological - tectonic analysis (Hok, <u>et al</u>., 1995 - <u>see</u> Vol. III, Ch. 9), it may be concluded that there are no seismoactive tectonic faults in the region of the Gabčíkovo section of the G/N Project on the Slovak side of the Danube.

Although the author of this Chapter of Hungary's "Scientific Evaluation" allegedly lacked data about the "Gabčíkovo fault", he is able, nevertheless, to conclude that "it is possible that this fault should also be considered as an earthquake source". In other words, the lack of access to data - which is acknowledged to exist - leads to the startling conclusion that it must be assumed that an earthquake of major proportions will strike Gabčíkovo, having a peak ground acceleration even exceeding 0.3g, which Slovakia's calculations have demonstrated is 4 times too high <u>for an earthquake occurring at Komárom (not at Gabčíkovo)</u> of M = 5.7 and I = 8.5.

(5) *The bulk fill of the headrace canal dykes comprises Danube gravel.*

...

Such materials when recompacted tend to be easily eroded by water and are potentially internally unstable when subject to through-flow of water. Gradings of the Danube gravel that I have examined fail the criteria of Kenney and Lau -1985), which has been shown to reasonably predict internal instability observed both in the laboratory and in the field. In the 1960s and 1970s, such materials were generally considered as stable. The potential vulnerability of these materials is of concern, and increases the risk of a breach of the dykes occurring in the event of damage to water-proofing membranes or over-topping.

This is simply incorrect. <u>See</u>, Vol. III, Ch. 11.

(6) *I have not had access to such details on the Slovak side and recommend that such a review be carried out by an independent review board. I have some concern over the performance in the retained-water membrane detailed for the Variant C dykes.*

Hungary, as joint partner in the Project, has had complete information concerning the construction of dykes under the Project. The details concerning the "retained-water membrane" used for the limited additional dykes needed for Variant "C" were published in Slovak papers submitted in connection with the International Conference referred to earlier. <u>See</u>, Comment 4 to the "Scientific Evaluation" p. 204, above. The membrane poses no risk (<u>see</u>, <u>ibid</u>., Comment 7, above, Comment 9 to "Scientific Evaluation" p. 220, below and Vol. III, Ch. 11, fn. 2. Apparently, this information was not made available by Hungary for the preparation of Chapter 6 of this "Scientific Evaluation".

(7) *As discussed in Chapter 6.2.3, the very low penetration resistance of the recent fine sands and silts in the region indicate these materials to be susceptible to liquefaction.*

All these materials were removed in constructing the dykes, as Hungary was well aware. This is not subject to doubt. See, Vol. III, Ch. 11 and, in particular, Figs. 1-4 thereto.

(8) *In the worst credible scenarios, therefore, facilities at Dunakiliti, Čunovo and Gabčíkovo would be just within areas of potential liquefaction surrounding the source zones.*

A "worst credible scenario" would not place the critical areas of the G/N Project "just within the areas of potential liquefaction surrounding the source zones". The fallacy in such a scenario - based on postulated fault lines, in no way established to be active, and based, further, on the scientifically false assumptions concerning zones - has already been shown in the Comments to this Chapter.

The material potentially subject to liquefaction has all been removed.

(9) *There are similarities between ground conditions at Edgecumbe and those in the Szigetköz.*

Here, Hungary's "assessment" takes as a case study an earthquake in New Zealand. The reason such far-flung examples are needed for Hungary's examination is that there are inadequate earthquake data for the Danube basin, since it is a low risk area.

The "assessment" again ignores the fact that the material subject to liquefaction was removed in constructing the dykes in the G/N Project.

1

present, I do not have sufficient information on ground conditions to fully appraise potential settlements. It seems likely, however, that the Danube gravel would not be susceptible to settlement during shaking. If this is the case, then total settlements due to compaction of the overlying Holocene could approach 0.3 m, without liquefaction having taken place. Evidence is, however, required to exclude the Danube gravel as contributing to possible settlement. Settlements of greater than 0.3 m within the foundations of the dykes can be expected where liquefaction and lateral spreading of the dykes takes place. Tectonic sinking would be additional to these movements.

The freeboard allowance applied to the headrace canal is 2.0 m, and is 2.5 m in the lower reaches of the Čunovo Reservoir and the dykes of Variant C. These allowances are broadly consistent with overseas practice. The Soviet SNIP II regulations apply the following relationship in estimating the height of earthquake-generated waves (Δh):

$$\Delta h = 0.4 + 0.76(I-6) \text{ (metres)}$$

which gives $\Delta h = 2.7$ m for $I = 9$. Under the Soviet criteria, the freeboard is possibly too low for the case of the likely Maximum Credible Earthquake. Of concern, however, is the freeboard in relation to settlements that might occur as a result of strong shaking, particularly in view of the potential for liquefaction and settlement as illustrated by observations made during the 1987 Edgecumbe earthquake, the 1964 Alaska Earthquake, and the 1977 Vrancea Earthquake.

6.3.3.4 Geotechnical issues relating to impoundment at Nagymaros

2

A number of geotechnical problems were identified by Mantuano (1989) relating to the impoundment upstream of Nagymaros. These problems were principally of river bank stability, and the effect of rising groundwater on existing land slipping. Although solutions had been investigated in some areas, other areas remained unresolved. Above Zebegény, rising groundwater would potentially have caused flooding of low lying areas. Prevention of flooding would have required permanent pumping. The economic impact of these geotechnical issues would have been significant, and certainly required evaluation.

6.4 EARTHQUAKE DESIGN

6.4.1 SEISMOLOGY

3

The seismic zoning for the project was conceived in 1965, and was based simply on historical records of earthquakes in the region. The application of this approach is widely recognised as underestimating the risk associated with large, critical

projects. More recently, probabilistic and deterministic methods of evaluating seismic hazard have been developed, and re-evaluation of the safety of existing dams has been recommended by the International Commission on Large Dams (ICOLD, 1989). A limited application of these methods to the project has confirmed that a revision of the seismic zoning of the original project was necessary. As far as I am aware, no systematic attempt has been made to re-zone the project using methods of hazard evaluation that comply with current practice.

3

In areas of low rates of energy release, it is often difficult to establish source zones and recurrence relationships that are necessary for carrying out probabilistic analyses of extreme events. In the region, the reliable history of large events is probably no more than 500 to 1,000 years; this is a short time period in relation to extreme events, which may have return periods of tens of thousands of years.

4

Risk analyses are complicated by the large geographical extent of the project, and the difficulty of assessing economic loss in the case of a breach of the containment system. To my knowledge, a full risk analysis has not been carried out. When considering the size of the project and its location, and importance, a risk analysis would, by present standards, be regarded as mandatory.

5

Any decision on input parameters for seismic design should be conservative, realistic, and based on sound engineering judgement. A simplistic assessment of risk based on ICOLD Bulletin 72 would probably place the project in a high risk category. This suggests that the structures should be designed to withstand the Maximum Credible Earthquake, without uncontrolled release of the impounded water. Subject to a risk analysis being carried out, a sensible approach for present review is to adopt source zones on the basis of the recent geological, seismological and tectonic studies (for example, Balla, 1994), and apply a worst possible earthquake of M=6.5 within these zones. Site response studies, such as that made by Bondár (1992) should be used to determine input parameters. Consideration should also be given to the potential capability of the fault line located 700 m downstream of Gabčíkovo.

6

6.4.2 ACCELERATION

7

The levels of acceleration embodied in the Joint Contractual Plan are for use in pseudo-static design methods, and are not directly comparable to peak ground accelerations which are used in more modern design methods. If earthquake design were based on the concept of Maximum Credible Earthquake, as described in 6.4.1 above, the effect would be similar to applying the original design levels of ground motion for the zone 1770 rkm to 1764 rkm (Komárom) over the entire project.

Pseudo-static design methods are not, however, appropriate in assessing displacement and potential for liquefaction and settlement during earthquakes.

Critical structures should be examined using modern finite element techniques, in which allowance can be made for strain softening of the foundation materials.

8

Simplified methods used to examine liquefaction and settlement rely on peak ground acceleration; in the case of the maximum credible event, this would be of the order of 0.3 g over much of the project. This level of acceleration is comparable to that applied to large critical structures in other European countries with low levels of seismicity. In the UK, for example, peak ground accelerations of up to 0.375 g are recommended for high risk dams (Charles *et al.*, 1991).

6.4.3 VULNERABILITY AND DAMAGE

Compacted soil embankments with membranes on the retained-water side, as adopted for much of the project, are well suited to resisting earthquake shaking without substantial damage or deformation. From the limited information available it is likely that the level of acceleration expected during the maximum credible event would be sufficient to cause liquefaction of the recent sands and silts. As these materials are known to extend to depths of up to 30 m near Gabčíkovo, it is very unlikely that all liquefiable material was removed during construction of the headrace canal; liquefiable material is also likely to extend beneath the dykes of the Čunovo Reservoir.

Liquefaction beneath dykes would be accompanied by lateral spreading and a reduction of crest height. Other mechanisms such as settlement due to compaction, and tectonic subsidence could also lead to a reduction of crest height, and possibly over-topping. The allowance for freeboard (typically 2 m) is probably adequate to cover seismically induced waves, but may not be sufficient to deal with subsidence of the dyke foundations under extreme earthquake loading. The bulk fill forming the dykes is potentially easily eroded, and overtopping would be very likely to develop into a major breach in a short space of time.

9

The detail of the water-proofing membrane of the Variant C dyke is also of concern. Under strong shaking materials overlying the membrane could slide on the membrane, causing cracking at the crest of the dyke and possible rupture of the membrane.

10

6.4.4 CONCLUSION

I have not been able to carry out an exhaustive check on the adequacy of the design details. On checking the basic design concepts, however, I have reached the following conclusions:

1) Although consistent with practice in 1965, the methods used for determining the seismic zoning do not comply with current practice;

they do not adequately reflect the importance of the project nor do they meet with modern standards of acceptable risk.

2) There are substantial uncertainties in assessing risk; nevertheless, studies should be carried out to identify and quantify risks. Subject to such a study being carried out, immediate review should be based on the application of a Maximum Credible Earthquake. Liquefaction and settlement beneath containment dykes, loss of freeboard and consequent uncontrolled release of impounded water are likely under this criteria.

3) There were significant geotechnical problems associated with impoundment upstream of Nagymaros that were not fully resolved in 1989.

11

To my knowledge, a detailed risk analysis has not been carried out. There were certainly grounds for concern over design standards and unresolved difficulties in 1989. These were, in themselves, sufficient to justify a reappraisal of design standards and operating conditions for structures already built. This could, in effect, involve a reappraisal of the economics of the entire project.

(1) At present, I do not have sufficient information on ground conditions to fully appraise potential settlements. It seems likely, however, that the Danube gravel would not be susceptible to settlement during shaking. If this is the case, then total settlements due to compaction of the overlying Holocene could approach 0.3 m without liquefaction having taken place. Evidence, is, however, required to exclude the Danube gravel as contributing to possible settlement.

"I do not have sufficient information on ground conditions": the question is why sufficient information was not provided to the author of this Chapter of the "Scientific Evaluation"? The dyke on the Hungarian side, whose safety was of direct concern to Hungary, was constructed by Hungary. The safety of the dyke along the headwater canal was of far greater concern to Czechoslovakia than to Hungary. In any event, as joint participants Hungary knew all the details about ground conditions and the methods of dyke construction. As is demonstrated in Vol. III, Ch. 11, great care was taken in dyke construction to remove sediments subject to liquefaction and to replace them with high quality gravel, using established techniques to prevent settlement.

(2) A number of geotechnical problems were identified by Mantuano (1989) relating to the impoundment upstream of Nagymaros. These problems were principally of river bank stability, and the effect of rising groundwater on existing land slipping. Although solutions had been investigated in some areas, other areas remained unresolved. Above Zebegény, rising groundwater would potentially have caused flooding of low lying areas. Prevention of flooding would have required permanent pumping. The economic impact of these geotechnical issues would have been significant, and certainly required evaluation.

These "geotechnical problems" have <u>absolutely</u> <u>nothing</u> to do with seismology and earthquake engineering, the subject of this Chapter of the "Scientific Evaluation". The problems "identified" concerned the possible effects of impoundment of water upstream of Nagymaros on river bank stability and the possible effect of rising groundwater on existing land slipping. These were problems that were both obvious and well recognised before 1989 (but mainly existing on the Slovak side).

This account itself indicates that solutions had been found in some areas but not in others. It is concluded that the "economic impact" of "geotechnical issues" would have been significant. But there were all sorts of similar "significant" problems being dealt with throughout the development of the Project.

(3) The seismic zoning for the project was conceived in 1965, and was based simply on historical records of earthquakes in the region. The application of this approach is widely recognised as underestimating the risk associated with large, critical projects. More recently, probabilistic and deterministic methods of evaluating seismic hazard have been developed, and re-evaluation of the safety of existing dams has been recommended by the International Commission on Large Dams (ICOLD, 1989)

...

As far as I am aware, no systematic attempt has been made to re-zone the project using methods of hazard evaluation that comply with current practice.

As noted above (at Comment 1 to "Scientific Evaluation" p. 201), the contention that the G/N Project was constructed on the basis of 1965 criteria long since outmoded is totally wrong. The Project was repeatedly reassessed and its criteria updated, and a seismic microzoning was completed in 1980. Since 1970, the calculation of accelerograms and spectra of seismic response has been in use. Peak acceleration has been calculated from

these. The latest information from the latest structural-tectonic studies has been incorporated.

(4) *To my knowledge, a full risk analysis has not been carried out. When considering the size of the project and its location, and importance, a risk analysis would, by present standards, be regarded as mandatory.*

Once again, this Chapter's authors have seemingly been kept in the dark by Hungary. There have been repeated risk analyses, the most complete having been prepared in 1982 (see, Comment 1 to "Scientific Evaluation" p. 201, above). Slovakia has undertaken another full risk analysis in the light of the contentions set out in Hungary's Counter-Memorial, which appears in Vol. III, Ch. 10. This analysis also reveals the serious flaws in the analysis specially prepared by Hungary for this case.

(5) *A simplistic assessment of risk based on ICOLD Bulletin 72 would probably place the project in a high risk category. This suggests that the structures should be designed to withstand the Maximum Credible Earthquake, without uncontrolled release of the impounded water. Subject to a risk analysis being carried out, a sensible approach for present review is to adopt source zones on the basis of the recent geological, seismological and tectonic studies (for example, Balla, 1994), and apply a worst possible earthquake of M=6.5 within these zones.*

"A simplistic assessment ... would probably place the project in a high risk category": this sort of hedging in Hungary's "Scientific Evaluation" cannot be accepted. Earthquake risk assessment is, by its very nature educated guesswork; but it is necessary in order to arrive at safe design and construction criteria. Once having made a risk assessment, it cannot be further qualified as "probably" leading to a certain conclusion, or that it would "probably place the project in a high risk category".

Moreover, Hungary reaches this entirely incorrect conclusion by feeding incorrect, greatly exaggerated data into its computations, as is shown in the Slovak analysis appearing in Vol. III, Ch. 10. Risk analyses have been carried out - the most recent being Slovakia's 1995 assessment annexed hereto. There is no basis for arriving at a "worst possible earthquake" of M = 6.5 (on the Richter scale) and a maximum calculated acceleration of 0.3 g. Slovakia's 1995 analysis in accordance with the opinion of foreign experts Bune, Brouček and Szeidovitz indicates the maximum assumptions for an earthquake at Komárom should be M = 5.7; I = 8.5, and A = 0.079. But these values are for Komárom only, not for Gabčíkovo, 45 km away.

(6) *Site response studies, such as that made by Bondár (1992) should be used to determine input parameters. Consideration should also be given to the potential capability of the fault line located 700 m downstream of Gabčikovo.*

Hungary's "Scientific Evaluation" contains no reference to Bondár (1992); only to Bondár (1994), extracted as Annex 22. There is no evidence of such a 1992 Hungarian study; the Bondár study was specifically prepared for use in this case.

In contrast, Slovakia had started its Maximum Credible Earthquake Analysis in 1993 - well before it received Hungary's "Scientific Evaluation". The Slovak calculations show Hungary's assumption of a worst case earthquake of M = 6.5, if applied to the critical areas of the Project, to be greatly exaggerated. In particular, the "potential capability" of what is known as the Gabčíkovo fault is well established and requires no further investigation; it is an inactive fault creating no earthquake risk. (See, p. 206, Comments 1 and 2 to "Scientific Evaluation" p. 206, above, for an explanation of why the Gabčíkovo step was moved 700 m upstream of this fault.) In addition, a realistic analysis directed by

Halouzka et. al. under the auspices of DANREG confirms the evaluation that if any faults exist in the proximity of Gabčíkovo they are not active.

The question of earthquake risk is always subject to updating on the basis of new data and methods. The earthquake studies relating to the G/N Project, both before and after 1977, have been continually reassessed and brought up to date.

(7) *The levels of acceleration embodied in the Joint Contractual Plan are for use in pseudo-static design methods, and are not directly comparable to peak ground accelerations which are used in more modern design methods.*

The assumed levels of acceleration on which the construction of the G/N Project were based relied on modern design methods. However, Hungary's calculation of maximum acceleration of 0.3 g is grossly exaggerated. As is shown in the Slovak analysis, a reasonable figure would be a maximum value of 0.0796g - see, Comment 3 to pp. 218-219, above.

(8) *Simplified methods used to examine liquefaction and settlement rely on peak ground acceleration; in the case of the maximum credible event, this would be of the order of 0.3 g over much of the project. This level of acceleration is comparable to that applied to large critical structures in other European countries with low levels of seismicity. In the UK, for example, peak ground accelerations of up to 0.375 g are recommended for high risk dams (Charles et al., 1991).*

Hungary's suggestion that an acceleration value of 0.3 g or more can be justified on the basis of comparison with that allegedly applied to "large critical structures in other European countries" or to "high risk dams" is quite remarkable. The exact calculated values based on real models of the G/N Project are far less than the exaggerated values of acceleration arrived at by Hungary based on examples far removed from the region of the Project.

(9) *The detail of the water-proofing membrane of the Variant C dyke is also of concern. Under strong shaking materials overlying the membrane could slide on the membrane, causing cracking at the crest of the dyke and possible rupture of the membrane.*

The imagined concern expressed here regarding the water-proofing membrane of the Variant "C" dyke was the sort of problem carefully considered before the membrane was installed. The relevant data have been published but apparently was not examined in preparing this "Scientific Evaluation" (see, Vol. III, Ch. 11; see, also, Comment 6 to p. 215, above). It would have been advisable not to have commented here rather than to have postulated a problem that does not exist.

(10) *I have not been able to carry out an exhaustive check on the adequacy of the design details. On checking the basic design concepts, however, I have reached the following conclusions:*

1) *Although consistent with practice in 1965, the methods used for determining the seismic zoning do not comply with current practice; they do not adequately reflect the importance of the project nor do they meet with modern standards of acceptable risk.*

2) *There are substantial uncertainties in assessing risk; nevertheless, studies should be carried out to identify and quantify risks. Subject to such a study being carried out, immediate review should be based on the application of a Maximum Credible Earthquake. Liquefaction and settlement beneath containment dykes, loss of freeboard and consequent uncontrolled release of impounded water are likely under this criteria.*

3) There were significant geotechnical problems associated with impoundment upstream of Nagymaros that were not fully resolved in 1989.

Each of these three conclusions is clearly wrong:

(1) Design and construction criteria of the G/N Project are not those of 1965 but were updated and frequently reassessed and reflect "modern standards of acceptable risk" - see, Comment 1 to "Scientific Evaluation" p. 201, above.

(2) Extensive studies have been made to assess risks, including application of the MCE criteria. The danger of liquefaction was carefully studied and resolved by the total removal of sediments prone to liquefication before construction of the dykes. The details of this operation, which were known to Hungary, were seemingly not made available by Hungary to the author of this earthquake risk "assessment".

(3) Astonishingly, the final conclusion has nothing whatsoever to do with seismology or earthquake risk. It is a pure irrelevance and points by itself to the real lack of substance to Hungary's evocation of earthquake risk - most particularly as to Nagymaros, in connection with which earthquake risk was first mentioned by Hungary in 1989 to justify its breach of the 1977 Treaty.

(11) To my knowledge, a detailed risk analysis has not been carried out. There were certainly grounds for concern over design standards and unresolved difficulties in 1989. These were, in themselves, sufficient to justify a reappraisal of design standards and operating conditions for structures already built. This could, in effect, involve a reappraisal of the economics of the entire project.

The validity of these conclusions is severely hampered by the fact that, apparently, the person preparing this Chapter for Hungary was unaware of the extensive risk analysis and studies into all aspects of earthquake risk conducted in connection with the G/N Project. He mistakenly thought the Project's design was fixed as of 1965 as to earthquake risk.

It is regrettable that it has been necessary for Slovakia to spend a great deal of money - and to divert the efforts of some of its leading scientists and engineers - in order to rebut such frivolous claims.

Slovakia is forced to say that a respectable scientific assessment of earthquake risk cannot result from incomplete, inaccurate information as to basic aspects of the problem. It is not surprising that, as the Slovak studies in Vol. III demonstrate, in many respects Hungary reaches unscientific, alarmist conclusions that almost appear designed to satisfy the requirements of Hungary's legal case.

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CHAPTER 7

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Luc Hens, Muraleedharan Valappil and Dimitri Devuyst

7.1 THE CONCEPT OF EIA

1

Environmental Impact Assessment (EIA) is a process for acquiring, analysing and reporting the facts about the social, economic and environmental effects of economic development plans, programs and projects. EIA addresses the constraints and opportunities that the natural environment brings to the success of development. Its aim is to discover problems at an early stage and to provide for their solution so that the benefits of economic growth can be achieved without unacceptable damage to environmental values. It specifies monitoring and post development audits to ensure that environmental predictions are accurate and that implementation of measures and precautions reduces or avoids adverse environmental effects (Carpenter and Maragos, 1989).

The EIA process consists of the EIA procedural steps, the Environmental Impact Statement (EIS), and the link between EIS and decision-making, monitoring and post-development audit. EIA procedural steps include screening, scoping, baseline studies, public participation, prediction and preparation of initial and final EISs, review by public and independent experts, decision-making, monitoring and post-project auditing. An EIS should cover the need for the project and alternative ways to achieve the goal or purpose. It should describe present environmental conditions and the technology to be used, and then predict the consequences with and without the project. It should compare the net present value of all the costs and all the benefits associated with the project throughout its life time and the distribution among societal groups of costs and benefits - who pays and who gains. It may also identify alternatives to the proposed project, as well as the "no-action" alternative.

In this way EIA is generally considered as an important instrument for the prevention of environmental effects of major projects. This has also been recognised both by Hungary and Slovakia.

It was however only in June 1993 that the Hungarian Government issued its EIA Decree (No. 86-1993 VI.4) for Provisional Regulation of the Assessment of Environmental Impact of Certain Activities. This represents a turning point in the history of Hungarian EIA regulation since the decree established the framework for systematic investigation of a broad range of activities and linked it to the decision-making process (Radnia, 1993).

Also in Slovakia the need for EIA procedures was documented. The National Report of the Czech and Slovak Federal Republic to UNCED (1992) points to the following elements:

- "During the last forty years there were no effective legislature measures to stop or at least limit the impact of unfavourable development in our country. Where few did exist, their distorted application rendered them ineffective." (page 118)
- "A system for evaluating the environmental impacts of constructions, technologies and products is an important means of preventing pollution which has been successfully employed in advanced western countries, but it has not been fully implemented in our country." (page 119)

2

The need for a proper EIA in relation to the G/N project was, for example, demonstrated in a PHARE programme request on behalf on the Federal Committee for the Environment and the Slovak Ministry of Water and Forest Resources and Wood Manufacturing Industry (1990). In this project proposal, of which the cost was estimated at three million ECU, it is stated that the "strategic position of this Danubian lowland and the new large hydropower scheme under completion, 'Gabčíkovo', require a thorough and complex study of a proper impact assessment model, enabling authorities to ensure the protection of natural and anthropic resources, balanced ecological development, as well as optimised decision making and management."

The situation changed in the same year when the Federal Act on the Environment No. 17/1992 was adopted. This Environmental Act is concerned with environmental impact assessment and also with activities when they have consequences exceeding state boundaries.

National legislative developments must also be evaluated in conjunction with the evolution of international environmental regulations. The main elements in this context are:

- the Rio Declaration on Environment and Development which mandates EIA for proposed activities that are likely to have a significant adverse impact on the environment (1992);
- the UN Convention on Environmental Impact Assessment in a Transboundary Context (1991) which in its Appendix I mentions explicitly large dams and reservoirs as activities subject to a mandatory EIS as provided for in the Convention;
- the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992);
- the Convention on Co-operation for the Protection and Sustainable Use of the Danube River (Sofia, 1994).

3

It is evident that both Hungary and Slovakia eventually felt the need for a proper and in depth EIA on the G/N Project. The lack however of a formal legal framework before 1992 coinciding with the EIA concept as outlined in this section may explain why no EIS was ever done.

7.2 THE EVOLUTION OF EIA

7.2.1 EVOLUTION IN PROJECT EVALUATION TECHNIQUES

EIA is a project evaluation technique. Project evaluation techniques have evolved over the years, especially during the period 1970-1990. Trends in project evaluation during this time can be summarised as follows:

-before 1970

Mostly analytical techniques were used. These were very close to economic and technological feasibility studies. In these studies there was only limited attention to efficiency criteria and safety concerns. There was no possibility of public debate.

-around 1970

Mostly cost-benefit analysis with multiple aims was used. The systematic counting of advantages and disadvantages and their geographic distribution was stressed. Project evaluation was organised through planning, programming and budget control. There was no attention to environmental and social consequences of a project.

-1970 - 1975

EIA was introduced and focused on the description and prediction of ecological changes and modifications in land use. EIA also introduced public participation in the project evaluation. Attention is paid to surveillance of the project and to mitigating measures.

-1975 - 1980

Multi-dimensional EIA is encouraged – it includes among other things the reporting of impacts at the social level (social impact assessment). Public participation now becomes a fully integrated part of the project evaluation. More attention also goes to risk analysis of dangerous installations.

-1980 - 1990

EIA is no longer considered an isolated event. It is closely linked with higher level policy planning and the implementation management phases. Monitoring, post-project analysis and process-evaluation are stressed. The need for a scoping phase is recognised. More attention goes to health aspects.

The main components of present EIA systems in most countries (applicable at all levels of planning) is given by Wathern (1992) in *Figure 1*.

This evolution in aims, targets and content of EIA and EIS is reflected in national and international regulations. Main steps in this process are:

- the National Environmental Policy Act in the US (1969), which has been under constant substantial evolution (Blumm, 1988)
- the Environmental Assessment and Review Process in Canada (1973) which was updated by the Canadian Environmental Assessment Act (1992) (Couch, 1991)
- the EC Directive 85/337 (1985)
- the Resolution of the CPSU Central Committee and the USSR Council of Ministers of December 28th No. 898 (1972) which was further elaborated in the Resolution of the CPSU Central Committee and USSR Council of Ministers of 7 January 1988, No. 32 (1988) (Govorusko, 1990)
- In 1990 these regulations were completed with elements of international law e.g., the Rio Declaration (1992), the Conventions of Espoo (1991), Helsinki (1992) and Sofia (1993).

Practice in this respect has also been influenced by the role of international organisations such as the World Bank, the International Union for the Conservation of Nature and the United Nations Environmental Program.

This analysis of main trends and their legal basis shows that the aims and outcomes of EIS have changed substantially during the last 20 years. From basic analytical, descriptive studies, the requirements evolved into a complex and contextual instrument, assuring a maximum of relevant elements allowing a decision in which environmental quality can have its legitimate place.

7. COMMENTS TO HUNGARY'S "SCIENTIFIC EVALUATION", CHAPTER 7: ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

(1) Environmental Impact Assessment (EIA) is a process for acquiring, analysing and reporting the facts about the social, economic and environmental effects of economic development plans, programs and projects. EIA addresses the constraints and opportunities that the natural environment brings to the success of development. Its aim is to discover problems at an early stage and to provide for their solution so that the benefits of economic growth can be achieved without unacceptable damage to environmental values. It specifies monitoring and post development audits to ensure that environmental predictions are accurate and that implementation of measures and precautions reduces or avoids adverse environmental effects (Carpenter and Maragos, 1989).

As an initial point, it must be noted that Hungary writes as if it was introducing the concept of the EIA to parties otherwise ignorant or unsure of its meaning and purpose. It is quite clear, however, that both Hungary and Czechoslovakia were fully aware of the existence of the EIA procedure and the goals it could achieve well before the current dispute. As evidence, it is sufficient merely to quote the introduction to Hungary's own 1985 EIA (a document which Hungary now seeks to present as inadequate and outmoded):

> **"The Environmental Impact Assessment as a method has barely [existed] longer than 10 years in the world. Preparation of Environmental Impact Assessment first was ordered in the United States in the local environmental act (NEPA = National Environmental Policy Act) in 1969. Other countries - so far those which have introduced the Environmental Impact Assessment - followed the United States with several years of delay. (For example in Japan there are EIAs prepared since 1974, but at governmental level still they could not succeed to order the preparation of EIAs.)**
> **In our country the 46/1984 (6 September) decree of the Council of Ministers about the "procedure of investments" imposed the preparation of the Environmental Impact Assessments as part of the preparatory and approval procedure."(Hungarian Memorial, Vol. 5, Annex 4 (at pp. 15-16)**

There is therefore no need to introduce the concept of the EIA by the elaborate definition contained in the "Scientific Evaluation" (especially as it is taken from a 1989 Training Manual produced in Hawaii and relevant to environmental impact on tropical islands and coastal areas).

(2) The need for a proper EIA in relation to the G/N project was, for example, demonstrated in a PHARE programme request on behalf on the Federal Committee for the Environment and the Slovak Ministry of Water and Forest Resources and Wood Manufacturing Industry (1990). In this project proposal, of which the cost was estimated at three million ECU, it is stated that the "strategic position of this Danubian lowland and the new large hydropower scheme under completion, "Gabčíkovo", require a thorough and complex study of a proper impact assessment model, enabling authorities to ensure the protection of natural and anthropic resources, balanced ecological development, as well as optimised decision making and management."

The PHARE project is not an EIA and was never intended as such, and in wishing to proceed with the program Czechoslovakia was in no way pointing to a lack of research, but a desire to optimise ground water conditions. Moreover, the focus of attention of the PHARE program is the Danubian lowland, not simply the Gabčíkovo Project.

(3) It is evident that both Hungary and Slovakia eventually felt the need for a proper and in depth EIA on the G/N Project. The lack however of a formal legal framework before 1992 coinciding with the EIA concept as outlined in this section may explain why no EIS was ever done.

Hungary's comment is confusing and contradicts its own findings. An EIA is an environmental impact assessment whilst an EIS is an environmental impact statement, the basic written document behind an EIA. The "Scientific Evaluation" (at p. 248) specifically states that Hungary's 1985 assessment "can be called an EIS". It is therefore inconsistent to claim that "no EIS was ever done".

It may also be pointed out that enactment of what Hungary considers to be adequate legislation post-1992 has not led to "a proper and in-depth EIA of the G/N Project" being carried out by Hungary. In HC-M, Vol. 4 (Part 2) Annex 23, reference is made to a Hungarian 1993 study, which Slovakia has never seen. Hungary describes it as "too incomplete to be given the name EIS" (ibid.). It is also evident that the "Scientific Evaluation", prepared for the purposes of the present case, cannot possibly be called an EIA or an EIS (and Hungary does not claim otherwise).

please turn to next page

Table 7.1: Overview of the evolution of EIA procedures in the US, Canada, the EEC and the World Bank.

U.S.A.	1970 introduction NEPA	1971 courts take active role in quality control	1976 EIA for programmes and policies	1978 introduction CEQ regulations/ strengthening scoping process, public participation and justification of decisions taken by the authorities	1990s changes are proposed to improve alternatives, global env. impacts, public participation, monitoring and the application of NEPA abroad
Canada	1973 introduction EARP	1979 the mechanics of the process are definitively outlined	1984 systematic procedures for screening and monitoring are introduced, social effects should be studied, quality control by Panel is improved	1990s EIA regulations become legally binding, the CEAA is introduced	
E.C.	1985 EC Directive 85/337 is introduced	1990s aspects to be improved in a number of Member States: scoping, quality control, public participation, rules for studying transboundary impacts			
World Bank	1984 a policy statement is issued requiring that env. considerations are taken into account	1989 introduction of Operational Directive on EIA (OD 4.00, Annex A)	1991 screening, public consultation and quality control mechanisms are improved		

7.2.2 EVOLUTION IN EIA PROCEDURES

A distinct evolution in EIA procedures can be distinguished for the period pre 1970-1993. As shown in *Table 7.1*, it is, however, not possible to identify clearly marked years in which certain changes were made in all countries or institutions at once. Each country or institution introduced EIA at its own time. Once EIA is operational shortcomings become obvious within a few years resulting in the adoption of amendments.

Canada and the World Bank first tried to introduce EIA as a policy which was not binding. Both of them realised that more stringent rules were necessary. In all places the need for clearly outlined EIA procedures becomes evident after a few years of EIA practice. Screening, scoping, public participation, quality control and monitoring were steps in the EIA process which needed improvement or special attention in the pre 1970-1993 period and will continue to be important in improving EIA in the future.

The historic evolution of "EIA state-of-the-art" can be broadly subdivided into three decades:

–1970s: high hopes and experimentation

The 1970s was the period of high hopes and experimentation. EIA was thought to be a very powerful instrument which would introduce objective scientific knowledge into the decision-making, resulting in a more environmentally friendly, efficient and open management of human activities on earth. The first reports were prepared, experience was gained, positive and negative aspects of the approach were identified.

–1980s: realism, expansion and new procedural steps

In the 1980s it became very clear that EIA as it was applied in the 1970s would not solve society's environmental problems. EIA can only be effective in case that all parties involved are willing to co-operate in the event that the environmental consequences of policies, plans and programmes are taken into account, in the case that "environment" is defined to include social aspects, cumulative effects, etc. Although it is clear that EIA has its limitations, it was introduced for the first time in the 1980s in many countries outside North America. New procedural steps to make EIA more effective are tried out: screening, scoping, justification of decisions, quality control and monitoring are introduced.

–1990s: establishment of new procedural steps and legislation, unresolved problems

In the 1990s the need and function of procedural steps such as screening, scoping, justification of decisions, public participation, quality control and monitoring are recognised. It becomes clear that the dramatic changes which EIA causes in the decision-making process can only be introduced by way of legislation and detailed, transparent and verifiable procedures. It becomes clear that EIA is still not solving our environmental problems: the prediction of cumulative impacts and the introduction of EIA for policies, plans and programmes remain largely unresolved.

1

2

This background highlights also that in 1977, when the G/N treaty was signed between Czechoslovakia and Hungary, not only clear-cut EIA procedure existed, but moreover the period can be characterised as very experimental from an EIA point of view. In 1989, however, when the treaty was given up, it was clear that a proper, complex and refined procedure was able to provide a realistic basis for decision making. In the 1990s there was, also on the basis of existing national and international regulations, no justification for implementing Variant C without an EIA as defined in a contemporary context.

7.2.3 EVOLUTION IN THE CONTENTS OF EIS'S

Like EIA procedures the contents of EISs are also undergoing changes as more and more experience is gained in the EIA of different sectors. Despite minor differences throughout the world, there is a general consensus on the content of an EIS.

Before 1977 it was not clear for many proponents or authorities what information should be included in an EIS. This was due to a lack of experience, but has changed since 1978, when the US Council on Environmental Quality (CEQ) first issued regulations which gives more detailed guidelines on the content of EISs. The Council periodically publishes procedural guidelines and requires that each Federal agency publish its own guidelines in response. There is provision for revision of the guidelines at appropriate periods in the light of experience with the system's operation and recent advances in EIA methodology. These guidelines, and similar ones adopted in other countries, have assisted in the development of a broad consensus on EIS standards.

Contents of EISs in the US

It is the responsibility of the proposing agency to prepare the EIS. According to regulations in the US, for example, an EIS must contain the following (Munn, 1989):

1. Description of the proposed action; statement of purposes; description of the environment affected;

2. Relationship to land-use plans, policies, and controls for the affected area;
3. Probable impact-positive and negative; secondary or indirect, as well as primary and direct; international environmental implications;
4. Consideration of alternatives;
5. Probable adverse effects which cannot be avoided;
6. Relationship between local and short-term uses and long-term environmental considerations;
7. Irreversible and irretrievable commitment of resources;
8. Description of what other Federal considerations offset adverse environmental effects of proposed action and relation of these to alternatives.

In addition, the comments received from reviewers must be attached. This is the general requirement for all types of development projects including the water resource projects.

Contents of EISs in Canada

In Canada the EIS is a detailed documented assessment of the environmental consequences associated with the project prepared in accordance with the guidelines issued by the Environmental Assessment panel (expert body formed for specific projects). The type of detailed information required is determined by the nature and location of the project.

Contents of EISs in Japan

In Japan (Barrett and Therivel, 1991) the draft EIS should cover similar items like those in the U.S. Surveys and studies, prediction and evaluation mentioned should be conducted in accordance with guidelines which should be established for each category of relevant projects by the competent minister in consultations with the Director-General of the Environmental Agency. The final EIS should cover:

1. the contents of the draft EIS as explained above;
2. a summary of the comments received from the residents of the related area;
3. comments of the prefectural governor with jurisdiction over the related area;
4. views of the project undertaken on the comments received from the residents and prefectural governor.

(1) *It becomes clear that EIA is still not solving our environmental problems: the prediction of cumulative impacts and the introduction of EIA for policies, plans and programmes remain largely unresolved.*

This comment is baffling. The prime purpose of an EIA is to reveal environmental risks and impacts. It points up potential risks and dangers so that the ensuing political decision may be based on better information as to the possible environmental effects of a development and so that variants and alternatives may be considered that lessen these effects. It is also surprising in the light of the current focus placed by Hungary on EIAs that it should call into question here the whole purpose of the EIA.

(2) *This background highlights also that in 1977, when the G/N treaty was signed between Czechoslovakia and Hungary, not only [no] clear-cut EIA procedure existed, but moreover the period can be characterised as very experimental from an EIA point of view. In 1989, however, when the treaty was given up, it was clear that a proper, complex and refined procedure was able to provide a realistic basis for decision making. In the 1990s there was, also on the basis of existing national and international regulations, no justification for implementing Variant C without an EIA as defined in a contemporary context.*

The relevance of this is unclear and the presence of legal-type conclusions (e.g., in relation to "international regulations") in a "Scientific Evaluation" is questionable.

The following facts are of relevance:

1. Prior to the signature of the 1977 Treaty, the G/N Project was studied intensively from an environmental point of view, in particular through the 1975-1976 Bioproject. It may be that "no clear-cut EIA procedure existed" at this epoch, but this does not call into question the essential validity of the Bioproject or its 1986 update.

2. Hungary introduced the EIA in 1983 in relation to the G/N Project and in 1984 followed this by Governmental Decree 46/1984 making an EIA obligatory for all major projects under governmental control. The 1985 EIA shows that Hungary was very well informed of the background to and purpose of an EIA. See, Comment 1 to "Scientific Evaluation" p. 234, above.

3. If, as Hungary contends, it became clear to it in 1989 that there was a need for a "complex and refined procedure", that is, for an EIA, it is surprising that in the same year Hungary in fact repealed - and did not replace - its 1984 EIA Decree (see, Comment 3 to "Scientific Evaluation" p. 247, below).

4. Variant "C" is not a new and previously unresearched project. It is a variant of the G/N Project that puts into operation the bypass canal, the Gabčikovo step and part of the planned reservoir. It was perfectly acceptable to draw on past EIA work in relation to the G/N Project and update this as necessary.

Assessment of both the social environment (safety and amenity of communities, cost/benefit for individuals and the public including employment, income, population density, consumption, land-use pattern, industrial structure, finance, and public service etc.) and the natural environment (quality and quantity of natural features, pollution, disaster) are considered. These are determined through field surveys.

Contents of EISs in the European Communities

1

The EC Directive 85/337 requires Member States to include the following aspects in the EIS: a description of the likely significant effects on the environment, direct and indirect, of the development with reference to human beings, flora, fauna, soil, water, air, climate, the landscape, the interaction between any of the foregoing, material assets, the cultural heritage. A summary in non-technical language of the information specified above should also be included (Lee and Colley, 1990). Next to the aspects considered above, the European Communities EIA directive requires proponents to highlight areas of uncertainty by indicating 'technical deficiencies or lack of know-how' encountered in compiling information included in an environmental assessment (Council of the EC, 1985).

Contents of EISs in the USSR and Central and Eastern European Countries

In the former USSR forecasting practice to predict environmental implications for implementing the electrification plan in Russia was already existing in the 1920s, although this experience was not further developed or applied during the following years. The USSR returned to the idea of systematic environmental impact study of projects again in 1972, and this was made instrumentally more detailed in 1988. In a 1990 evaluation, Govorushko concludes that there were considerable difficulties in implementing EIA in the Soviet Union: lack of procedures considering regional and social specifications, acute deficits in numbers of specialists, etc.

In the Eastern European countries the central planning system provides a coherent framework for EIAs. In the 1980s the Council for Mutual Economic Assistance (CMEA which included Hungary, Bulgaria, Cuba, Czechoslovakia, GDR, Mongolia, Poland, Romania, and USSR) required the assessment to include several phases and to be technological, bio-medical, economic, or social, the latter being the most comprehensive. General systems include the natural environment, the man-made environment and socio-economic activities.

The overall picture which emerges is that the most influential country in the region paid attention to EIS, but that their content had no influence on the outcome of the decision record.

Contents of EIS in Slovakia

According to Annex 2 of the Environmental Act (17/1992), which is fully in force into both the Czech Republic and the Slovak Republic, the documentation and the EIA of projects must contain the following elements:

a) a description of planned activity and its objective;

b) a description and assessment of adequate and justifiable variants of the project, the ecologically optimum variant;

c) a description of the environment likely to be significantly influenced by the project or its variants;

d) a description of assumed environmental impact of the project or its proposed variants and an estimate of their significance (not only assumed direct impacts, but also indirect, secondary, cumulative, synergic, short-term, long-term and permanent effects). This includes the impact on the population (health hazards, social consequences, economic consequences), effect on ecosystems, their components and functions, effect on anthropogenic systems, their components and links, effect on the structure and exploitation of the land)including the effect on the aesthetic quality of the landscape), and large-scale influence of the project on the landscape, i.e., an assessment of the ecological carrying capacity of the territory;

e) a description of the measures proposed for the prevention, elimination, minimisation and/or compensation for the environmental impact of the proposed variants of the project.

According to Annex 4 to the Environmental Act the environmental impact assessment of projects which affect areas beyond the State border must contain at least:

a) a description of the planned activity and its objectives;

b) a description of reasonable alternatives to the planned activity;

c) a description of the environmental component likely to be substantially influenced by the planned activity or its alternative variants;

d) a description and assessment of the possible impacts of the planned activity and any alternative variants on the environment;

e) a description of the measures intended to minimise the scope of the adverse influence on the environment;

f) a specification of concrete forecasting methods and assumptions upon which the measures are based and the corresponding environmental data used, etc.

The scope of the environmental impact assessment must be discussed by the appropriate assessment authorities of the State administration authorities concerned, with the communities the territories which are affected by the impact of the project, and with the public.

Contents of EIS according to the Espoo Convention:

Information to be included in the environmental impact assessment documentation shall, as a minimum, contain, in accordance with Article 4:

a) a description of the proposed activity and its purpose;

b) a description, where appropriate, of reasonable alternatives (for example, locational or technological) to the proposed activity and also the no-action alternative;

c) a description of the environment likely to be significantly affected by the proposed activity and its alternatives;

d) a description of the potential environmental impact of the proposed activity and its alternatives and an estimation of its significance;

e) a description of mitigation measures to keep adverse environmental impact to a minimum;

f) An explicit indication of predictive methods and underlying assumptions in compiling the required information;

g) an identification of gaps in knowledge and uncertainties encountered in compiling the required information;

h) where appropriate, an outline for monitoring and management programmes and any plans for post-project analysis; and

i) a non-technical summary including a visual presentation as appropriate (maps, graphs, etc.).

Although the content of EIS varies among countries and over a period of almost 20 years, there is a clear idea of what an EIS should contain consistent with the aims of the EIA procedure since the period 1975-1985. Moreover, as the main lines of contents are written down in national and international agreements since the 1990s, there can be no doubt about the minimum requirements for the content of an EIS.

The quality of EIS depends on the level of technical sophistication, consistency in terms of coverage of topics, executive summaries, clearly organised sections, objective orientation, adequate project description, sufficient analysis of all topics, consideration for public input and participation in planning and review processes (Kim and Murabayashi, 1992).

7.3 SUSTAINABLE DEVELOPMENT AND EIA

7.3.1 THE CONCEPT OF SUSTAINABLE DEVELOPMENT

The World Commission for Environment and Development (WCED) defined Sustainable Development (SD) in ethical, social and economic terms as the new path of economic and social progress that "meet the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). SD is a strategy for the development of the quality of life of people based on the maintenance of three forms of capital (man made, human and natural capital). Sustainability is defined as the 'indefinite survival of human species (with a quality of life beyond mere biological survival) through the maintenance of basic life support systems (air, water, land, biota) and the existence of infrastructure and institutions which distribute and protect the components of these systems' (Liverman *et al.*, 1988). Environmental sustainability refers to natural capital which is a stock of environmentally provided assets which results in a flow of useful goods and services. Sustainability depends on interaction of economic changes with social, cultural and ecological transformations.

Translation of the concept into practice is still a very difficult task. The concept has, however, proven useful, in raising awareness of environmental and social concerns in economic development planning and decision-making.

7.3.2 LINKING SUSTAINABLE DEVELOPMENT AND EIA

Sustainable development is a unifying concept which consists of ecological, economic and the social aspects of welfare of present and future generations. EIA is one of the most useful tools for checking the development activities for environmental, economic and social sustainability. It helps to integrate environmental and social concerns of a project/policy at an early stage without stopping economic development in its tracks. EIA has the potential to check the integration of the three vital components of the sustainable development equation i.e. environmental, social and economic issues in the development decision-making process. Dalal-Clayton (1992) argues that the achievement of sustainable development requires, inter alia, the development of a framework of an appropriate 'tool' to aid project, programme and policy development and implementation. A modified EIA process can effectively include social, participatory and economic issues in order to address the key links between environmental impact and sustainable development.

2

Sustainable development depends on sustainable use of resources. EIA assists sustainable economic development (Carpenter and Maragos, 1989):

– EIA points out both the dangers to environmental values and the opportunities to use these resources;

(1) *The EC Directive 85/337 requires Member States to include the following aspects in the EIS: a description of the likely significant effects on the environment, direct and indirect, of the development with reference to human beings, flora, fauna, soil, water, air, climate, the landscape, the interaction between any of the foregoing, material assets, the cultural heritage.*

The EC Directive makes an EIA mandatory only for those developments listed in its annex I. Hydroelectric power projects are not listed in annex I; they are in fact listed in annex II to the Directive. EIAs are to be carried out in relation to developments listed in annex II at the Member State's discretion. There is therefore no mandatory requirement under EC law for an EIA for hydroelectric projects.

The Directive is still not fully implemented in all Member States - see, SR, Annex 2.

In any event, in its technical annex, Hungary evaluates the 1985 EIA in terms of its examination of Project impacts on "human beings, flora and fauna, soil, water, air, climate, material assets, cultural heritage (including architectural and archaeological heritage)". In other words, Hungary applies exactly the same test as applied by EC Directive 85/337. According to this test, Hungary's 1985 EIA was classed "A", that is "generally well performed, no important tasks left incomplete" - see, HCM, Vol. 4, Annex 23 (at pp. 903, 907-908).

(2) *Sustainable development depends on sustainable use of resources. EIA assist sustainable economic development (Carpenter and Maragos, 1989):*

Once more it is questioned whether a 1989 training manual relating to tropical seas and coastal areas is an apposite choice for a useful definition of the link between sustainable development and EIA in relation to a dam project in Central Europe built under a 1977 Treaty regime.

- EIA is a constructive pro-development tool for management that improves the success and lengthens the life of projects;
- EIA quantifies the factors making up sustainability and predicts the future productivity of the landscape (e.g. in mining);
- EIA specifically treats the risks to human health from technologies and urbanisation accompanying development;
- EIA is concerned with biological diversity and the aesthetic and recreational values of intact natural systems;
- the surveys and inventories conducted as part of EIA may reveal unexpected natural resource values.

SD has broad social, economic and environmental objectives for survival and improvement of quality of life of all human beings in present and future generations (*Figure 2.1*). EIA can help and support the attainment of most of the objectives. It allows public participation, is pro-development and hence helps economic growth and poverty alleviation. At the same time social justice for the affected population is discussed. EIA assesses the social impact of the development activity and takes note of the disturbance to the social cohesion. It supports the use of cost effective technology and of optimal siting for development projects and hence supports efficiency. EIA is an important tool to achieve certain environmental objectives like ecosystem integrity, conservation of biodiversity, carrying capacity and climate stability.

EIA is an important tool to achieve conditions for SD (i.e., 'the strategic imperatives for SD' put forward by WCED) as shown in *Figure 3*.

All the international attempts for SD have highlighted the importance of EIA as an efficient tool for achieving the SD goals. Sustainable development as an idea had been espoused in the World Conservation Strategy (WCS) in 1980, which recommends advance assessment of the likely environmental effects of all major actions as a priority national action (IUCN, 1980). The Brundtland Report "Our Common Future" (WCED, 1987) which made the concept of Sustainable Development popular recommends to undertake, or require prior assessments to ensure that major new policies, projects and technologies contribute to sustainable development (WCED, 1987). The Earth Summit at Rio in 1992 which set the planet on a new course toward global sustainable development, also stressed the importance of EIA in sustainable development. Principle 17 of the Rio Declaration states: "EIA, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on environment and are subject to a decision of a competent national authority"(Johnson, 1993). Different chapters of Agenda 21 highlight the need for making sure that environmental concerns are duly taken into account in development planning.

7.4 TRENDS OF INTERNATIONAL DECISION-MAKING ON DAMS 1

Despite the evidence of social and environmental damage, large dam building is an ongoing enterprise in many parts of the world. Large dams are generally projected as sources of clean energy and water supply by their proponents, but have been criticised on grounds of social unacceptability, environmental unsustainability and economic inviolability all over the world.

The history of environmental consideration in large dam decision-making in different countries can be divided into three stages: the pre EIA, early EIA and current EIA procedure periods. Many countries have sector specific guidelines for EIA, but major steps in EIA procedures are similar.

The environmental considerations in large dam project planning and decision-making in the various periods are analysed here through a literature survey and through case studies of large dams in each period. Large dam projects prepared in the pre-EIA period resulted in major impacts as a result of not considering environmental aspects. These projects show the importance of proper EIA in project planning and implementation. The EIA procedures during the early EIA period show the inadequacies in EIA application. During the early EIA period, EIA was imposed on the ongoing project planning and implementation necessitated by the new legislation of environmental consideration in project planning. The current EIA period shows more or less proper EIA procedures in at least some of the countries. 2
Even though EIA has been started at different times in different countries, the trend of evolution is similar everywhere. In particular, all large dams financed by the World Bank are subject to an EIA.

7.5 LACK OF EIA ON THE GNB PROJECT

7.5.1 HUNGARY

Historical Context

The EIA situation in Hungary in the pre 1970-1993 period is not clear-cut. It is, however, safe to say that there was no well established EIA procedure or legislation in Hungary in the pre 1970-1993 period. Several sources confirm that the need for EIA was felt for the first time as a result of the Gabčíkovo-Nagymaros controversy. EISs prepared on the GNBS, in other words, did not follow one clear and obvious EIA procedure, but were prepared on an *ad hoc* basis.

The EIA adoption process started in 1983 with the resolution of the National Council 3
on Environmental Protection. It was followed by a decree which made it obligatory to undertake impact studies for major projects under governmental control. This decree was repealed in 1989 (Radnia, 1993). In 1992 Bochniarz stressed the importance of EIA in Hungarian environmental legislation: "Hungarian legislation

should give particular attention to EC Directive 85/337 and the IUCN draft convention regarding EIA..."

It was only in June 1993 that the Hungarian Government issued its EIA Decree (No. 86/1993 (VI.4) for Provisional Regulation of the Assessment of Environmental Impact of Certain Activities). This represents a turning point in the history of Hungarian EIA regulation since the decree established systematic investigation of a broad range of activities and linked it to the decision-making process (Radnia, 1993).

In conclusion, it is possible to situate the two Hungarian studies on the GNBS in the historic framework developed in previous sections. It is clear that Hungary is only today in the stage of developing EIA procedures and legislation, comparable with the 1970s period in the US and the 1980s period in the European Communities. The preparation of the Gabčíkovo-Nagymaros environmental documents (1983, 1985) can be placed into the early EIA period, which means that these studies were imposed on the project which was, at that time, in an advanced planning stage, and construction was already started. 4

Since Hungary did not have any prior experience with EIA and did not incorporate a systematic screening of environmental impacts into its legislation, the Gabčíkovo-Nagymaros EISs can be considered "experiments". There was no previous experience, no established procedures or guidelines and no EIA traditions to form a basis for the preparation of environmental reports of high quality.

At the time that the Gabčíkovo-Nagymaros environmental documents were prepared, the necessary information and expertise to prepare high quality EISs for large dam projects was available in other countries, e.g. in North America. It should, however, be taken into account that Hungary was still part of the former Eastern Europe Communist Bloc during the mid-1980s and that scientists and decision-makers will have looked to the USSR for expertise and not to the US or Canada.

Hungarian Study of April 30th, 1983

The document of 1983 states that it is not a full EIS and that a complete impact study can be expected within two years. The document only gives an overview of the conclusions from earlier investigations. In Chapter 4 only the predictable impacts are examined, only ecological impacts are considered and these are only partly considered. The material does not contain any figures or tables (except one map from the region). There are no references used in the text.

Hungarian Study of June 1985 5

This 1985 study is the most comprehensive when compared to the 1983 and 1993 document. In fact, it is the only document which can be called an EIS. The other two documents are too incomplete to be given the name "EIS".

The 1985 report has been examined in two different ways: first it has been subjected to the Lee and Colley review package (1990) and second it has been checked to what degree the report conforms with a checklist developed for the quality review of EISs for dam projects. 6

The Lee and Colley review package (1990) consists of a list of review topics, a list of assessment symbols and a collation sheet. Two reviewers have to check the quality of the EIS independently and compare their results. If major differences in assessment occur the two reviewers should come together and discuss the problematic topics. The list of review topics is divided in four major parts: description of the development, the local environment and the baseline conditions; identification and evaluation of key impacts; alternatives and mitigation; and communication of results.

The Gabčíkovo-Nagymaros EIS prepared in 1985 contains parts which are well intentioned. The whole must, however, be considered as unsatisfactory because of omissions and inadequacies. 7

The major limitations of this document can be summarised as follows:

- there is no discussion on the scope of the document: why have certain aspects been studied and others not?
- although a lot of background studies have been made for the proposed project, these studies are not discussed in an integrated way in the main body of the text;
- although alternatives and mitigation measures have been proposed in the EIS, they are not the "heart" of the document. Alternatives and mitigation measures are limited and not studied in sufficient detail;
- although impacts are examined, it is not discussed what was the basis for the interpretation of the data. The choice of standards, assumptions and value systems used is not explained;
- the communication of the results is insufficient. The layout is confusing, the reference system is not correct and reviewers have doubts about the objectivity of the study. 8

The EIS should be a document which allows anyone who is interested in the proposal to learn in a short period of time what the project is about, what the possible impacts will be, what alternatives and mitigation measures are available to reduce adverse effects and what the local and general population think about it. The EIS in question does not fulfil these requirements: the document is rather confusing and leaves the reader with a lot of questions.

(1) *Despite the evidence of social and environmental damage, large dam building is an ongoing enterprise in many parts of the world. Large dams are generally projected as sources of clean energy and water supply by their proponents, but have been criticised on grounds of social unacceptability, environmental unsustainability and economic inviolability all over the world.*

"Large dams": It is noted that <u>the G/N Project is not a large dam project</u> according to Hungary's own technical assessment - <u>see</u>, HCM, Vol. 4, Annex 23 (at p. 893). It is misleading to have omitted this important fact from the "Scientific Evaluation". The significance of this fact becomes clear from Hungary's technical discussion in HCM, Vol. 4, Annex 23, from which the following extract is taken:

> **"The social and environmental effects of large-scale projects are much greater than those of small and medium sized projects. ... Small and medium scale projects are the best for sustainable resource use and for reduction of disastrous effects." (at p. 916).**

Under Hungary's own criteria, the G/N Project is a "medium scale project".

(2) *In particular, all large dams financed by the World Bank are subject to an EIA.*

The relevance of this is unclear given that, according to Hungary's technical assessment, the G/N Project is <u>not a large dam project</u>. The World Bank does finance truly large dam projects, the environmental impacts of which are on a scale that completely dwarf the G/N Project impacts. The fact that such projects may be "subject to an EIA" does not alter this fact.

(3) *It was followed by a decree which made it obligatory to undertake impact studies for major projects under governmental control. This decree was repealed in 1989 (Radnia, 1993).*

Hungary's suspension of works in 1989 is characterised by the "Scientific Evaluation" as a call for a "comprehensive EIS" (environmental impact statement) (at p. 252). In fact, in 1989, Hungary repealed its existing EIA legislation (which had been put in place as early as 1983-1984 and led, notably, to Hungary's 1985 EIA). The legislation repealed in 1989 was not replaced until June 1993. It is impossible to square this fact with Hungary's claims that its change of regime in 1989-1990 led to a new awareness of environmental issues, in particular in relation to the G/N Project.

(4) *Since Hungary did not have any prior experience with EIA and did not incorporate a systematic screening of environmental impacts into its legislation, the Gabčíkovo-Nagymaros EISs can be considered "experiments". There was no previous experience, no established procedures or guidelines and no EIA traditions to form a basis for the preparations of environmental reports of high quality.*

These statements are incorrect: Hungary did have EIA experience and established procedures prior to 1989. In its technical annexes, Hungary accepts that the 1985 EIA's assessment on the G/N Project's impact on "flora and fauna, soil, water, air, climate, landscape, material assets, cultural heritage ..." should be classed as "A", that is "generally well performed, no important tasks left incomplete" - <u>see</u>, HCM, Vol. 4, Annex 23 (at pp. 903, 907-908).

(5) *This 1985 study is the most comprehensive when compared to the 1983 and 1993 document. In fact, it is the only document which can be called an EIS.*

Here Hungary admits that the 1985 EIA "can be called an EIS" (an environmental impact statement).

The 1993 study, which HCM, Vol. 4, Annex 23 purports to review (but, in fact, does not), has not been placed in evidence by Hungary and has not been seen by Slovakia. Only the briefest references to this study are made in Annex 23 and the "Scientific Evaluation".

(6) *The Lee and Colley review package (1990) consists of a list of review topics, a list of assessment symbols and a collation sheet.*

The review package used to assess Hungary's 1985 EIA is aimed at large dams only - HCM, Vol. 4, Annex 23 (at p. 882). The G/N Project is not a large dam project according to Hungary's technical evaluation - ibid. (at p. 893). In any event, in its essential aspects, the 1985 EIA was reviewed favourably under Hungary's review system - ibid. (at pp. 907-908).

(7) *The major limitations of this document can be summarised as follows:*

The "major limitations" are noticeably insubstantial. They relate principally to structure and presentation, i.e., the criticisms are as to: "no discussion on the scope"; "studies are not discussed in an integrated way"; "choice of standards ... is not explained"; "layout is confusing". This does not constitute criticism of the substance of Hungary's 1985 EIA. Note, that even Annex 23 to HCM, Vol. 4 concludes (at p. 908):

> "Overall, the 1985 Gabčíkovo-Nagymaros EIS is considered a border line case when it comes to its quality. Although certain parts are well done and the document presents a lot of very important information, there are also many tasks left incomplete or not attempted at all."

(8) *The EIS should be a document which allows anyone who is interested in the proposal to learn in a short period of time what the project is about, what the possible impacts will be, what alternatives and mitigation measures are available to reduce adverse effects and what the local and general population think about it. The EIS in question does not fulfil these requirements: the document is rather confusing and leaves the reader with a lot of questions.*

This 1994 opinion as to how an EIA should be presented is quite beside the point. The fact is that Hungary's 1985 assessment was indeed an EIA carried out under Hungary's 1984 Decree; it cannot be dismissed by Hungary today, and in fact Hungary's technical Annex ranks it as "A" in its most important part: "generally well performed, no important tasks left incomplete" (see, Comment 4, above). The 1985 EIA's basic aim was to inform the Government of Hungary whether the G/N Project was environmentally sustainable; and it certainly fulfilled this function.

please turn to next page

7.5.2 CZECHOSLOVAKIA

Historical Context

It is not easy to reconstruct the status of EIA in Czechoslovakia in the period before 1992, when the Environmental Act was adopted. A number of elements are, however, relevant:

> – The USSR as a leading country in the area engaged in its first examination as early as the 1920s and in a more systematic way since 1972. Although specific logistic structures were set up since 1988, the process was characterised by many difficulties (Govorushko, 1990).
>
> – The SM states that "environmental impact had been carefully studied by both parties to the 1977 Treaty both before and after the conclusion of the Treaty" (para 1.118). The SM claims that the Bioproject and its 1986 update was thorough, stating that "these studies showed that the Project was sustainable in environmental terms" (paras 1.4 and 1.22). In the context of the evolution of EIA, these quotes are testimony to a profound belief in the capacity of analytical descriptive studies as a substitute for the whole process, with its complex content. Scientifically this is an example of overestimation of the power of analytical descriptive studies, at a moment when the contextual limitations were already established.
>
> – The internal legal situation is most clear with the Environmental Act in 1992.

Bioproject and Other Czechoslovakian Studies

1

It was not possible to examine the Slovak documentation in the same way as the Hungarian document because no Slovak documents in the format of EISs were provided.

To analyse the relevant material mentioned in the SM, these studies which "showed that the Project was sustainable in environmental terms" (para 2.24) and which "demonstrated to the satisfaction of the parties that the Project would not affect surface or ground water in an unacceptably negative way and, to the contrary, would lead to certain specific improvements in water quality" (para 2.15) were asked for by the "Note Verbale" of June 1994. The last letter was a reply to a letter of 3 August 1994 in which Dr. Tomka, the Agent of the Slovak Republic, states: "These two Annexes are adduced in support of contention that the [Project] was indeed very carefully researched. This contention does not relate to the individual findings of specific reports, but to the fact of their existence. The actual contents of the reports were not relevant to the contention and there is therefore no need to annex the reports." From a scientific point of view it is, however, impossible to evaluate sustainability without knowing the content, scope and conclusions of the studies showing and discussing these elements.

It is not clear to what degree the seven mitigation measures discussed on pages 52 and 53 of the Slovak Memorial are developed in detail in the Bioproject and its 1986 update.

With the information available it is not possible to evaluate the Bioproject making use of the evaluation instruments (lists of review topics).

Studies which were completed between 1974 and 1990 summarised in Annex 24 of the Slovak Memorial tackle the following subjects:

	number
construction	13
design, general arrangement and lay-out (technical)	48
economical considerations	2
effects on Austria	2
effects on drinking water supply	1
energetic aspects	1
forest ecosystems	1
groundwater	3
hydrology	22
ice discharging	2
location alternatives	5
monitoring of GN project	2
navigation	5
operation of the project	2
power transmission lines	2
protection measures	6
summary documentation	1
water quality	1

Based on the summaries included in Annex 24 it seems that the majority of the 118 studies mentioned focus on technical aspects of general design, construction and the hydrological regime of the Danube river. It is not clear if environmental aspects have been taken into account in these reports.

Eleven studies (on forest ecosystems, groundwater, location alternatives, protection measures and water quality) are clearly related to topics which should be included in an environmental impact assessment.

7.5.3 REALISATION OF HUNGARY AND CZECHOSLOVAKIA THAT NO EIS WAS EVER PERFORMED

Both Hungary and Slovakia initiated their EIA laws in the early 1990s. At that moment both countries were more conscious about the value of the procedure and were concerned to establish a content requirement which was in agreement with the international state of the art.

2

The analysis provided in this chapter shows that Hungary concluded correctly when it suspended the construction in Nagymaros in May 1989 and at Dunakiliti in July 1989, calling for a joint comprehensive EIS. The country seemed to be fully aware of the fact that no proper EIS had ever been performed.

3

Also Slovakia implicitly and explicitly recognised the lack of a proper EIS. Implicitly because of the overestimation of the value of analytical descriptive studies (which were not made accessible for evaluation of their content). Explicitly because of the 1990 project proposal which should result in a "proper impact assessment model" for the Danube and its water resources.

7.6 CONCLUSIONS

It can be concluded that EIA is not static, but a learning process which is continuously in evolution. Not only the EIA procedures and EIA process but also the contents of the EIS have changed over time. The most recent trend focuses on the link between EIA and sustainable development, both generally and specifically in terms of dams.

Based on the information available to the researchers it can be concluded that the Gabčíkovo-Nagymaros environmental documents are early EIA period pieces. Although EIA procedures were well advanced in many countries around the globe in the mid 1980s Hungary did not yet have a tradition of introducing environmental concerns into its decision-making. It was only as a result of public controversy in relation to the Gabčíkovo-Nagymaros project that the need for EIA became clear and that an EIA was imposed on the proposed project. A literature review revealed that EISs prepared in an early EIA period most often do not result in high quality documents.

4

Research also indicates that the presence of a well established EIA procedure is one of the major requirements for EIA to be successful. Since an EIA procedure was only formally established in Hungary with the introduction of an EIA decree in 1993, the Gabčíkovo-Nagymaros environmental documents were not prepared in optimal conditions.

The two environmental documents prepared in Hungary which were examined cannot be considered satisfactory. The 1983 report does not satisfy the basic requirements and should not be given the name EIS. The 1985 report is an EIS which has a number of defects. The documents prepared in Czechoslovakia also appear unsatisfactory.

The general conclusions are:

> – although EIA procedures and contents are continuously being improved as a result of experience gained, there have not been major changes or significant developments in the state of the art of EIA during the 1980s;
>
> – although EIA was not yet introduced in all countries by the end of the 1980s, it was generally available as an instrument for environmental protection. At the end of the 1980s it was generally accepted that large infrastructure projects might cause substantial environmental effects and that EIA can be used to detect and mitigate adverse effects;
>
> – no true EIS has ever been done on GNBS;

(1) *It was not possible to examine the Slovak documentation in the same way as the Hungarian document because no Slovak documents in the format of EISs were provided.*

It appears that Hungary did not provide the authors of the "Scientific Evaluation" with the many studies of environmental effects produced by Czechoslovakia, including the Bioproject (updated in 1986), copies of all of which are in Hungary's possession. Hungary's "Evaluation" here seems more concerned with "format" than with substance.

(2) *The analysis provided in this chapter shows that Hungary concluded correctly when it suspended the construction in Nagymaros in May 1989 and at Dunakiliti in July 1989, calling for a joint comprehensive EIS.*

"Concluded correctly": The contention here is that Hungary's acts to suspend work at Nagymaros and then at Dunakiliti were in order to conduct an EIA. But there is not a shred of evidence of Hungary "calling for a joint comprehensive EIS" in either May or July of 1989. It is admitted that, in 1989, Hungary in fact repealed its existing EIA legislation.

(3) *Also Slovakia implicitly and explicitly recognised the lack of a proper EIS. Implicitly because of the overestimation of the value of analytical descriptive studies (which were not made accessible for evaluation of their content). Explicitly because of the 1990 project proposal which should result in a "proper impact assessment model" for the Danube and its water resources.*

The reference to an implicit recognition is simply not understood. Czechoslovakia has naturally relied on the findings of its own environmental impact assessments (notably the Bioproject) and the findings of Hungary's 1985 EIA. It is impossible to discern why it should not have been fully entitled to act in this way and why this constitutes an implicit recognition of the lack of a proper EIS. Further, it is Hungary that is responsible for not making Czechoslovak studies, copies of which are in its possession, "accessible for evaluation". This failing on Hungary's part is very significant.

It is not clear whether the "overestimation" of the value of analytical descriptive studies relates also to the impartial assessments of the EC Working Group of Experts.

"Explicitly": See, Comment 2 to "Scientific Evaluation" p. 234, above.

(4) *It was only as a result of public controversy in relation to the Gabčíkovo-Nagymaros project that the need for EIA became clear and that an EIA was imposed on the proposed project. A literature review revealed that EISs prepared in an early EIA period most often do not result in high quality documents.*

"Public controversy": It is clear that, as early as 1985, Hungary and Czechoslovakia were open to and keen to solicit public opinion. See, SR, para. 7.06, et seq. Hungary in fact decided to carry out a 2 year EIA as a result of its 1983 assessment, not merely as a response to public demand - see, HCM, Vol. 4, Annex 23 (at p. 888). And Czechoslovakia's Bioproject was carried out in 1975-1976 - before the 1977 Treaty was even signed.

As to the Bioproject, the HQI report found that this and other pre-Treaty studies were "comparable with those carried out in North America" at the same epoch - see, HM, Vol. 5, Annex 9 (at p. 298). It is noted that Hungary quotes from this page of the HQI report (at HCM, para. 137), but omits the sentence with this important conclusion.

PART II

LIST OF ANNEXES

Annex 1

Agreement between the Government of the Slovak Republic and Government of the Republic of Hungary concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube, 19 April 1995

Note Verbale of the Ministry of Foreign Affairs of the Republic of Hungary to the Embassy of the Slovak Republic, 19 April 1995

Declaration by the Government of the Republic of Hungary, 19 April 1995

Letter from Dr. Peter Tomka, Agent of the Slovak Republic to Mr. Eduardo Valencia-Ospina, Registrar, International Court of Justice, 19 April 1995

Note Verbale of the Ministry of Foreign Affairs of the Slovak Republic to the Embassy of the Republic of Hungary, 3 May 1995

Letter from the Ambassadors of Hungary and the Slovak Republic to the Director General for External Political Relations, Commission of the European Communities, 5 May 1995

Note Verbale of the Ministry of Foreign Affairs of the Slovak Republic to the Embassy of the Republic of Hungary, 5 May 1995

Note Verbale of the Embassy of the Republic of Hungary to the Ministry of Foreign Affairs of the Slovak Republic, 8 May 1995

Statute on the activities of the Nominated Monitoring Agents envisaged in the Agreement of 19 April 1995, 29 May 1995

AGREEMENT
BETWEEN THE GOVERNMENT OF THE SLOVAK REPUBLIC AND GOVERNMENT OF THE REPUBLIC OF HUNGARY CONCERNING CERTAIN TEMPORARY TECHNICAL MEASURES AND DISCHARGES IN THE DANUBE AND MOSONI BRANCH OF THE DANUBE

The Government of the Slovak Republic

and

the Government of the Republic of Hungary

have agreed as follows:

Article 1

1. Immediately following the conclusion of this Agreement. the Slovak Party will increase the discharge of water through the intake structure at Čunovo into the Mosoni branch of the Danube to 43 m3/s subject to hydrological and technical conditions specified in Annex 1 to this Agreement. This value includes the flow of water through the seepage canal on the right side of the reservoir from Slovak territory into Hungarian territory.

2. The competent Slovak and Hungarian authorities shall take all necessary measures on their respective territories to enable the continuous flow of the increased discharge of water from Slovak territory into Hungarian territory.

3. The water will be distributed, on Hungarian territory, between the branch system on the right side of the Danube, the protected area and the Mosoni branch of the Danube.

Article 2

1. The day following the conclusion of this Agreement the discharge into the main riverbed of the Danube below the Čunovo weir will be increased to an annual average of 400 m3/s, in accordance with the rules of operation contained in Annex 2 to this Agreement. Discharges entering the main riverbed of the Danube through the inundation weir are excluded from the average calculation.

2. During the construction of the weir pursuant to Article 3 the discharge into the main riverbed of the Danube below the Čunovo weir will be regulated in accordance with Annex 3 to this Agreement.

Article 3

1. There will be a weir partly overflowed by water and constructed by the Hungarian Party in the main riverbed of the Danube, at rkm 1843. The main parameters of the weir are specified in Annex 4 to this Agreement.

2. The Parties undertake to ensure the issuance, without delay, of the administrative authorization required by their respective national legislation for the construction and maintenance of the weir in accordance with this Agreement.

3. The costs of the construction and maintenance of the weir will be borne by the Republic of Hungary.

4. The construction of the weir will begin not later that 10 days following the conclusion of this Agreement and is anticipated to be completed within a period of 50 days from the commencement of works.

Article 4

The Parties undertake to exchange those data of their environmental monitoring systems operating in the area that are necessary to assess the impacts of the measures envisaged in Articles 1-3. Collected data will be regularly exchanged and jointly and periodically evaluated with a view to making recommendations to the Parties. The observation sites, parameters observed, periodicity of data exchange, the methodology and periodicity of joint assessment are contained in Annex 5 to this Agreement.

Article 5

1. In the event that either Party believes the other Party is not complying with this Agreement. and fails to persuade the other Party that it is in breach, the Party may invoke the good offices of the Commission of the European Union and both Parties agree to give close cooperation to the Experts of the Commission and to take duly into consideration any opinion rendered by them.

2. If, for whatever reason, the good offices are not provided or are unsuccessful and the material breach continues to exist, the Party affected will be entitled to terminate this Agreement with a one month notice.

Article 6

This Agreement has a temporary character, pending the judgment of the International Court of Justice in the case concerning the Gabčíkovo-Nagymaros Project and is without prejudice to existing rights and obligations of the Parties as well as to their respective positions in the dispute before the Court and, in any event, unless otherwise agreed, it shall terminate 14 days after the judgment of the International Court of Justice in the case concerning the Gabčíkovo-Nagymaros Project.

Article 7

On the termination of this Agreement and unless otherwise agreed or decided, Hungary shall at its own expense remove the weir referred to in Article 3.

Article 8

This Agreement shall enter into force on the date of its signature.

Done at Budapest on the .19.. day of April, 1995, in duplicate, in the Slovak, Hungarian and English languages, the English text to prevail in the event of any discrepancy.

For the Government
of the Slovak Republic

For the Government
of the Republic of Hungary

Annex No. 1

Hydrological and technical conditions for the increase of the discharges into the Mosoni Danube

1/ The increase of the discharge into the Mosoni Danube and into the right side seepage canal of the Hrušov reservoir from 20m^3/sec up to 43 m^3/sec will be ensured subject to the following hydrological and technical conditions:

1.1 Provided that minimum difference between the water-level of the Mosoni Danube and the Hrušov reservoir is 5.10 m.

1.2 Provided that the minimum water level of the Hrušov reservoir is 130.40 m above sea level.

1.3 Provided that the water-level of the Mosoni Danube does not exceed 125.30 m above sea level.

1.4 Provided that the entrances to the intake structure are unobstructed. Whenever the discharges of the Danube exceed 4000 m^3/sec (involving the inundation of the flood-plain), the water-borne materials will move to a greater extent this may restrict the amount of water which can be provided.

1.5 Provided that there is no failure in the electricity network system. If the network system is damaged or in the event of any other failure of the generating capacity, the energy system will turn off automatically and the capacity of the intake structure will be reduced to half of the original.

2/ At the request of the Hungarian party the Slovak party will moderate the discharge for a period specified by the Hungarian party.

3/ The selected site for the measuring of the discharge of the Mosoni Danube is a gauge at 0.160 km on the left bank of the canal on the territory of the Slovak Republic. The selected site for the measuring of the discharge of the right side canal of the Hrušov reservoir is on the regulating weir at 1.100 km on the territory of the Hungarian Republic.

Annex No.2

Rules of operation

The volume of water discharged through the Čunovo weir into the main river bed of the Danube to correspond to the annual average of 400 m^3/sec.

The annual average discharge in Bratislava corresponds to 2025 m^3/sec. The annual average discharge into the main Danube river bed in each specific year will correspond to the formula:

$$V_{Danube} = \frac{(V_{Devin} \times 400)}{2025}$$

where V_{Devin} is the average yearly discharge in the Devín profile in the specific year.

V_{Danube} is the average yearly discharge to the main Danube river bed in the specific year.

- During the growing season the discharge into the main river bed will be higher than during the dormant season.
- The discharge into the main river bed of the Danube will correspond to actual discharges in the Devín profile.
- The discharges released through the inundation weir during flood will not be included in the calculation.

The discharges in the Devín profile together with the corresponding discharges at the Čunovo weir.

January		February		March		April		May		June	
600	250	600	250	600	250	600	400	600	400	600	400
2200	250	2000	250	1500	250	1100	400	700	400	700	400
2300	251	2100	258	1600	250	1200	400	800	400	800	400
2400	273	2200	280	1700	271	1300	400	900	400	900	400
2500	295	2300	301	1800	392	1400	400	1000	400	1000	418
2600	317	2400	323	1900	314	1500	400	1100	400	1100	440
2700	339	2500	345	2000	336	1600	400	1200	400	1200	462
2800	360	2600	367	2100	358	1700	400	1300	400	1300	483
2900	382	2700	389	2200	380	1800	400	1400	405	1400	505
3000	404	2800	410	2300	401	1900	414	1500	427	1500	527
3100	426	2900	432	2400	423	2000	436	1600	449	1600	549
3200	448	3000	454	2500	445	2100	458	1700	471	1700	571
3300	469	3100	476	2600	467	2200	480	1800	592	1800	592
3400	591	3200	498	2700	489	2300	501	1900	514	1900	600
3500	513	3300	519	2800	510	2400	523	2000	536	4600	600
3600	535	3400	541	2900	532	2500	545	2100	558		
3700	557	3500	563	3000	554	2600	567	2200	580		
3800	578	3600	585	3100	576	2700	589	2300	600		
3900	600	3700	600	3200	600	2800	600	4600	600		
4600	600	4600	600	4600	600	4600	600				

July		August		September		October		November		December	
600	400	600	400	600	250	600	250	600	250	600	250
700	400	900	400	1100	250	1500	250	1800	250	2000	250
800	400	1000	400	1200	262	1600	250	1900	264	2100	258
900	400	1100	400	1300	283	1700	271	2000	286	2200	280
1000	400	1200	400	1400	305	1800	292	2100	308	2300	301
1100	400	1300	400	1500	327	1900	314	2200	330	2400	323
1200	400	1400	400	1600	349	2000	336	2300	351	2500	345
1300	400	1500	400	1700	371	2100	358	2400	373	2600	367
1400	405	1600	400	1800	392	2200	380	2500	395	2700	389
1500	427	1700	421	1900	414	2300	401	2600	417	2800	410
1600	449	1800	442	2000	436	2400	423	2700	439	2900	432
1700	471	1900	464	2100	458	2500	445	2800	460	3000	454
1800	492	2000	486	2200	480	2600	467	2900	482	3100	476
1900	514	2100	508	2300	501	2700	489	3000	504	3200	498
2000	536	2200	530	2400	523	2800	510	3100	526	3300	519
2100	558	2300	551	2500	545	2900	532	3200	548	3400	541
2200	580	2400	573	2600	567	3000	554	3300	569	3500	563
2300	600	2500	595	2700	589	3100	576	3400	591	3600	585
4600	600	2600	600	2800	600	3200	600	3500	600	3700	600
		4600	600	4600	600	4600	600	4600	600	4600	600

The capacity of the by-pass weir when open under conditions of a minimum water level in the reservoir (which is 128.2 m above sea level), is 290 m^3/sec. The discharge of 400 m^3/s can be assured under the condition that the water level in the reservoir is 128.45 m above sea level, and 600 m^3/sec under conditions of a water level of 129.05 m above sea level.

The water level in the reservoir is lowered only when required for construction or reparation works or when the discharge in Devín is below 925 m^3/s.

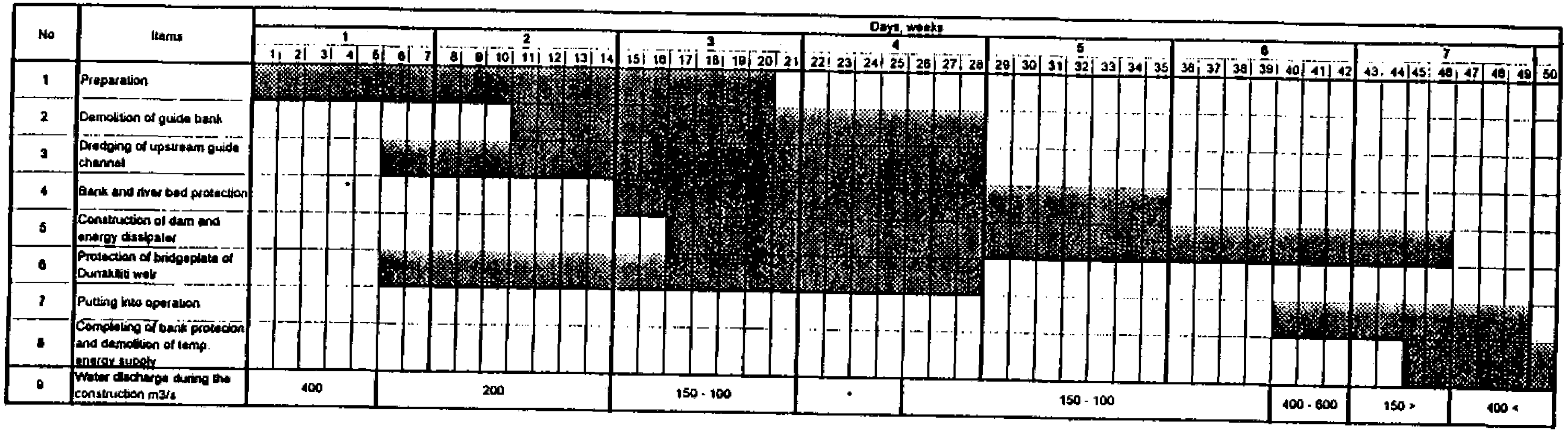
The possible differences in discharges which will be ascertained through monitoring by 31 Oct. will be adjusted within the shortest possible period by the end of the same year so that the average of 400 m^3/sec is attained.

The changes in the discharges through the Čunovo weir will occur at intervals of 200 m^3/sec. measured at the Devín site. Thus for instance at 800, 1000, 1200, 1400.... 2000, 2200 m^3/sec.

This distribution of the water resources shall be in force for 1995 and will be adjusted before the 1996 growing season on the basis of the results of a joint evaluation of the monitoring.

Annex No III.

Time table of planned underwater weir's construction at rkm 1843



No	Items	Days, weeks																																																	
		1							2							3							4							5							6							7							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
1	Preparation	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																														
2	Demolition of guide bank											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																						
3	Dredging of upstream guide channel						▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																						
4	Bank and river bed protection															▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨																						
5	Construction of dam and energy dissipater																	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨															
6	Protection of bridgeplate of Durakiliti weir						▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨				
7	Putting into operation																																								▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
8	Completing of bank protecion and demolition of temp. energy supply																																													▨	▨	▨	▨	▨	▨
9	Water discharge during the construction m3/s	400					200									150 - 100							*				150 - 100														400 - 600			150 >				400 <			

* ecological minimum 50 m3/s

Annex No.4

* Main parameters of the weir to be constructed at rkm 1843 of the Danube

1. The weir which is partly overflowed by water will be constructed at rkm 1843 of the Danube.

2. Main parameters of the weir:

width between banks	300 m
width of the crest	5 m
width of the overflowed section	100 m
height of the center point of the overflowed section	121.80 B.s.l.
gradient of the downstream slope	1 : 10
gradient of the upstream slope	1 : 3

3. The elevation of the weir crest will be established in such a way that at the discharge of 600 m^3/s, the backwater at rkm 1851.7 of the Danube would not exceed an elevation of 124.00 Bsl.

4. The water level regulation at rkm 1843 take place when the discharge of the Danube is between 250-1300 m^3/s.

5. A maximum quantity of 150 m^3/s will be discharged into the right side branch system on the Hungarian side.

* Based on the documentation approved under the number
No. VOD 161/A 28/1993-V
No. 21.663/17/1993

Annex No. 5

Matters relating to monitoring of environmental impacts .

Monitoring is divided into the following monitoring items:

Monitoring of surface water levels and discharges

the Danube:
profile at Devín
profile at Medveďov
profile at Komárno - Komárom
profile at Štúrovo - Esztergom
profile at Rajka
profile at Dobrohošť
profile at Dunaremete
profile downstream and upstream of overflowed weir at rkm 1843, (water level only)
Reservoir at Čunovo and the Danube downstream and upstream of the by-pass weir (water level only)
Reservoir at Gabčíkovo (water level only)
Tailrace canal downstream of Gabčíkovo (water level only)

Malý Danube:
at Bratislava
at Trstice

Mosoni Duna:
downstream of the intake structure at Čunovo
at Mecser
at Györ

Structures at Rajka
Seepage canal at Čunovo (on the Slovak territory)
No. 1. Lock of the outlet
No. 2. Lock of the water level control
No. 6. Lock of the water level control - Mosoni Duna
No. 1. Lock of the side branch Kilify)- Cikolai, Zátonyi Duna
No. 5. Lock at the seepage canal

Frequency of measurements: continuous on a daily basis

Monitoring of surface water quality

the Danube:
upstream Bratislava *
at Dobrohošt

at Gabčíkovo
at Medveďov *
at Gönyü
at Komárno - Komárom
at Štúrovo - Esztergom

Reservoir, bypass canal, seepage canals, river branches:

- upper part of the reservoir at Rusovce *
- the reservoir at Kalinkovo (left and right side)
- downstream of Mosoni Danube the intake structure
- the profile at Šamorín (left, middle and right side)
- the power canal at the ferry station
- the tailwater canal downstream of Gabčíkovo *
- the seepage canal at Čunovo *
- the seepage canal at Hamuliakovo
- the Mosoni Duna at Rajka
- the Mosoni Duna at Mecser
- the Mosoni Duna at Vének
- the Malý Dunaj at Kolárovo
- the river branches Helena and Doborgaz
- the Šulianske river branch

Frequency of measurement:
- stations marked by * - 12 times per year, between the 10th and 20th of each month,
- all other stations in: January, March, April, May, June, July, September, November, between the 10th and 20th of each month.

List of parameters:
- temperature, pH value, conductivity at 25°C, O_2
- cations: Li, Na, K, Ca, NH4, Mn, Mg, Fe
- anions: HCO3, Cl, SO4, NO3, NO2, PO4, P
- trace elements: Hg, Zn, As, Cu, Pb, Cr, Cd Ni, Vanadium
- COD, BOD, dissolved materials (mineralization)
- biological parameters: Saprobility index, bioseston, chlorophyll,
- number of algae, zooplancton, macrobenthos, according to the decision of the monitoring group,
- microbiological parameters, coliform bacteria, mezophilic bacteria, psychrophilic bacteria
- organic matters, TOC, Nonpolar extractable - UV, - IR, EOX, AOX, phenols, humic acids,
- organic micropollutants, polyaromatic hydrocarbons, - polychlorobiphenyls (and others, to be agreed)

Sediments:
- at jointly selected stations, e.g. at places of surface water quality sampling,
- three places in the Slovak and three in the Hungarian flood plain

Extent of parameters:

granulometric curves, organic matters and other selected parameters

Frequency of measurement: once per year in autumn

Monitoring of ground water levels

Monitoring of ground water levels will be carried out on wells between the Malý Danube and the Lajta - Mosoni Danube. Wells to be chosen in profiles based on maps containing all observation wells. [At least at 150 wells on the Slovak territory and at least at 100 wells on the Hungarian territory to be chosen.]

Frequency of measurement: once per week

Monitoring of ground water quality

Ground water quality will be monitored on the municipal water supply [and ground water] wells between the Malý Danube and the Laita - Mosoni Danube, [at least 10 localities on each territory. In addition to this other at least 10 selected ground water quality wells on each territory] should be monitored. These wells should be those which satisfy hygiene criteria for drinking water wells and sampling should be commonly agreed.

Frequency of measurement: once per month.

Quality should be evaluated according to the standards for drinking water in force in both countries.

Monitoring of soil moisture (aeration zone)

[At least 10] monitoring areas to be selected on each territory from among the localities already monitored.

Frequency of measurement: once every 10 days, but in winter (November, December, January and February) twice a month. Each locality should also include a ground water level monitoring well.

Monitoring of biota:

- microbenthos and macrobenthos in the Danube and river branches at places of water level measurements
- fish, in all surface waters
- [Forestry, on at least 8 selected places from among existing monitoring localities on each side]
- Special water related organisms as for example: Odonata, Ephemeroptera, Trichopetra, Braconidea and others, jointly selected.

Special monitoring

For the estimation of the impact of the overflowed weir special monitoring to be carried out. This will include measurements of flow velocities, water levels, water quality, micro and macro benthos, sediments, ground water quality in the impounded reach etc.

Submitting of data and reports:

Both sides will use data jointly agreed and will use jointly agreed methods of evaluation. All monitoring items and locations, and methods of measurements to be jointly agreed. Annual reports will include only measured data in tabulated, graphical and map forms with short explanations.

Joint and verification measurements will be carried out at any location where a discrepance occurs.

Data exchange will be carried out at three month intervals. Annual reports to be submitted as joint reports by the end of each calendar year and covering a period of a hydrological year.

Annual reports will be issued in English language with standardised graphical annexes in Hungarian or Slovak languages.

Statute

Monitoring will be carried out in accordance with the Statute of nominated Monitoring Agents.

Statute will be prepared by: Ing Arpád Kovács, Ministry of Environment (Hungary), Ing. Dominik Kocinger, Government plenipotentiary for the GNP (Slovakia)

Draft statute will be prepared jointly following the signing of this document and before 31.May 1995.

Text in square brackets [] contains Slovak proposals subject to agreement by the Monitoring Agents.

MINISTRY OF FOREIGN AFFAIRS
OF THE REPUBLIC OF HUNGARY

J-2/B/8/1995

Note Verbal

The Ministry of Foreign Affairs of the Republic of Hungary presents its compliments to the Embassy of the Slovak Republic and with reference of the signature of the Agreement between the Government of the Republic of Hungary and the Government of the Slovak Republic concerning certain temporary technical measures and discharges in the Danube and Mosoni branch of the Danube, has the honour to enclose herewith a declaration by the Government of the Republic of Hungary issued in connection with the signing of the aforesaid Agreement.

The Ministry of Foreign Affairs of the Republic of Hungary avails itself of this opportunity to renew to the Embassy of the Slovak Republic the assurances of its highest consideration.

Budapest, April 19, 1995

Embassy of the Slovak Republic

Budapest

1394 Budapest 62, Pf. 423
Tel: 117.[illegible] Fax: 117.77.28

MINISTRY OF FOREIGN AFFAIRS
OF THE REPUBLIC OF HUNGARY

Declaration

by the Government of the Republic of Hungary in connection with the signing of the Agreement between the Government of the Republic of Hungary and the Government of the Slovak Republic concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube

The Government of the Republic of Hungary declares, in connection with the signing of the Agreement between the Government of the Republic of Hungary and the Government of the Slovak Republic concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube, that the conclusion of this Agreement shall not be considered as a fulfillment of the obligation of the Parties, pursuant to Article 4 of the Special Agreement for the Submission to the International Court of Justice of the Differences between the Republic of Hungary and the Slovak Republic concerning the Gabčikovo-Nagymaros Project, to establish a temporary water management regime.

The Government of the Republic of Hungary hereby reaffirms its position it has represented during the negotiations that the Agreement signed today is intended to introduce a temporary mitigation measure in order to alleviate damage in the Szigetköz region. The Agreement is without prejudice to the position of Hungary in the dispute before the International Court of Justice and is applicable pending the judgment of the Court or until an agreement on a temporary water management regime under Article 4 of the Special Agreement is concluded between the two Parties.

Budapest, April 19, 1995

1394 Budapest 62, Pf. 423
Tel: 117.63.02 Fax: 117.77.38

MINISTRY OF FOREIGN AFFAIRS
OF THE SLOVAK REPUBLIC

19 April 1995

Sir,

I have the honour to inform you that Slovakia and Hungary signed today the Agreement concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube. The copy of this Agreement is herewith enclosed for the information of the Court. As article 6 provides for, the Agreement has a temporary character, pending the judgement of the International Court of Justice in the case concerning the Gabčíkovo-Nagymaros Project.

May I recall, at this occasion, that the conclusion of an agreement of this kind was envisaged in the Preamble and Article 4 of the Special Agreement for Submission to the International Court of Justice of the differences concerning the Gabčíkovo-Nagymaros Project, signed on April 7, 1993.

Accept, Sir, the assurances of my highest consideration.

Peter Tomka
Dr. Peter Tomka
Agent of the Slovak Republic

Mr. Eduardo Valencia-Ospina
Registrar
International Court of Justice

<u>The Hague</u>

No.: 1108/95-OMSD

The Ministry of Foreign Affairs of the Slovak Republic presents its compliments to the Embassy of the Republic of Hungary and, with reference to the "Declaration by the Government of the Republic of Hungary in connection with the signing of the Agreement between the Government of the Republic of Hungary and the Government of the Slovak Republic concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube" of April 19, 1995, has the honour to state the following:

The Ministry of Foreign Affairs of the Slovak Republic is unable to share the view according to which:

> "the conclusion of [the] Agreement [mentioned above] shall not be considered as a fulfillment of the obligation of the Parties, pursuant to Article 4 of the Special Agreement for the submission to the International Court of Justice of the Differences between the Republic of Hungary and the Slovak Republic concerning the Gabčíkovo-Nagymaros Project, to establish a temporary water management regime"

for, inter alia, the following reasons.

Since the signature of the Special Agreement Slovakia and Hungary had been involved in negotiations aimed at establishing a mutually acceptable water management regime of a temporary character, applicable pending the Judgement of the International Court of Justice in the case concerning the Gabčíkovo-Nagymaros Project. The main elements under discussion were the discharge into the old river bed of the Danube, technical measures to enable the supply of the right side arms system with water and the discharge into the Mosoni Branch of the Danube. These elements were common to a number of proposals submitted during these negotiations.

The Agreement of 19 April 1995 deals with the same subject-matter. A detailed water management regime is specified in Annexes No 1 and 2. Thus it is crystal clear that the conclusion of this Agreement is the fulfillment, by the parties, of their commitment, expressed in Article 4 of the Special Agreement, to establish, pending the final Judgment of the Court, a temporary water management regime for the Danube.

Embassy of the

Republic of Hungary
Bratislava

The Ministry would like to note, that the subject-matter and purpose of the Agreement of 19 April 1995 and the subject-matter and purpose of an agreement envisaged by Article 4 of the Special Agreement were implicitly recognized as identical by Hungary itself in paragraph 2 of its Declaration where the possibility of termination of the Agreement of 19 April 1995 as a consequence of the conclusion of a successive agreement pursuant to Article 4 of the Special Agreement is implied - a possibility which does not exist except for treaties relating to the same subject-matter (Article 59 of the Vienna Convention on the Law of Treaties of 23 May 1969).

Moreover, Article 5 of the Agreement of 19 April 1995 is fully consonant with Article 4, paragraph 2, of the Special Agreement which provides for consultations and, if need be, reference to experts of the Commission of the European Communities.

Accordingly, the Ministry of Foreign Affairs of the Slovak Republic reafirms its view that the Agreement of 19 April 1995 is an agreement pursuant to Article 4 of the Special Agreement.

At the same time this Ministry reafirms that the Agreement of 19 April 1995 is without prejudice to existing rights and obligations of the Parties as well as to their respective positions in the dispute before the International Court of Justice.

The Ministry of Foreign Affairs of the Slovak Republic avails itself of this opportunity to renew to the Embassy of the Republic of Hungary the assurances of its highest consideration.

Bratislava, May 3 , 1995

Mission of the Republic of Hungary
to the European Communities
Brussels

Mission of the Slovak Republic
to the European Union
Brussels

Brussels, 5 May 1995

Dear Mr. Director General,

We have the honour to inform you that, on 19 April 1995, an Agreement was signed in Budapest between the Government of the Republic of Hungary and the Government of the Slovak Republic concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube.

The Agreement entered into force on the date of signature and its implementation has begun according to its provisions. Please find enclosed herewith for your information a copy of the English version of the Agreement.

May we draw your attention to Article 5 of the Agreement which envisages the possibility for the Parties to invoke, under certain conditions, the good offices of the Commission of the European Communities. We do recognize that the Commission should have been consulted earlier by the Parties but they were unable to do so due to the fact that this provision was adopted at a late stage of the negotiations and both Parties saw advantage in bringing the Agreement into effect as soon as possible.

./.

Mr. Günter BURGHARDT
Director General
for External Political Relations
Commission of the European Communities
<u>Brussels</u>

We would like to express the sincere hope that the Commission, who actively helped the Parties in the past to find appropriate ways and means for solving their differences concerning the Gabcikovo-Nagymaros Project, will accept this function and, should the need arise, give favourable consideration to the request for its good offices.

Please accept, Mr. Director General, the assurance of our highest consideration.

(Dr. Endre JUHÁSZ)
Ambassador of the
Republic of Hungary

(Ján LISUCH)
Ambassador of the
Slovak Republic

No: 1096/95-OMSD

The Ministry of Foreign Affairs of the Slovak Republic presents its compliments to the Embassy of the Republic of Hungary and, with reference to the Agreement between the Government of the Slovak Republic and Government of the Republic of Hungary concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube, signed at Budapest on 19 April 1995, has the honour to propose the following:

As it was jointly observed by the Parties at the occasion of the signature of the above mentionned Agreement the following corrections have to be made in the text of the Agreement:

<u>The Slovak language</u> (both originals):
Article 5, paragraph 1, reads:
" 1. V prípade, že sa niektorá strana domnieva, že druhá strana nedodržiava túto dohodu a nepresvedčí druhú stranu, že dohodu porušuje, táto strana môže požiadať o dobré služby Komisiu Európskej Únie a obe strany súhlasia, že budú úzko spolupracovať s jej expertmi a zoberú náležite do úvahy ich stanoviská."

Annex No. 2, the title reads:
" Prevádzkový poriadok"

Annex No.2, last line of the table reads:
" _____ __ 4600 600 4600 600 4600 600 4600 600 4600 600"

Annex No. 4, paragraph 3, reads:
" 3. Kóta koruny dnovej prehrádzky bude stanovená tak, aby pri prietoku 600 m3/s vzdutie v rkm 1851,7 Dunaja neprekročilo kótu 124,00 mBpv."

Embassy of the

Republic of Hungary
<u>Bratislava</u>

The Hungarian language (both originals):

Article 4, third sentence, reads:

" A mérőhelyeket, a megfigyelt paramétereket, a közös értékelések metodikáját és időszakosságát a jelen Megállapodás V.sz. Melléklete rögzíti."

Annex No. 2, page 3, para 4 reads:

"A Dunacsúni lépcsőnél a változások a Dévénynél mért 200 m3/sec.-os intervallumokban fognak bekövetkezni."

Annex No.5, page 1, text sub Kis Duna, second line, reads:

"Trstice"

The English language (the original of the Slovak Republic only):

Annex No. 4, paragraph 3, reads:

" 3. The elevation of the weir crest will be established in such a way that at the discharge of 600 m^3/s the backwater at rkm 1851.7 of the Danube would not exceed an elevation of 124.00 Bsl."

The English language (the original of the Republic of Hungary only):

Annex No.5, page 1, text sub Malý Danube, second line, reads:

"at Trstice"

This note and the note containing affirmative response will constitute an agreement between the Parties concerning the above mentioned corrections.

The Ministry of Foreign Affairs of the Slovak Republic avails itself of this opportunity to renew to the Embassy of the Republic of Hungary the assurances of its highest consideration.

Bratislava, May 5 , 1995

A MAGYAR KÖZTÁRSASÁG NAGYKÖVETSÉGE
VEĽVYSLANECTVO MAĎARSKEJ REPUBLIKY
Sedlárska 3
814 25 BRATISLAVA

8-19/95

The Embassy of the Republic of Hungary presents its compliments to the Ministry of Foreign Affairs of the Slovak Republic and has the honour to refer to the Note of the Ministry of Foreign Affairs of the Slovak Republic No.1096/95-OMSD of May 5, 1995 which reads as follows:

" The Ministry of Foreign Affairs of the Slovak Republic presents its compliments to the Embassy of the Republic of Hungary and, with reference to the Agreement between the Government of the Slovak Republic and Government of the Republic of Hungary concerning Certain Temporary Technical Measures and Discharges in the Danube and Mosoni Branch of the Danube, signed at Budapest on 19 April 1995, has the honour to propose the following:

As it was jointly observed by the Parties at the occasion of the signature of the above mentionned Agreement the following corrections have to be made in the text of the Agreement:

The Slovak language (both originals):
Article 5, paragraph 1, reads:
" 1. V prípade, že sa niektorá strana domnieva, že druhá strana nedodržiava túto dohodu a nepresvedčí druhú stranu, že dohodu porušuje, táto strana môže požiadať o dobré služby Komisiu Európskej Únie a obe strany súhlasia, že budú úzko spolupracovať s jej expertmi a zoberú náležite do úvahy ich stanoviská."

Annex No. 2, the title reads:
" Prevádzkový poriadok"

Annex No.2, last line of the table reads:
" -- -- 4600 600 4600 600 4600 600 4600 600 4600 600"

Annex No. 4, paragraph 3, reads:
" 3. Kóta koruny dnovej prehrádzky bude stanovená tak, aby pri prietoku 600 m3/s vzdutie v rkm 1851,7 Dunaja neprekročilo kótu 124,00 mBpv."

Ministry of Foreign Affairs
of the Slovak Republic

Bratislava

<u>The Hungarian language</u> (both originals):
Article 4, third sentence, reads:
" A mérőhelyeket, a megfigyelt paramétereket, a közös (joint) értékelések metodikáját és időszakosságat a jelen Megállapodás V.sz. Melléklete rögzíti."

Annex No. 2, page 3, para 4 reads:
"A Dunacsúni lépcsőnél a változások a Dévénynél mért 200 m3/sec.-os intervallumokban fognak bekövetkezni."

Annex No.5, page 1, text sub <u>Kis Duna</u>, second line, reads:
"Trstice"

<u>The English language</u> (the original of the Slovak Republic only):
Annex No. 4, paragraph 3, reads:
" 3. The elevation of the weir crest will be established in such a way that at the discharge of 600 m^3/s the backwater at rkm 1851.7 of the Danube would not exceed an elevation of 124.00 Bsl."

<u>The English language</u> (the original of the Republic of Hungary only):

Annex No.5, page 1, text sub <u>Malý Danube</u>, second line, reads:
"at Trstice"

This note and the note containing affirmative response will constitute an agreement between the Parties concerning the above mentioned corrections.

The Ministry of Foreign Affairs of the Slovak Republic avails itself of this opportunity to renew to the Embassy of the Republic of Hungary the assurances of its highest consideration."

Upon the instruction of the Ministry of the Republic of Hungary this Embassy has the honour to confirm its consent with the above mentioned proposal.

Thus the note of the Ministry of Foreign Affairs of the Slovak Republic and this note constitute an agreement between the Parties concerning the above mentioned corrections.

The Embassy of the Republic of Hungary avails itself of this opportunity to renew to the Ministry of Foreign Affairs of the Slovak Republic the assurances of its highest consideration.

Bratislava, May 8, 1995

STATUTE
on the activities of the Nominated Monitoring Agents envisaged in the

"Agreement
between the Government of Republic of Hungary and
the Government of the Slovak Republic
concerning Certain Temporary Technical Measures and
Discharges in the Dànube and the Mosoni Branch of the Danube",
signed on April 19, 1995

According to the Article 4 of the "Agreement between the Government of Republic of Hungary and the Government of the Slovak Republic concerning Certain Temporary Technical Measures and Discharges in the Danube and the Mosoni Branch of the Danube", signed on April 19, 1995 (in the following Agreement) the Parties undertake to exchange data of their environmental monitoring systems operating in the affected area which are necessary to assess the environmental impacts of the measures envisaged in Articles 1-3 of the Agreement.

According to the assignment contained in the Article 4 and Annex 5 of the Agreement, Nominated Monitoring Agents (Representatives of Parties):

Árpád Kovács, Deputy State Secretary of the Ministry for Environment and Regional Policy of Hungary

and

Dominik Kocinger, Plenipotentiary of Government of Slovak Republic for Construction and Operation of Gabčíkovo-Nagymaros Waterworks

agreed on the Statute concerning the exchange of data and joint periodical evaluation thereof (in the following Statute).

Article 1

1. Nominated Monitoring Agents are responsible for the exchange and evaluation of data from the environmental monitoring systems of the Parties which are necessary to assess the environmental impacts of the measures envisaged in Articles 1-3 of the Agreement:

2. The Nominated Monitoring Agents will submit the joint evaluations and proposals prepared periodically to their respective Governments.

Article 2
Data from the environmental monitoring system

1. The monitoring sites, objects and items based on Annex 5 of the Agreement are specified in the Annexes to this Statute. Annex 1 contains monitoring sites, objects and items for the Slovak Republic, and Annex 2 contains monitoring sites, objects and items for Hungary, both Annexes specifying the dates of data exchange.

2. The in situ survey of monitoring sites and objects or joint measurements will be carried out where a discrepancy occurs to measured data, or through agreement by the Nominated Monitoring Agents.

3. The Nominated Monitoring Agents are entitled to change or add a monitoring site, object or item by mutual consent.

4. Exchange of the data is made through the Nominated Monitoring Agents in writing and on magnetic media. The Nominated Monitoring Agents undertake to put at each other's disposal necessary topographical maps (M 1:10000) and any other maps in other scale under mutual agreement.

Article 3
Monitoring evaluation

1. The joint evaluation of exchanged data refers to one hydrological year. The Joint Annual Report will be carried out four months following the respective hydrological year. The Joint Annual Report will be prepared in Slovak, Hungarian and English languages, the English text shall prevail in the event of any discrepancy.

2. The National Annual Report will include the measured data in tabular, graphical and map forms with short explanations. The Parties will exchange National Annual Report three months following the respective hydrological year, and Nominated Monitoring Agents will call a meeting to carry out the joint evaluation of presented data.

Article 4
Activity of Nominated Monitoring Agents

1. Meetings will be held according to need, but at least two times in a calendar year. Meetings are called by both sides alternately. All necessary conditions for a meeting have to be secured by the receiving Party, and the meeting is chaired by the Nominated Monitoring Agent of the receiving Party. Minutes from the meeting will be prepared and will be signed by both Nominated Monitoring Agents.

2. Nominated Monitoring Agents have the right to invite experts to the meetings.

3. When a joint measurements or an in situ site survey will be carried out the receiving Party is obliged to secure all necessary conditions for measurement and access to the monitored site or object, subject to mutual agreement.

4. Meetings of the Nominated Monitoring Agents are to be held in the Slovak and Hungarian languages. Minutes from the meetings are prepared in the Hungarian, Slovak and English languages, the English text will prevail in the event of any discrepancy.

Article 5
Miscellaneous Provisions

1. All expenses connected to the activity of Nominated Monitoring Agents and meetings are covered by the Parties independently. Expenses connected to the preparation of the English version of the Joint Annual Report are covered by the Parties equally.

2. The Nominated Monitoring Agents begin their activities upon the approval of this Statute.

3. This Statute shall terminate with the termination of the Agreement.

4. This Statute is prepared in duplicate, in the Slovak, Hungarian and English languages, the English text will prevail in the event of any discrepancy.

Agreed at Gabčíkovo on 29th May, 1995.

Kovács Árpád
Nominated Monitoring Agent
of the Republic of Hungary

Dominik Kocinger
Nominated Monitoring Agent
of the Slovak Republic

Annex 2

(Excerpts)

EIA Newsletter 8, Winter 1993

technologies. However, this will only be sustained so long as the perceived benefits exceed the costs of EIA implementation. So far more consideration has been given to the former than the latter. The proposed 'EIA summit' has identified 'cost-effectiveness in the EIA process' as a key issue to be addressed - this may prove to be very timely.

(The views expressed in this Newsletter are those of the individual authors. They do not necessarily coincide with the views of any organisation with which they are associated, of the EIA Centre, the European Commission or others contributing to the Newsletter. All contributions relate to the situation prevailing at (approximately) the beginning of October 1993 unless otherwise stated.)

REVIEW OF THE IMPLEMENTATION OF DIRECTIVE 85/337/EEC

The European Commission finally published, in April 1993, its review of the implementation of the EIA Directive. It consists of a comparative analysis of the Directive's implementation in the twelve Member States and separate, more detailed, reports for each Member State (see 'Book Reviews' in this Newsletter, and EIA Centre *Leaflet 14* for further details). It covers the period up to July 1991 and this should be taken into account when interpreting its findings because there have been a number of significant developments since then - and more are in the pipe-line.

One of the key issues examined in the Review is formal compliance i.e. the extent to which Member States have transposed the requirements of the Directive into their national laws. Despite substantial EIA legislative activity there was still, as at July 1991, a number of remaining deficiencies, particularly in certain Member States. This especially applied to the coverage of Annex II projects. Since then some of the deficiencies have been reduced but a number remain.

A second major issue is that of practical compliance i.e. how far are the requirements of the Directive being implemented in practice and is the EIA process as a whole working satisfactorily within the Member States? Evidently, substantial EIA activity is taking place. By July 1991 very considerable numbers of EISs (or their equivalent) were being produced in many of the Member States and, since then, the numbers produced each year have further increased. After analysing the available evidence the Review concluded that the benefits of EIA implementation appear to exceed its costs. However, it also noted that considerable variations in the quality of EIA practice were observable. These occur in the timing of commencement of the EIA process, the use made of scoping procedures and methods, the quality of EISs and the procedures and methods used to ensure good quality control, the public availability of EISs, the effectiveness of consultation and public participation, the practical use made of EIA findings in decision-making, and the provisions made for monitoring and post-auditing.

The Review concluded that, despite its net beneficial effect, the full potential of the EIA Directive had not yet been realised. Although further progress has been made, since it was completed, this conclusion is still broadly true. There are many ways in which further improvements may be achieved but three of these may be highlighted:

- individual Member States should ensure full formal compliance with the Directive's requirements;
- the contents of Directive 85/337/EEC should be re-examined, in the light of the Review's findings, to determine what revisions and/or extensions to its provisions may be desirable; and
- the provisions made for guidance and training, in support of the more effective practical application of EIA, should be strengthened.

All of these types of measures are now being considered and it is hoped that they will make a sizeable contribution to the further strengthening of the EIA process in the near future.

Carys E. Jones and Norman Lee

EIA: A COMPARATIVE REVIEW

A comparative review is being undertaken by the EIA Centre, University of Manchester, of the EIA systems in eight jurisdictions: the United States, California, the United Kingdom, the Netherlands, Canada, the Commonwealth of Australia, the State of Western Australia and New Zealand. Each of these EIA systems is being evaluated against a set of evaluation criteria. The 13 criteria relate to the various stages in the EIA process and cover, for example, the treatment of alternatives, scoping, public participation, mitigation and monitoring and the overall benefits and costs of the EIA system. The ultimate purpose of the comparative review is to make suggestions to improve the effectiveness of the EIA systems examined.

The USA has had an EIA system since 1970, California since 1971, Canada since 1973, the Commonwealth of Australia and New Zealand since 1974, the Netherlands and Western Australia since 1986 (after extensive investigations of different approaches to EIA) and the United Kingdom since 1988, as a direct consequence of the European Directive on EIA.

A number of conclusions are emerging from the study, including the following:

- An early concern with the methodology of impact forecasting, and decision-making, especially in the United States, gave way to an emphasis on administrative procedures for EIA (in all the jurisdictions and most particularly in California where numerous changes in the California Environmental Quality Act are proposed annually). This, in turn, gave way to a recognition of the crucial relationship between EIA and its broader decision-making and environmental management context (perhaps best practitioner's handbook of good practice for cumulative effects assessment.

Patrice LeBlanc

EIA IN THE CZECH REPUBLIC

Implementation of EIA within the Czech legal system has been undertaken in accord with the European directive on EIA. There are three relevant Czech legal regulations:

- Law no 17/1992 of 15 December 1991 on the environment;
- Law no 224/1992 of 15 April 1992 about environmental impact assessment;
- Ministry of Environment Notice No. 499/1992 of 1 October 1992 about bodies competent to evaluate environmental impacts and about public participation.

Czech EIA law no 244/1992 relates to projects, development plans and products.

Projects

Impact assessment is applicable to construction, activities and technologies listed in annexes 1 and 2 of the EIA law. The competent authorities can also require an EIS if the project is to be carried out in the areas protected under separate regulations (even if they are not listed in annexes 1 and 2). The Ministry of Environment is responsible for projects listed in annex 1 and district authorities for projects listed in annex 2.

The developer issues a formal announcement about the project to the competent authority. At the same time the EIS must be submitted. This EIS can be written only by a responsible body which has a certificate of specific competence. The contents of the EIS are specified in annex 3 of the law.

The EIS is sent to the relevant state administration and local government bodies for an opinion. The public has the opportunity to participate through the local authorities. The public is usually separately represented both by individual citizens and by public organisations. After all the comments have been received on the EIS the competent authority (which is not the body preparing the EIS) prepares an expert opinion. This expert opinion contains documented details of comments by all the authorities on the environmental impacts of the project, mitigation measures and a number of other features. The expert opinion is subject to public discussion which is initiated by an announcement to the public and to the authorities. On the basis of the expert opinion, in which the details of the project are summarised, a statement is prepared by the competent authority (the content of which is specified in annex 4 of the law). Without this statement, the competent authority cannot issue a permission for the project to proceed.

Time limits for the different steps in the procedure are specified in some instances (for example, the public have 30 days to comment on the EIS) but others are not determined. The whole procedure lasts a minimum of 3 - 6 months and, for complicated cases, the time requirement is longer.

Development Plans

The EIA law also sets down a mechanism for assessment of plans which are approved by the central state agencies. The environmental impacts of the plans have to be evaluated and the public must have the opportunity to comment on the proposal. The central agency is not permitted to approve the proposal until the Ministry of the Environment has issued its statement on the plan.

Products

The EIA law in the Czech Republic extends to products. Evaluation is provided by way of certification according to specific regulations. There are specified rules relating to the production process concerned. Inspections by the appropriate body can give rise to penalties.

The EIA and environment laws contain provisions for the evaluation of environmental impacts across state borders. Since mid-1992, when the various laws mentioned above were implemented in the Czech Republic, EIA has become an important tool in the protection of the environment. EIA strengthens the prevention principle and has permitted the participation of the informed public in the decision processes. Despite the adoption of the EIA procedure, there are problems in relation to public participation and the screening and scoping stages in the EIA process. These should be overcome with practice and time.

Helena Čížková and Lukáš Ženatý

EIA IN HUNGARY

In June of this year the Hungarian Government issued its EIA Decree (No. 86/1993(VI.4) for Provisional Regulation of the Assessment of Environmental Impact of Certain Activities). This represents a turning point in the history of Hungarian EIA regulation since the decree established systematic investigation of a broad range of activities and linked it to the decision-making process.

The EIA adoption process started in 1983 with the resolution of the National Council on Environmental Protection. It was followed by a decree which made it obligatory to undertake impact studies for major projects under governmental control. (The latter was repealed in 1989.) In 1991, Hungary signed the Espoo Convention. In 1992 a governmental decree was issued on the socio-economic and environmental impact assessment of major power plants. EIA also forms part of the draft of a complex environmental law but owing to the slow drafting and legislative process the environmental administration initiated governmental level regulation based on the previous proposals.

The decree regulates the extent of EIA-obligatory activities, the EIA process, its general requirements and its linkage with the licensing procedure. Two annexes attached to the decree contain the lists of EIA-obligatory activities. This pre-selective approach is very close to the European Communities regulation with two major differences: first, activities in Annex II require EIA only if the proposed site is within a nature protection area; second, it is discretionary whether a full EIA is necessary or not (except in the case of activities listed in Annex I of Directive 85/337/EEC). The latter reduces the inflexibility of the pre-selective approach, screening out the activities which have non-significant impacts in particular cases.

The EIA process consists of preparatory and detailed impact assessment phases. Each phase is completed by the preparation of a document. The preliminary environmental impact study (EIS) should describe the proposed activity, its emissions and direct consumption (use) of natural resources, identify the possible environmental impacts and determine the potential environmental issues demanding further investigations.

The detailed EIS should contain a description of the proposed activity with exact data on emissions and the use of natural resources; a description and comparison of the environment of impacted areas with and without the proposed activity; an estimate of the environmental health and socio-economic consequences due to the changes in the environmental state of impacted areas; a description of mitigation measures; a description of monitoring and post-project control measurements; a discussion of uncertainties and lack of knowledge in the assessment of impacts; and a non-technical summary.

The impact forecast should cover the impacts coming from land-use, construction, operation, decommissioning, possible accidents, and closely connected activities such as waste disposal and transport.

The decree establishes a new licensing procedure for EIA-obligatory activities. In this procedure the decision maker is the regional environmental authority. The environmental authority should always request the opinion of nature conservation and public health authorities and also other authorities if they are concerned in the particular case.

The procedure, like the impact assessment process, consists of two phases. The first starts when the proponent of the activity submits the preliminary EIS to the competent regional environmental authority. The competent authority conducts scoping of the full EIA after considering the concerned authorities' comments. The outcome (the decision) may be either the determination of the scope of further investigations or, when the available information is sufficient, the grant or refusal of the environmental permit.

The second phase starts when the proponent submits the detailed EIS to the competent authority. In addition to consultations with the concerned authorities a public hearing should be held. The final decision can be either the refusal or the granting of the environmental permit.

Evidently, the implementation process - especially in the first years - will not take place without difficulties. Because of the complex nature of the EIA procedure the emerging problems will be similarly complex, reflecting all the deficiencies of Hungarian environmental protection. However, most of these deficiencies can be overcome only by the practice of EIA. 'Learning by doing' promotes the better application of EIA.

Anna Radnai

EIA EXPERIENCE IN KOREA

The problems of environmental degradation in Korea basically arose from rapid economic development. The proportion of heavy industry to total industrial output was one of the highest among newly developing countries during the last decade. Such rapid industrialisation, together with urbanisation in large urban centres, was accompanied by unexpected adverse effects on the environment that required urgent remedial action.

Korea's major environmental statute was the Environment Preservation Act enacted in 1977. The Authority to enforce the Act fell under the responsibility of the Ministry of Public Health and Social Affairs. In 1980 the Constitution was amended to guarantee people the right to live in a clean and healthy environment. As the new Environment Administration Agency was established at sub-cabinet level, the Act could start to introduce important measures and features of environmental regulation such as environmental standards, monitoring, emission control and environmental impact assessment.

Environmental impact assessment was first introduced in 1981 as an important tool for the prevention of possible environmental disruption from development projects. Under the EIA system adopted by the Act for major public projects, the developer was to prepare an environmental impact statement and submit it to the Agency for planning and technical consultation. The benefits of most public works such as the construction of highways, multipurpose hydrodams and large scale housing projects generally have great influence on governmental decision making processes and the effectiveness of environmental impact assessment has been somewhat limited as a result.

The experience of administering the Environment Preservation Act before 1985 demonstrated the need for major reforms to improve the enforcement function. The following year saw the Act expand its application of the environmental impact statement to development projects in the private sector. The total number of EISs has increased significantly: 120 EISs were prepared in 1989, followed by 212 in 1990. The Special Committee on Government Organisation recommended that the Environment Administration Agency be elevated to cabinet level as the Ministry of Environment (MOE) which has prime responsibility for the administration of environmental protection.

Annex 3

Federal Committee for Environment: Technical-Economic Study on Removal of the Water Work Gabčíkovo with the Technique of Reclaiming the Terrain, July 1992

FEDERAL COMMITTEE FOR ENVIRONMENT
Prague 2, Slezská 9

Prof.Ing. Ludevít Végh, DrSc. and collective

TECHNICAL-ECONOMIC STUDY ON REMOVAL OF THE WATER WORK GABČÍKOVO WITH THE TECHNIQUE OF RECLAIMING THE TERRAIN

Part I - STUDY

Prague, July 1992

CONTENT

MEMBERS OF EXPERT GROUP

On the basis of order of the minister-chairman of the Federal Committee for environment, Ing. Josef Vavroušek, the working group of chosen experts was set up by the head of the group, Prof.Ing. L. Végh, DrSc., member of the council of experts of the Federal Committee for Environment.

The members of the group are:

Chairman and the head
Prof.Ing. Ludevít Végh, DrSc.
Members:
Doc.Ing. Jiří Krátký, CSc.
ČVUT Prague, Faculty of Civil engineering,
department of construction material
Prague 6, Thákurova 7
Ing. Jiří Jílek
HYDROPROJEKT Prague
Prague 4, Táborská 31
Ing. Dalibor Peprný
VOJENSKÉ STAVBY Prague
Prague 2, B. Němcové 5
Advisors:
Doc.Ing. Jaroslav Novák, CSc.
ČVUT Prague, Faculty of Civil engineering
Prague 6, Thákurova 7
Ing. Vladislav Sommer
VOJENSKÉ STAVBY Prague, director
Prague 2, B. Němcové 5
Ing. René Sameš, CSc.
HYDROPROJEKT Prague,
head of department
Prague 4, Táborská 31
External cooperator
Ing. Petr Végh
University of Toronto, Civil engineering dpt.
35 st. George street, Toronto, Canada

External cooperators of BME Hungary did not accept the participation.

1. ASSIGNMENT

The assignment results from the following empowering letter of the minister-chairman of the Federal Committee for Environment Ing. Jozef Vavroušek, CSc, addressed to:

Prof.Ing. Ludevít Végh, CSc.
member of the Council of experts of the Federal Committee for Environment
Prague 10, Doubravčická 10

I empower you in this way to elaborate an technical-economic expertise concerning removal of the water work Gabčíkovo and connected with the area reclaiming and demolished concrete recycling method.

The required expertise should be 25-30 pages long and meet the following conditions and contain these parts:

a/ Alternatives and possibilities of technical solution including the way of realisation in keeping with the present practical and technical experience in the CSFR and abroad.

b/ The expertise shall contain preliminary economic assessment of all proposed variants with regard to the present CS prices.

c/ The proposed solution alternatives shall envisage recycling of demolished concrete and its re-utilization with alternatives of the transport route of the material, 10 and 100 km variants will be taken into account.

d/ Brief survey of CS and foreign experience in the area and readiness of CS enterprises to carry out the removal or clearance of the water works Gabčíkovo (it is necessary to determine stages of realization when foreign equipment will be necessary).

e/ The expertise should not contain:

- dismantling and economic rentability of the dismantled energy-producing equipment
- impact of unexpected and unpredictable or extraordinary events, neither adequate security measures
- measures against noise in the course of clearance and other particular physical aspect.

f/ Brief summary of the proposed solution, the extent of which should maximally 2 pages. Cumulated material for the study, calculation and other parts of the report, that can not be incorporated into the required limited, extent of the main part, can be enclosed in a special amendment.

The term of expertise elaboration is July 15, 1992, it shall be handed over in ten copies. Please form the expert group according to your consideration. All other necessary questions will be answered by Ing. Kazimour, including the respective order.

Prague, April, 1992

Minister-chairman of FCE
Ing. Jozef Vavroušek

2. STUDIES, CONTAINING FOREIGN AND CS EXPERIENCE IN THE SPHERE OF DEMOLITION AND RECYCLING OF CONCRETE CONSTRUCTIONS

2.1 INTRODUCTION

The objective of this chapter is to point out:

a/ the present state of foreign experience, development trends in the sphere of demolition and utilization of recycled concrete,

b/ survey of expert and practical experience in the same sphere in the CSFR.

2.2 EXEPERIENCE OF DEVELOPED COUNTRIES

2.2.1 Generally

Demolition, recycling and re-utilization of concrete from demolished objects began, according to reports of foreign journals, to be used in Europe as early as after the WW II. Development of this branch of the building industry on a commercial basis started in early 70. It began on experimental basis, more or less. For example in the USA, according to ACPA Iowa, technology of recycling on the first project was applied successfully in Lyon Country, 1976. Douglas Bernard, the chairman of the Federal office of Highway Construction in the USA, points out a complex of 8 highways 50 m long constructed with the utilization of recycled concrete. The projects were carried out at the international highway network in Oklahoma, Kansas, Iowa and Michigan. At two sections of the highway approximately 3 km long 50% of recycled concrete in one case and 100% recycled concrete in other case were successfully used. The state norm of the USA-ASTM C33-82, article 8.1 defines rough gravel for concrete as gravel made from concrete.

Recycled concrete was practically used on a commercial base particularly in the areas with lack of natural gravel of adequate quality, at the places, where the problem of utilization of waste of demolished construction exists (highway, roads, runways) or at the reconstruction of these facilities and in densely populated areas. Another reason for recycling were savings of building material and energy consumed, since the demolition material is a suitable source of gravel for new objects or their reconstruction. Extraordinarily topical is recycling of concrete in some advanced regions like for example Hong-Kong. There is a shortage of land for new constructions and prices of land are one of the highest worldwide.

In Japan, the Society of Japanese Businessmen founded the "Committee on Disposal and Re-use Construction Waste" that recommends, among other, application of recycled concrete for family houses, low constructions, noise barriers, production of semi-products.

In many countries is the use of recycled concrete based on norm regulations. For example, in England, it is the norm BS - 6543 - The use of industrial side-products and waste material in the branch of civil engineering.

In the ex-Soviet Union, in 1984, Recommendation for recycling of non-standard concrete and firm concrete product was adopted. In the Netherlands, a state norm was adopted, concerning re-use of recycled gravel.

However, not in all advanced countries respective norms all regulations exist. Remarkable were reached within last 15 years, as far as concrete recycling is concerned, particularly in some European countries like the Netherlands, Great Britain, Germany, Belgium, France, the USA and Japan.

Extraordinary big volume of production of concrete in many advanced countries stresses how topical is this problem worldwide. Such a fact can be clearly illustrated by so called equivalent layer of concrete (it means the size of a fictive layer of concrete covering the whole construction area in certain country or region). The volume of this fictive layer would equal to all concrete produced in 100 years in a country or region, calculation is based on the volume of production of concrete nowadays. The thickness of such a fictive layer reaches enormous size - 1,5 - 10 m.

Concrete durability as any other building material or concrete construction, is more or less limited. I can be limited sometimes by completely extraordinary aspects. All this proves the imperative topicality of the matter as, among other, a serious ecological problem. We can expect, that demolition, recycling and re-use of recycled concrete will gradually become one of the key problems of the environment protection and conservation for future generations.

The topicality of the problems is stressed by the attention payed by scientific and expert organizations. The international organization RILEM has established the Committee 37, called Demolition and Re-use of Concrete. It deals with the problems of this sphere from many points of view.

Many other national and international organizations, dealing with that problem many years, exist. In the CSFR, a research team of research experts (ČVUT) was established in January 1992, the members of it are experts from chosen specialized enterprises (the head of the team is Prof. L. Végh). This body is to carry out research in this area in the Czechoslovak conditions and from the CS viewpoint. The recycling of concrete and its re-use, based on many experiments and realized projects abroad, proves, that this is a new grade of development of concrete and other constructions, that cannot be solved without the application of ecological aspects.

In connection with the recycling arises the question concerning the quality and physical-mechanical characteristics of new concrete, made from recycled material, compared to an ordinary concrete.

2.2.2 MECHANICAL CHARACTERISTICS AND ENERGY CONSUMPTION OF RECYCLED CONCRETE

The recycled gravel made from old concrete can be described as follows:

a/ Suitable from the point of view of form, but the humidity absorption is higher by 5-10% than in case of natural gravel. Therefore this recycled gravel must be used saturated with water at the production of a new concrete. Compared to a natural gravel, the volume weight of it is relatively lower.

b/ The use of recycled concrete gravel for a new concrete does not influence to a considerable extent the ratio of the mixture and the way of use of it.

c/ If the recycled material is used in the shape of small pebbles, the consumption of concrete increases and it is more difficult to handle with it, due to the necessity to add water to the mixture. The characteristic of the recycled concrete can be improved if at least some natural gravel is added.

d/ The ability to resist low temperatures can be equal and higher as against to the original concrete, which depends on the small gravel quality. Also the concrete durability can be higher or identic. However, there in a higher danger of corrosion with regard to higher penetration of steam as against the original concrete.

e/ The resistance of the concrete against pressure is usually in case of recycled concrete, lower by 5-10% compared to an adequate concrete made from natural gravel. Also the flexibility module is lower and it is possible to form it longer.

The production technology in case of use of recycled concrete is practically equal as the technology of classic concrete (mixing, dosing, way of use of the concrete mixture).

Fine parts of recycled concrete are not very suitable for the production of a new concrete. They may used for other, more suitable purposes, for example for ground stabilization, biological filters etc.

In case of price disproportion between natural and recycled gravel, the ecological reason could justify possible state subsidy supporting re-use of recycled material in the new constructions. Consumption of energy at the concrete recycling differs form the production of a new concrete. Various stages of preparation of the recycled concrete, as milling, separation, division, transport, storage, recycling lines installation, works, security measures, control operations etc, are operations more complicated than those in case of production of a classic concrete from natural gravel. Nevertheless, foundation of new recycling capacities, new of future, if confrontated to ecological viewpoints, must be regarded as an inevitable stage of development.

The foreign sources unanimously state, that the energy consumption of the adjustment of demolished concrete is comparable to the production of milled gravel of higher quality at a quarry.

2.2.3 METHODS AND EXTENT OF DEMOLITION OF CONCRETE CONSTRUCTIONS IN ADVANCED COUNTRIES

Classification and survey of demolition methods according to /P-7-41/

a/ Simple (current) mechanical methods of demolition are the subject of the report of the technical commission RILEM number 37-DRC.

b/ Hammering demolition method.

c/ Hitting by, for example, iron ball, by automatical hit of a falling iron ball onto a concrete object.

d/ Hydraulic jacking demolition - developed in Japan.

e/ Hydraulic breaker demolition.

f/ Demolition by abrasion - demolition by a mechanic equipment like drilling, diamond disk cutting, water jet, water jet combined with iron abrasion.

g/ Demolition by breaking technique with the use of wedge, chemical expansion materials, dynamic breaking technique, water canon with the pressure of 40 MPa into a drilled out hole, by gas pressure, by explosives (particular security measures required) by the use of liquid CO_2 - CARDOX - as a consequence of beat the gas explodes, the speed of developed gas is 4000 - 7000 m/sec.

h/ Melting demolition - destruction of both concrete and the iron skeleton, by high temperature developed by burning special metals, organic fuels or laser beam.

i/ Peeling of concrete layers by high temperature, the object is heated up by induced electricity or micro-waves.

j/ Cutting of iron - concrete columns or chimneys at the bottom or by explosives.

Some of the referred methods are still in the development. Every used method depends on preparatory works (holes for explosives, chemical expansive material), on the extent of the demolished construction or its part, on a possible demand to disintegrate or mill the material for the recycling or on the character of the construction or its parts.

2.3 EXPERIENCE IN THE FIELD OF DEMOLITON AND RECYCLING OF CONCRETE CONSTRUCTION IN THE CSFR

In the Czech lands, there are the following enterprises, specialized on demolition works, waste dump project, recycling and waste economy:

1. Vojenské stavby, s.p., OZ Inženýrské stavby 03
   121 48 Prague, B. Němcové (ref. P-1)
2. Hydroproject Prague
   140 43 Prague 4, Taborská 31 (ref. P-2)
3. Armabeton, a.s.
   140 00 Prague 4, Antala Staška 1 (ref. P-3)
4. Stavby silníc a železníc, s.p.
   110 00 Prague 1, Národní třída 10 (ref. P-4)
5. Inženýrské a prumyslové stavby, a.s., Prague
   100 00 Prague 10, Kubánské nám. 13 (ref. P-5)
6. Metrostav Prague
   and many other.

The survey of experience of the refered enterprises is contained in the separate annex P-1 to P-5 of this expertise.

The enterprise Vojenské stavby (Military constructions) is the most experienced and it has carried out the biggest part of so-far realized demolition projects. Hydroproject has long-termed and important position and experience in the projection of waste dumps and waste economy. In the theoretical sphere, CVUT Prague is the centre of research and expert activities, particularly the faculty of civil engineering, Prague 6, Thákurova 7.

With regard to this, professor L. Végh, the head of the project, established his team, that consists of members or advisors from CVUT Prague, Vojenské stavby and Hydroproject.

None of the foreign projects is comparable, as to volume of demolished and recycled concrete, to the volume of concrete -1,6 million cubic meters - of the water work Gabčíkovo. The largest volumes of concrete constructions demolished and recycled abroad according to available sources, are much lower and they are not many times bigger than 100 000 cubic meters. Therefore this expertise can be based on foreign experience only partly.

2.4 SUMMARY OF THE MOST IMPORTANT EXPERT STUDIES FROM ABROAD

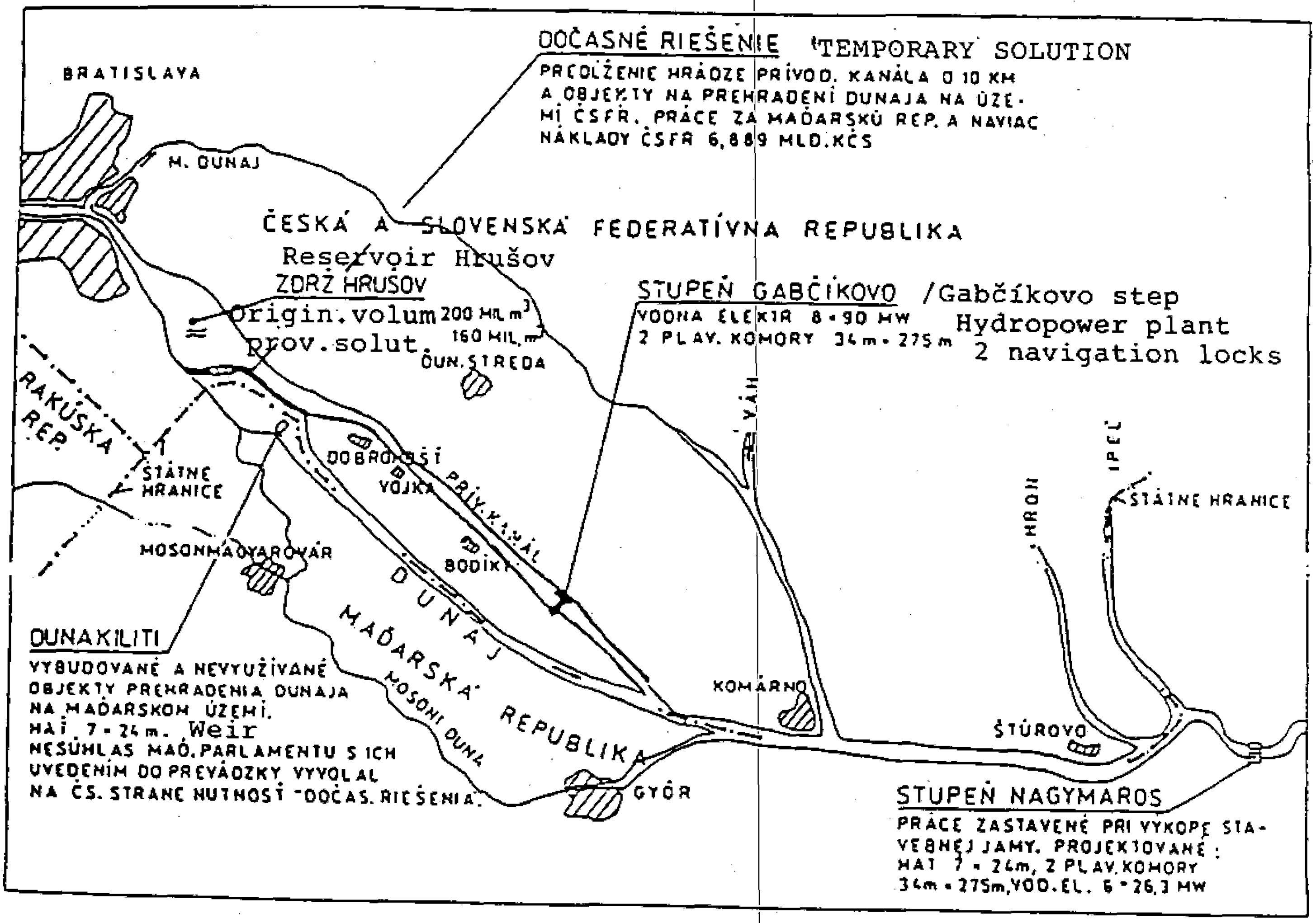
The summary was prepared from specialized journals, reports and publications, concerning this problems from the USA, England, Germany and Japan. The university in Toronto has been engaged into cooperations and we have used the international computer database. The list is enclosed in the enclosure G-N. It contains totally 123 entries.

2.5 SURVEY OF THE EXPERT STUDIES FROM THE CSFR

The survey has been set up by the realization team of the expertise on the basis of the long-termed monitoring of the problem in the CSFR by separate members and with the use of the computer database of literal entries USSI of the Institute of construction information, Prague. Ref. enclosure P-6

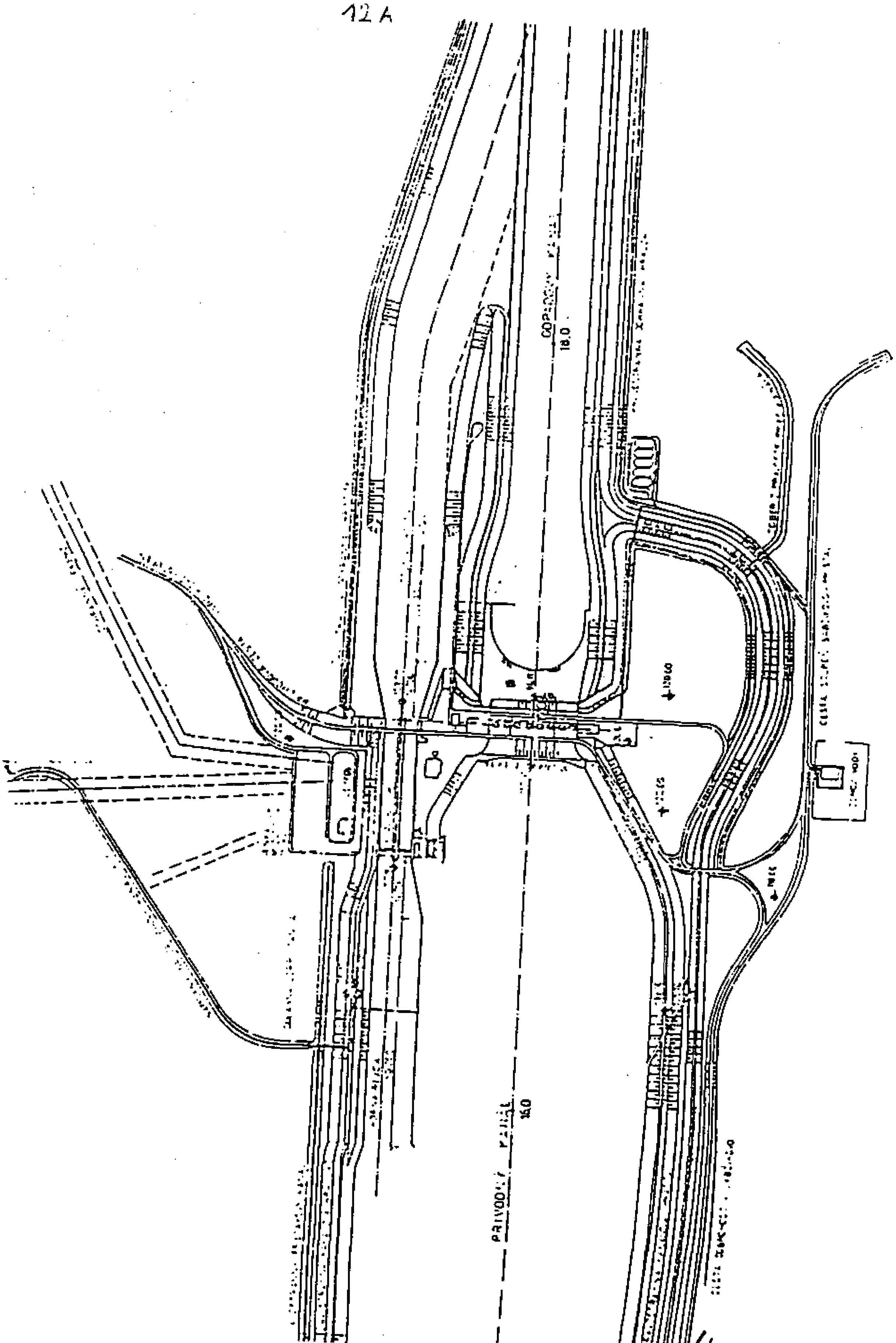
3. DOCUMENTS OF BUILT PARTS OF THE WATER WORK

According to the scheme, first of all the Gabčíkovo step and 16,9 km long canal to this step have been already carried out. Further on, we will not take into account the works, that are to be carried out in the frame-work of the so called Temporary solution of the water work (alternative C) we will take into consideration only those works necessary for change of the present state of the water work to the original state.



Situation of the Danube water work

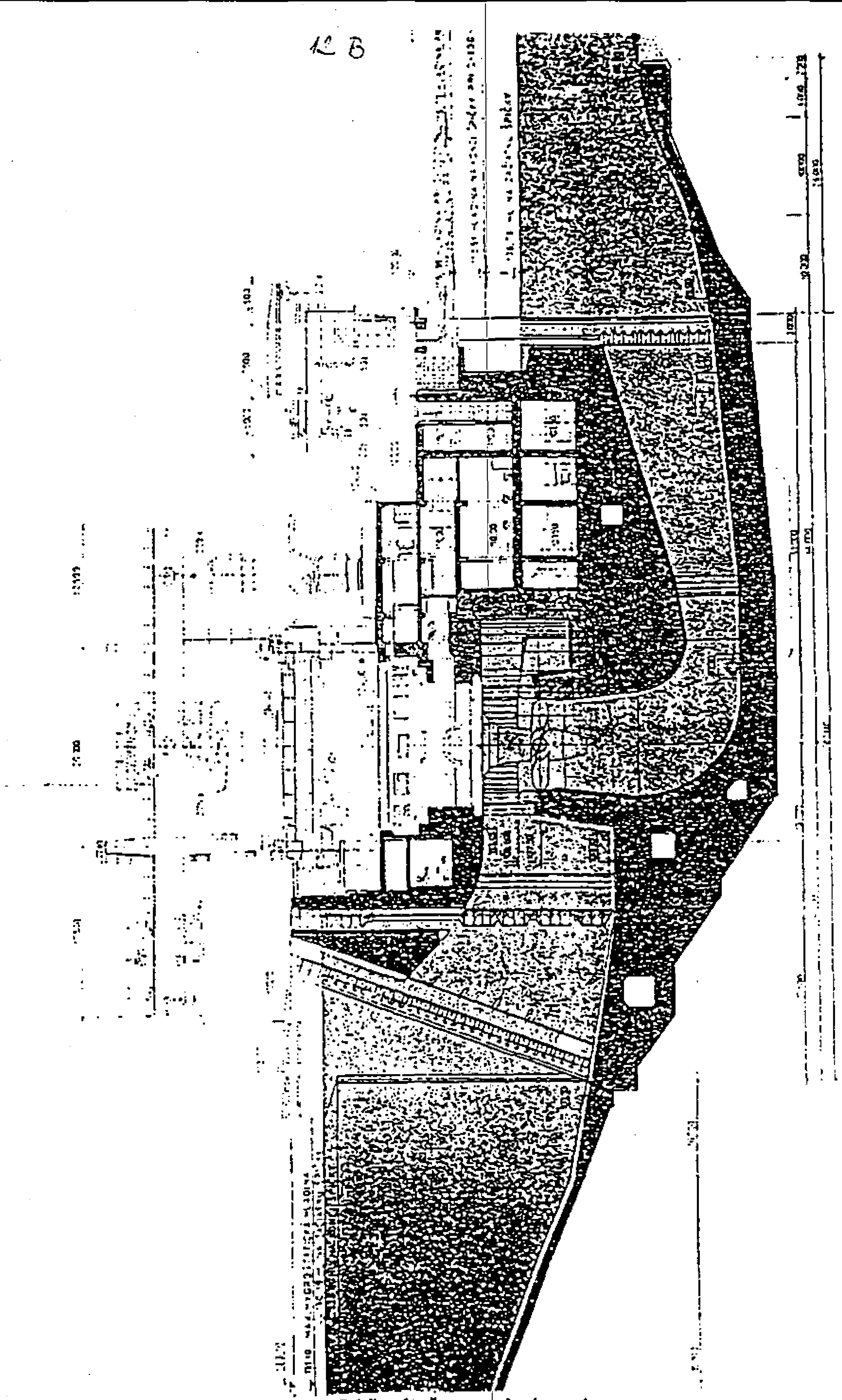
12 A



Situace stupně Gabčíkovo

Situation of the Gabčíkovo step

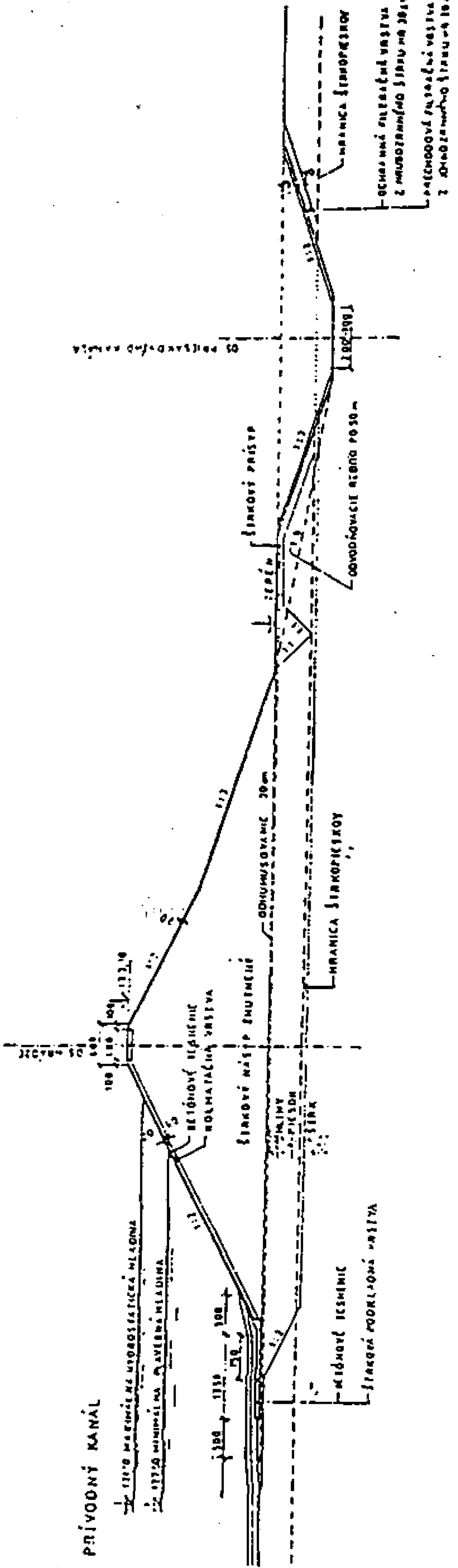
12 B



Příčný řez elektrárnou

Cross-section of the hydropower plant

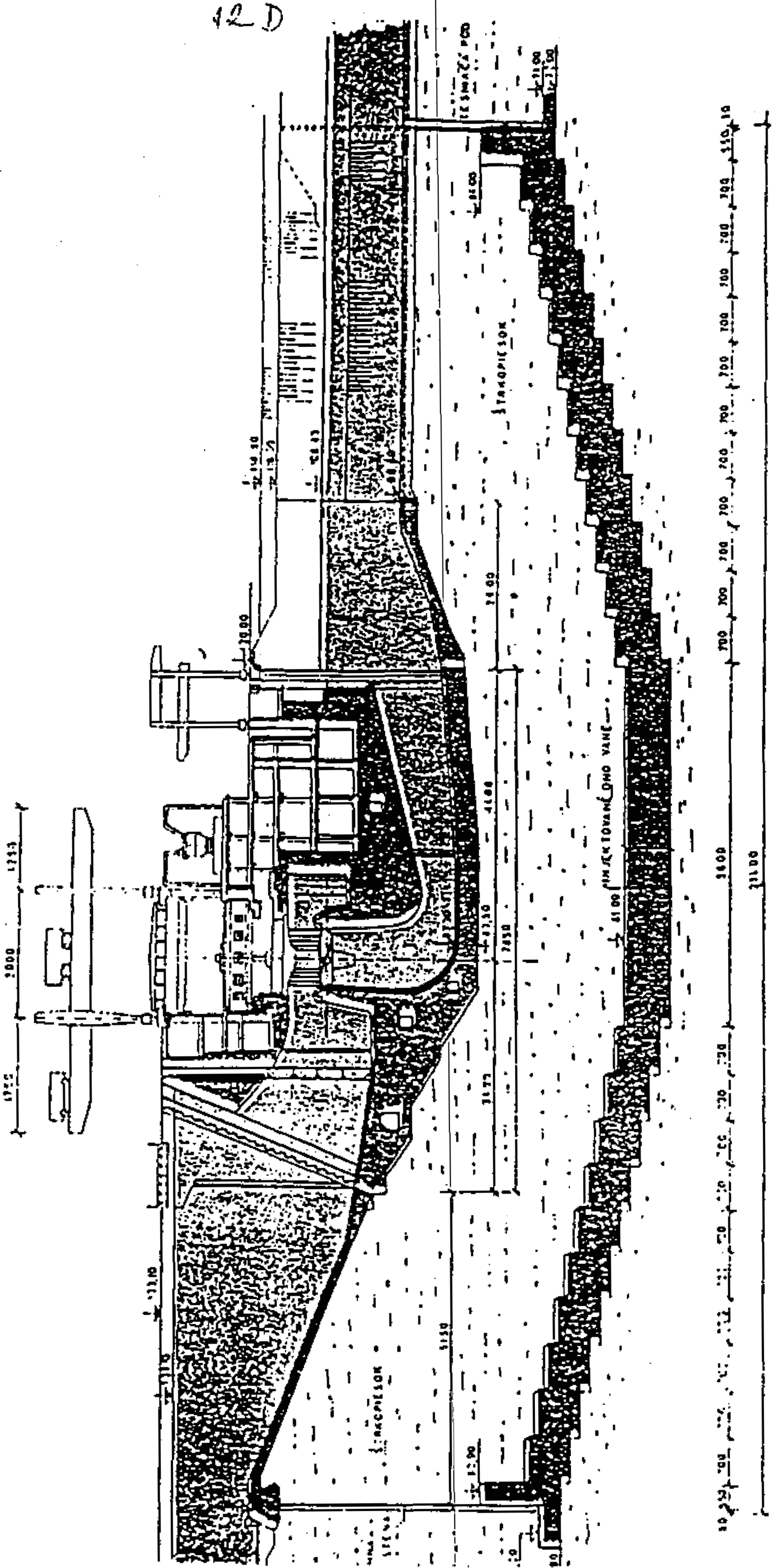
12 C



Charakteristický řez hrází přívodního kanálu

Characteristical cross-section of the power canal

12 D



Založení vodní elektrárny - příčný řez

Basement of hydropower plant - cross-section

To illustrate the volumes of material will have or take into account at the demolition of the water works, we offer a survey of already carried out works:

Concrete and iron - concrete constructions		1,6 mil.m^3
iron skeleton	almost	100 000 t
iron constructions		6 750 t
special iron constructions (for example iron gate)		10 650 t
injected space at the bottom of sealing tubs		1,4 mil.m^3
underground seals and construction walls		1,2 mil.m^3
stone ramparts		0,6 mil.m^3
asphalt - concrete seals		2,3 mil.m^2
foil sealing		7,0 mil m^2
material excavated		6,2 mil.m^3
strengthened ramparts		49,7 mil.m^3
total volume of transferred soil	approx	200 mil.m^3

Gabčíkovo step

Damming up the canal, wide at the bottom 737 m, it is possible to reach the levels difference up to 22 m for the peak output of the hydropower plant, that is the energetic basis of this water work. Besides the powerplant, there are navigation locks and other objects, like distribution facility of high voltage network at this locality (110 KV).

The main problem of demolition of the waterwork is the huge monolilic bloc of the plant made from strengthened high quality concrete. The very kernel of the bloc is 78,5 m wide, 300 m long and consists of concrete parts, thick, at certain places, dozens of meters. /Ref. cross-section of the power plant). Even if the injected base tub will not be demolished, it is 7 m thick, and situated 22 m under the bottom of the plant, the problem of the demolition of the object of powerplant will be the key one /ref. the basement of the power plant).

Power canal

Another key place of the demolition of the water work is a huge volume of works connected with removal of the dykes of the canal, that is 16,9 km long 9-16 m high and 6 m wide (ref. Cross-section of the power canal). The inner slopes of the dykes made from strengthened gravel-sand are sealed by an asphalt-concrete layer 160 mm thick and another inferior layer 300 mm thick. The bottom for the canal is sealed by a soft rubber film (PVC), protected by 1,1 m thick layer the surface of which was strengthened by a 300 mm thick cement stabilization. The original scheme of scheduled main construction works at the water works on the Danube is available in the enclosure P 7 of this expertise.

4. TECHNICAL SOLUTION OF THE WATERWORK REMOVAL

4.1 TECHNICAL EXTENT

The subject of the following consideration is a hypothetic solution of the clearance of objects and adjacent area of the water work Gabčíkovo with roughly approval of its technical and economic practicability and demands on it, based on detail calculation - (ref. enclosures P 8, P 9).

The objective can be achieved by many methods and procedures, both from the viewpoint of the whole unit, and parts of it. We cannot neglect also the point of view of extent of clearance of the whole unit and parts, that would become, in case of realization, a subject of a large project and it would very complex due to the fact, that such a project, as to the extent of destruction, is unique all over the world. In this branch only provisional or temporary objects have been removed so far. These objects, we supposed to demolish and also objects, that must have been removed owing to modernization, or their parts, have been destroyed.

Considering the destruction, we have to take into account many various facts, general and specific conditions, particularly specific conditions of the locality, technical and financial factors, safety, risks and term of realization, if necessary national and foreign made technique is available and how expensive it is, but also the question what to do with the demolished waste and how to substitute it, particularly in the underground. Climatic and hydrological conditions would play a certain role. This is a complex of co-related parameters, that must be assessed as mutually connected.

A detail project of the clearance would be an integral condition of the practicability of it. To elaborate such a project would require preparation of other expertise, both documents concerning already existing. Constructions and a study on the impact of realization of demolition works on the environment, particularly ground and underground water in the conditions of terms.

It is necessary to take into account that the demolition works can result into acceptable state of the area, but not to reach the state that existed before the beginning of the construction works.

4.2 VARIANTS OF REALIZATION

In this case the construction is enormous and it covers approximately 64 square km. Besides water area concrete and soil object predominate and they will considerably influence any consideration on demolition. Most objects have both underground and overground parts and in order to remove some of it would be necessary to carry out drainage as it is usual at the construction of large water works. To ensure the works it would inevitable to build up an ordinary construction site and secure perfectly technological preparation.

We propose to consider 4 variant of clearance of the water work - A, B, C, D. The most exacting is the variant A. The separate variants can described as follows:

Variant A:

It envisages complete removal of all objects of the water work down to the basement, except for uncompleted clearance of deep constructions of special basement.

To remove them, it would be necessary to do it in water. This variant envisages reclaiming of the land and its adjustment to the original ground level.

We have to stress, that neither this most expensive and longest variant will not ensure full return to the original state. It concerns particularly the basement tub of the very Gabčíkovo step.

Variant B:

It envisages removal of all constructions with shallow basement down to their basement. Deeper basements would be removed according to local conditions down to 10 m, roughly, under the level of the original ground. The surface of the area would be reclaimed to the original level. The underground part of the work would be broken so that ground water could move.

Variant C:

This variant counts on similar procedure as in two previous variants, but the constructions would be removed to 5 m under the surface of the original ground. The volume of demolition works would be minimalized. It would be, however, necessary to break partly the constructions of special basement. In this case, too, the ground would be reclaimed according to the original shape.

Variant D:

Concrete objects would be removed on the surface, only, maximally to 2-3 m under the level of the surface. Constructions made from soil would be removed partly, only. A new shape of the area would be created and the surface would be artificially adjusted to the original.

The special construction basement would not be touched.

As to the variants, there are many combined solutions or sub-variants of clearance, that would, nevertheless, make these preliminary consideration complicated from the technical and financial point of view. It should be considered if some of the parts of the canal dam should not be conserved for the purposes of antiflood protection in case of realization of variants A, B, C.

4.3 SURVEY OF ROUGH VOLUMES IN THE FRAMEWORK OF THE VARIANTS D-A.

In the further consideration we operated with the following technical data to which we added separate aggregated items (ref.P-8). These data are conform with the chapter 3. For a detail expertise we would need more exact data on the real realization.

activity and volume of transported material with regard to the assignment	extent of variants minimal variant maximal variant D - A
- works on ditches in the area and transport - 1 km	5,6 - 16,7 mil.m^3
- excavation of strengthened constructions and dumping of surplus, from 10 to 50 km	22,5 - 49,7 mil.m^3
- selective excavation of soil materials, transport - not more than 10 km	5,9 - 12,9 mil.m^3

- selective pulling of filtration layers from constructions with transport of 10 to 50 km	0,8 - 1,8 mil.m^3
- destruction of injected gravel-sand of the basement tub (will stay at the spot)	0,1 - 0,28 mil.m^3
- destruction of underground walls basement tub (will stay at the spot)	0,1 - 0,36 mil.m^3
- destruction of massive concrete, transport with regard to the assignment (ref.1c)	0,64 - 1, 60 mil.m^3
- destruction of various types of flat constructions, transportation - up to 10 km	0,9 - 2,0 mil.m^3
- selective excavation of stone ramparts, transportation from 10 to 100 km	0,45 - 0,60 mil.m^3
- demolition of the objects of the operational buildings, transportation, from 10 to 100 km	41 000 mil.m^3
- removal of film sealing, transportation, 30 - 100 km	4,6 - 7,0 mil.m^2
- suppression of asphalt-concrete sealing with transport of 30 to 100 km	0,57 - 2,3 mil.m^2
- dismantling of iron constructions, transportation 40 - 200 km	17 400 t
- excavation of concrete steel, transportation 40 - 200 km	40 000 - 100 000 t
- drainage for the clearance, dismantling of the drainage and transportation, up to 1 km	503 000 - 631 000 m^3
- reclaiming of the wholes after excavation of demolished constructions, transportation, up to 1 km (from the original object, or temporary storage)	18,1 - 41,8 mil.m^3
- technical reclaiming of the demolished area	1 260 ha
- pumping of water in the drainage system	4,5 - 7 years

In keeping with the assignment (ref 1 e) the following is not included:

- dismantling, transportation and sale of technological equipment
  - cca 24 600 000 t
- preparation of new construction site (the present facilities would be used)
- cost of architectonic - natural final part of reclaiming towards the original state

Remark: Cost of next CS and foreign technological equipment is included in the calculated prices.

4.4 PRACTICABLE WAYS OF DEMOLITION AND REMOVAL OF OBJECT

In course of clearance works we envisage the use of the procedures as follows, that will mostly influence the cost and terms. It would be possible to use many other specialized methods, procedures and activities, but they will not change considerably the calculation.

The basic procedures:

- destruction of firm constructions (concrete, iron-concrete, iron constructions) ref. 4 - 5,
- excavation of ground constructions, ground works, construction
- engineering works,
- dismantling of ironing and flat sealing systems,
- construction of temporary dams, drainage system, temporary sealing of the bottom,
- temporary storage and dumping of demolished and excavated material,
- recycling at the spot, transportation and sale,
- transportation to a recycling facility out of the site,
- technical reclaiming,
- permanent monitoring and indication of impact on the environment,
- checking the impact on environment by an independent, famous consultancy firm.

Some items of this chapter will be commented in detail further on.

4.5 DESTRUCTION OF SOLID CONSTRUCTIONS

From the currently known destructive methods, the following would be used in this case in various extent:

- explosive destruction
- mechanic disintegration - mechanical and manual
- chemical destruction by expansive materials
- destruction by water jet
- thermal destruction and peeling
- some other known methods (ref.chapter 2.2.3)

With regard to the nature of the objects and considerable volume of works the method that would predominate is disintegration with use of explosives and subsequent secondary destruction. We have to stress, that the separate methods considerably differ as to price, some of them are 10 times more expensive than the other. Therefore it would be necessary to carry out experiments in situ and elaborate a detailed study.

As well, it will be necessary to assess the impact of considered destruction works on the environment, particularly the danger of ground water pollution, dustiness, noise, smell, that are not a part of the assignment.

Demolished part of the construction and demolition waste can not stay at the construction site. It is necessary to consider re-use after previous adjustment or partial waste dumping.

In case of steel construction, there would not be difficulties, since the material is relatively new and of good quality. It would be probably difficult to ge rid of the construction waste and we don't mean only previous adjustment and transportation, but, particularly, the sale of huge quantity of material. The largest part will be the demolished concrete constructions.

It will be relatively good broken concrete gravel, it won't be necessary to separate undesirable parts. For the adjustment and use of it foreign currently available equipment can be used. They are similar like the equipment milling stone in our quarries. Technological adjustment facilities must be equipped with an efficient separators of ironing and the milling equipment must be protected. This problem has been already settled abroad.

Practicability of the facility, developed for the recycling purposes by VÚMS Trnava, would have to be assessed separately.

Certain quantity of demolished material would require to construct a complex specialized enterprise with mills and separation lines and storage system at the constructions site. If the optimal theoretical capacity was 500 000 t of demolished concrete every year, the operation of the facility would be secured for 5-6 years. It can be carried out only if the sale of production is ensured. For comparison, the cost of construction of a similar facility in Prague, with the capacity of 100 000 t every year, will be, according to the project 150 mil.Kcs (1991).

Since the recycled gravel contains also certain amount of non-hydrated cement and calcium hydroxide, it is impossible to store it for long. Also therefore the gravel must be sold quickly.

Efficiency of the recycling is connected with the substitution of natural raw material and it proves its advantages best in the regions with insufficient sources. In the area of interest, there are sufficient sources of high quality natural gravel-sand, both small fraction (0 - 4 mm) and, first of all the bigger fraction (4 - 32 mm), that could be completely replaced by recycled concrete without influencing the quality of new concrete. For this reason we have to take into account longer distances of transportation of recycled concrete. There is a problem connected with the protection of these natural sources by a suitable, may be subsidized market price of recycled gravel. The mentioned gravel-sand were used at he construction of the substantial part of the dam of the overground canal.

Their excavation is a substantial competitive source for the recycled concrete. The necessity of transportation of recycled concrete to new places of processing will negatively influence the economy. Just in the place of demolition the demolished recycled gravel can be commercially used for the production of new construction elements.

A side positive economic effect of the recycling of the demolished concrete would metallurgic re-use of a part of ironing

(100 000 t) - ref. scheme 4.1. The sale of it would not be difficult.

4.6 REMOVAL OF GROUND OBJECTS AND RECLAIMING

Current construction machines would be used for ground works, as well as transportation means. It is necessary to underline, that all excavated and again stored material must be processed in keeping with respective norms for ground works. Even if so, a considerable surplus would arise. It would be necessary to store it at special storage or temporary storage and squeeze separately every layer. All such ground bodies must be reclaimed, including the temporary storage of long-termed character.

4.7 DUMPING

Establishment of dumps and storage would be the most complicated part of the project at the water work Gabčíkovo. Without recycling it would require space capacity of 3 - 6,5 mil.m^3 of the second category of dumps and 0,3 - 1,2 mil.m^3 of fourth category, that need not be fully sealed.

Depositories of the first category, it means for inert waste, would have to have temporary capacity of 11-23 mil.m^3.

At the construction of depositories not only budget, but also problems how to acquire ground would play an important role, from the viewpoint of the possibility to gain them and the agreement of the public legal authorities and the very public. The total area of dumps and temporary dumps would reach cca 170 ha of ground with adequate ecological basement.

4.8 RECYCLING AND SALE OF ACQUIRED MATERIAL

As we have already said, it would be possible to count on re-use of steel and coloured metals, since there is a big demand in our country.

Demand can be expected as to stone, the prices should be lower, might be it would take more time. Quite problematic is the sale of huge amounts of recycled concrete demolished material, that would last long, probably.

Vice versa, sale of plastics, particularly thermo-plastics is guaranteed, inspite of the fact, the price would not be high. Even better situation is as to sale of asphalt-concrete seal cover of high quality, since there is a lack.

4.9 EXPENDITURES

At the determination of unit prices used for the estimate of prices of the clearance we based our calculation on the price relation in the CSFR at other comparable projects, and on analysis items referred in the enclosure P-8 of this expertise. Using the second method we checked the first one. We have reached acceptable harmony.

For the very calculation we used cumulated unit prices, already containing a reserve covering unexpected circumstances (20%) and side expenditures (also 20%). We have added the cost of transportation in different variants of distances. Separately we have elaborated the indicators for the main demolition items (concrete, ground works, flat seals) only for illustration. This way, the cost of removal of one 1 m^3 with transportation variants is 2300 Kcs, cumulated final cost according to separate variants is 2600 - 2900 Kcs/m^3 merely with dumping. All other characteristic cumulated items are similar.

Total estimates of experts are summarized in the enclosed scheme 41, that contains all expenditures including mechanization. This scheme distinguishes the cost according to separate variants (A, B, C, D), respect the minimal (10 km) and supposed distance of transportation (100 km) and two cases of demolition material handling, it means complete recycling or dumping, which represents an ecological problem.

4.10 TIME TABLE

The whole procedure of realization of possible demolition works was assessed with regard to real terms and at the same time mutual influences of groups of activities as to the locality and mutual correlation were judged. The use of transport means was found as limiting particularly in case of longer distances. The problem of time was solved according to separate variants, described as A, B, C, D, it means from the maximal interference to the almost finished work to measures, that are regarded as minimal according to this expertise. It would be necessary to carry out a detailed performance project in order to successive realization of works. The project preparation would last at least 10 months, including the approval procedure. This project would be followed by the preparation of demolition and acquisition of equipment that is not available in the CSFR (gravel mills), hydraulic disintegration equipment etc. It would be necessary to construct protective containers for some parts, the construction is supposed to last 1 year.

Removal of steel construction would last 1,5 - 3,5 years, the limiting factor would not be disintegration, but transportation and loading. In case of adjustment for recycling purposes, this term would be longer by 30% - 50% according to the capacity of equipment. Removal of steel constructions would require roughly 2,5 years practically in all variants and 50% of it would be carried out parallel with the demolition works at concrete construction.

The ground works will be as follows: disintegration, excavation, removal of ramparts and ditches, adjustment of slopes and surface, pressuring. It must be proceeded by removal of asphalt-concrete and polymeric flat sealing with the whole auxiliary construction of transition layers and filters. If the use of transport means was optimal and there were two shifts, the removal of ground objects would last, depending on variant, 3,5 - 6 years, it would be possible to reduce the period to 2 - 3 years by maximal use of means. Shorter period is excluded.

More than 90% of the works on the ground objects removal will be done at the same time as other clearance works. Dismantling of flat sealing would last 1 - 3,5 years in case of re-use of the demolished material. In case of use of mechanization regardless of the cleanness and quality of removed material (particularly filters) 1 - 2 years. Ground works can follow these works immediately. Construction of dumps and temporary dumps would last 3 - 6 years, it would be carried out 6 mouths before the demolition of respective objects.

The total time, necessary for the clearance of the whole water works, is according to our estimate, without preparatory works and final elimination of dumps and recycling works, roughly 4,5 (variant D) - 7 (variant A) years, if 1 800 workers operate in the area of clearance and 400 workers at auxiliary works, recycling and dumps centres. The worker must be mostly qualified, able to handle with machines.

Remark: The terms and number of workers - ref. enclosure P - 9

Scheme 4.1

Cost in millions of Kčs

Variant minimal transportion distance 10km longer distances of transportation 100 km

	of clearance (ref. the survey of volumes)		(ref. the survey of volumes)	
	destruction dumping depositing	destruction recycling sale	destruction dumping depositing	destruction recycling sale
A	19 300	15 500	23 400	19 600
(max				
var.)		+14 800		+18 900
B	15 800	14 400	18 100	16 700
		+13 800		+16 100
C	13 900	12 400	14 800	13 300
		+12 100		13 000
D	9 200	8 300	11 500	10 600
(min		+7 900		+10 100
var.)				

Remark:

-The cost is calculated with regard to direct sale of steel to foundries

- In case of destruction of deep constructions of special basement the cost will be increased by 2,4 bilion Kčs (without excavation, ref. enclosure P - 8)

- The survey does not take into account sale of dismantled technological equipment and architectonic-natural final adjustment of the area.

5. FINAL REMARKS

The clearance of the water works Gabčíkovo would be the first realized project of such a type worldwide. It does not concern only the very water works, but also the engineering constructions. Such a project would be very exacting as to removal and transportation of huge quantity of material, but also from the point of view of safe depositing of the material according to the original project.

Another problem would pose substitution of the original geological structure of the construction site by new material in order to reach a natural effect in deeping with the demand of technical reclaiming and subsequent natural-architectonic adjustment. Removal of the work would have not only technical and economic aspects, it would be, at the same time, a complicated ecological task, since it would be necessary to protect the adjacent area against impact of demolition works. Many experts and laics have commented the problem of impact of the water works upon environment in the course of construction and operation and a similar process would repeat, evidently, at the discussion on the concept of the demolition. Therefore it is necessary to consider participance of a prestigious foreign consultancy firm as a permanent adviser, checking all ecological aspects. It would require approx. 150 000 USD a year at least 3 - 4 years.

A very sensitive relation would arise in the sphere of underground water and the danger of pollution. The very process of demolition and other interference should be assessed in a theoretical way or be a model research.

A particular question is, which of the dams should not be demolished in order to protect Žitný ostrov against flood.

What we wouldn't be able to reach even in case of a very careful demolition, is renewal of original natural conditions of underground water streams enabling automatic cleaning and kinetics of chemical reactions in connection with biodegradation. Quite unsolved is the problem how to acquire and particularly pay back financial means, necessary for the hypothetical clearance of the work.

From the ecological viewpoint we have to consider the realization of this hypothetic project with emphasis on maximal recycling of concrete and its reuse.

Annex 4

Aide-Mémoire of the Discussions of the Co-Chairmen of the Czechoslovak-Hungarian Committee for Economic and Scientific-Technical Cooperation, 19 August 1985

AIDE-MEMOIRE

from the discussions of the chairmen of both Czechoslovak-Hungarian Committee for economic, scientific and technical cooperation

On August 19, 1985, the meeting of the chairmen of both Czechoslovak-Hungarian Committee for economic, scientific and technical cooperation (hereinafter only Committee) Rudolf Rohlíček, the vice-president of the Czechoslovak Government and József Marjai, the vice-president of the Council of Ministers of the Hungarian People's Republic took place. The questions of bilateral economic cooperation and joint construction of the GNP was on the program.

(....)

2. The chairman of the Hungarian part of the Committee informed about position taken by the Council of Ministers of the Hungarian People's Republic in connection with discussing the report on the situation and further tasks of the construction of the GNP and comprehensive study on possible impact of the Project on the environment. The chairman of the Hungarian part of the Committee, with aim to complete joint works on this section, submitted the proposal for further research and coordinated activities which would be needed during further construction of water works in a way of maximum utilisation of advantages following from the realization, as well as the improvement of environment, prevention and avoidance of eventual damages, including application of higher demands by construction.

The Hungarian side proposed a joint elaboration of further conditions which should make possible putting of the water work Nagymaros into operation as soon as possible after putting the water work Gabčíkovo into operation already in settled term.

The Hungarian side handed over the extracts of comprehensive study on impact of the GN project on environment. The chairmen of both parts of the Committee charged the government plenipotentiaries to discuss these tasks which must be solved jointly in working groups, a special attention must be paid to tasks of protection of environment and ecology.

The chairmen of both parts of the Committee charged the government plenipotentiaries, following the results of already realized works:

- to set up conditions of putting the water work Nagymaros into operation as soon as possible after putting the water work Gabčíkovo into operation in settled term and to submit a joint proposal to the chairmen of both parts of the Committee,
- to establish a working group within the Joint Operative Group for evaluation of questions of environment protection and ecology and to determine activities which are needed to be realized during construction and preparation of operation,
- to elaborate jointly in advance the operation order of the System of Water Works with special regard on the peak operation, preservation of the character of flowing water in the old river bed of the Danube, optimization of hydrological and energetic conditions, as well as conditions of protection of environment and navigation,
- following previous agreements, to realize a measuring and monitoring system of the water work in such a way that the effects of the whole system on environment be monitored with scientific accuracy and to guarantee reference data from the period before putting these structures into operation,
- to speed up the negotiations on preparation of regulations concerning energy operation of water works,
- to verify rational possibilities and to realize demands of economy during the construction of the System of water works, to find out rational solutions with necessary and possible changes of technical projects to reach maximum effects,
- to elaborate a joint report on the situation and tasks of the construction of the System of water works Gabčíkovo-Nagymaros and cooperation in protection of environment for the next XXI. session of the Committee.

The sides will ask the Czechoslovak Academy of Sciences, the Slovak Academy of Sciences and the Hungarian Academy of Sciences to speed up works within the framework of researches being realized and to extend their activity on questions set up by the working group for protection of environment.

The chairmen of both parts of the Committee charge the Czechoslovak-Hungarian Commission for Boundary Waters to monitor further water quality with special attention on the mentioned section of the Danube and to set up measures for realization of tasks aiming to decrease the pollution of water with wastes.

This record was done in two copies in the Czech and Hungarian language with the same validity.

In Prague August 19, 1985

Rudolf ROHLÍČEK József MARJAI

Annex 5

Hungarian Brochure, "Environmental and River Dams", 1988

"... protection and improvement of the environment, conservation of nature and the rational use of her resources are essential to the welfare of people and economic development of all nations ..."

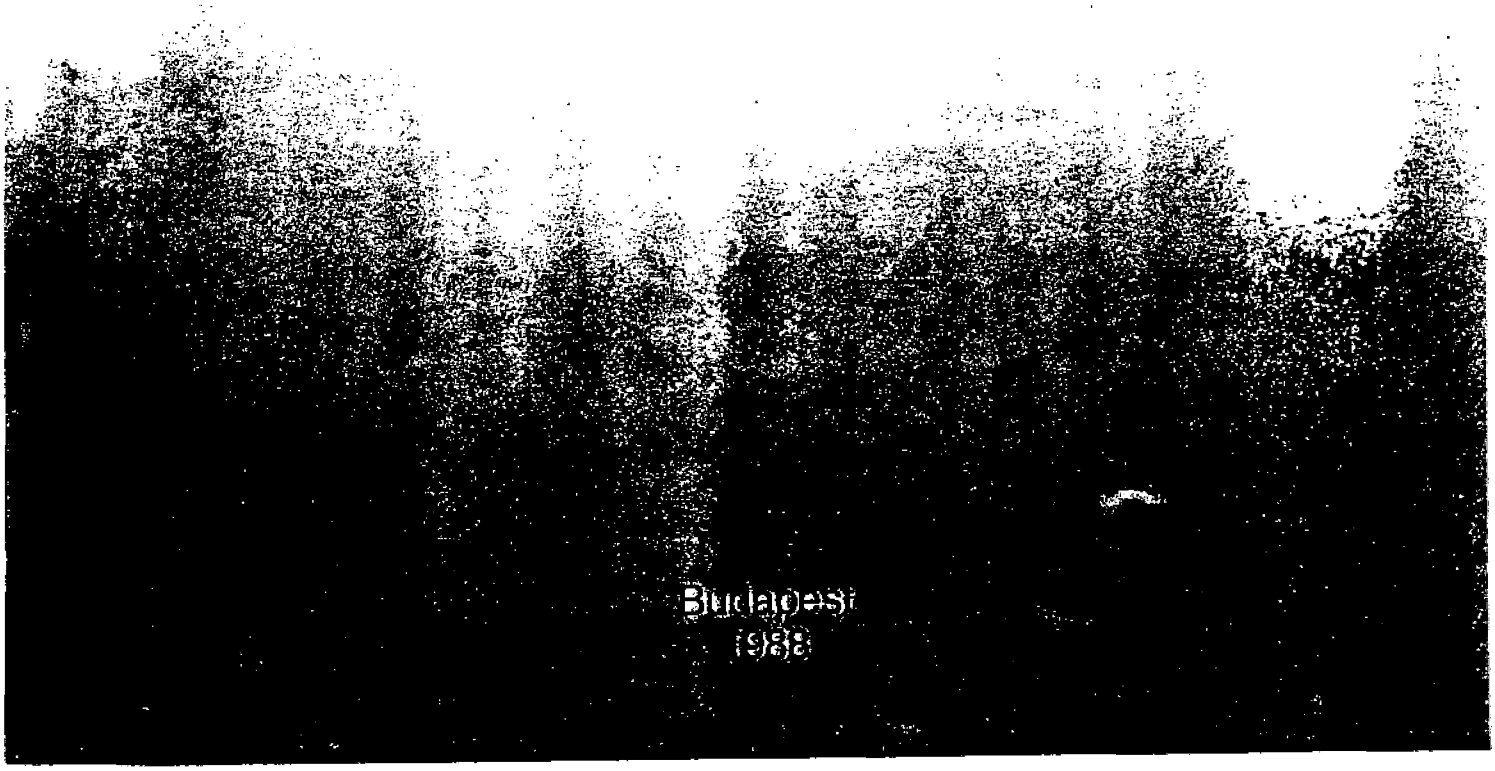
Helsinki, August 1, 1975

"It would be futile to expect streams to regulate and link themselves spontaneously. Human efforts, great efforts concerted and guided by true science are needed to accomplish this."

Count Stephen Széchenyi, 1830

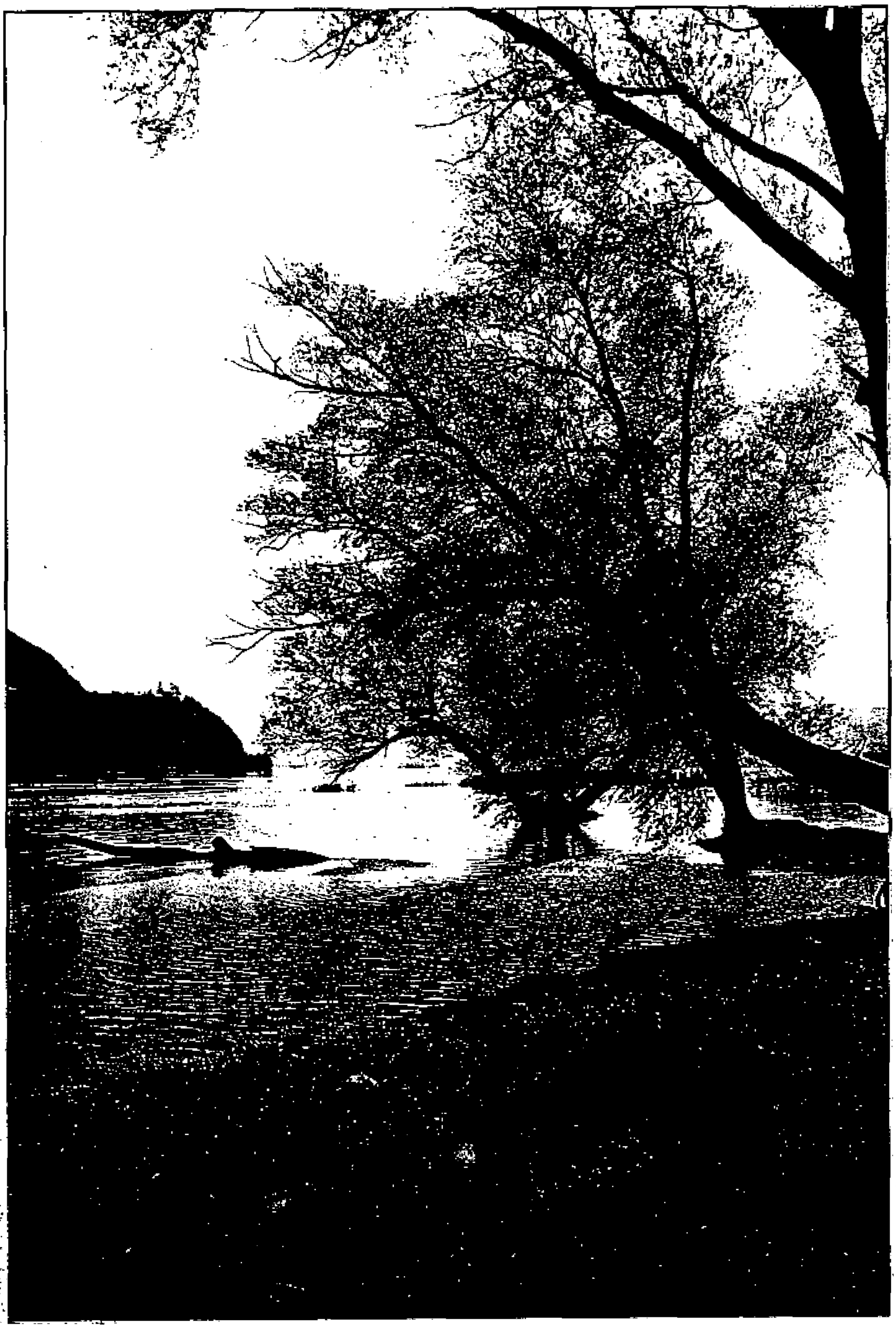
GABČIKOVO—NAGYMAROS

Environment and river dams



Budapest
1988

The former and present beds of the Danube on the map of Samuel Mikovíny from 1700



The Danube is the common
natural asset of Europe.
The gross national product generated
in the 817 thousand square kilometres
large river basin
makes her in terms
of economic output
the most important river
in the world,
although with a length
of 2,860 kilometres
she is only the twenty-eighth
on the list.

Over 70 million inhabitants
of eight riparian countries,
or twelfe per cent of the continent's
population are directly
influenced in the basin.
The vast flow carried in the river
is an essential element,
a vital factor of biological life,
human, plant and animal alike,
an irreplaceable raw material,
transport carrier to a continuously
developing economy, while
at the same time she is the recipient
of the effluents,
the waste waters of a wide variety
of human activities.

Following the inauguration
of the Danube—Main—Rhine Canal,
the Danube will become
the Eastern backbone
of the 3,500 kilometres long
transcontinental waterway linking
the Black and North Seas.
The people of Europe display
therefore, understandably a keen
interest in the fate
and future of the Danube.

Plans Over The Centuries

The importance of the Danube, the necessity of her 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. A memorial in the Kazan Gorge perpetuates the glory of the Emperor Traian under whom the project was completed.

Emperor August had a coin minted around the beginning of our era bearing the inscript "Salus rei publicae — Danubius", or "Danube — the welfare of the Empire".

The first to attempt the construction of a canal linking the Danube with the Rhine was Charlemagne. So that he could deploy his armies against the barbarians easier, he ordered, in 792, construction to begin on the Fossa Carolina to connect the two river systems. The level of technology was, however, too low at the time to permit the project to be completed.

Queen Mary, wife of Béla IV, who ruled from 1235 to 1270 had, according to some documents, a new straight bed excavated for the Danube between Bratislava (Pozsony) and Gönyü to protect her Moson estates from the floods on the river.

The people of Hungary have often been harassed by the errant rivers over the centuries. The lowlands in the Hungarian Plains were permanently inundated, or flooded each year as late as the middle of the past century.

Conditions conducive to the development of modern industries, transport and urbanization, and to raising the level of agricultural production were created by the ambitious project of river regulation, flood control and land drainage completed largely in the second half of the past century to the plans of Paul Vásárhelyi.

The organizing skills of Count Stephen Széchenyi (1791—1860), a prominent politician of the Hungarian reform era, the builder of the Budapest Chain Bridge named after him, and the founder of the Hungarian Academy of Sciences, were the driving force behind this vast reclamation project, referred to as the second conquest of the country. He was also the most ardent advocate and, subsequently as government commissioner, the manager, of the efforts at improving the conditions of navigation over the Lower Danube.

Today we appreciate the beauty of the Hungarian river landscapes as they were created and shaped by our predecessors. Most of the landscapes inspiring leisure, recreation and aesthetic pleasure, invoking the illusion of Nature undisturbed over the centuries have been shaped by deliberate and consistent human interference.

At the time of their conception these plans were subject to violent criticism. Paul Vásárhelyi, whose name is still being mentioned among the most outstanding representatives of the profession in Europe, fell victim to one of the debates questioning the soundness of his ideas. On leaving the meeting he suffered a heart attack and died. Evidently, we are fully aware of the adverse consequences which such projects entailed. Thus large parts of the flood plain forests have been lost, in some areas the probability of draught has increased. However, these adverse impacts are minimal in comparison with the benefits. The addition of two million hectares to the arable lands—representing over 30 per cent of the agricultural area—and the fact that formerly water-logged areas sustain almost one-half of the population and contain round 60 per cent of the national property, offset by far all the adcerse consequences.

Recent Advances

Economic growth in the twentieth century has necessitated an as complete and complex development of the Danube as possible. Multi-purpose dams generating hydropower, improving navigation, water supply, riparian development and flood safety have been built and additional ones are contemplated.

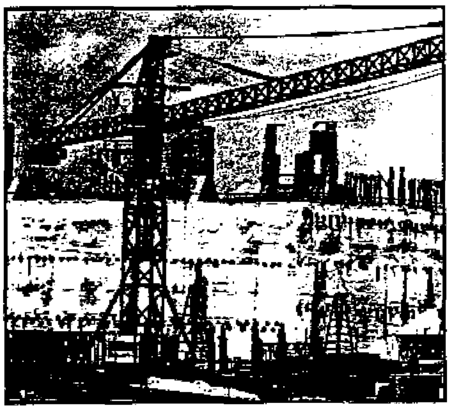
The first dam, the Kachlet Dam, inaugurated in 1927, was followed by 29 similar projects up to 1987. Work is at the present under way on three dams—besides the Gabčikovo (Bős)—Nagymaros project—the professionals having located a total of 47 potential sites for harnessing this continuously renewing source of power.

One of the ambitious projects changing the aspect of the river, the Gabčikovo (Bős)—Nagymaros project, is a means of developing long-neglected resources and a model example of creative co-operation between interdependent nations sharing the same fate.

Once completed, the project will upgrade the landscape, shape and enrich the lives of the people, improve the safety of property and production.

Emerging from the Vienna Basin through the Dévény Gate, the Danube enters the plains of the Kisalföld Region. The velocity of flow is attenuated, much of the sediment is deposited and the river meanders in an erratically shifting bed over the debris cone. The interwoven network of river branches accompanying the stream over a length of 30 kilometres between the Csallóköz Danube on the northern and the Moson Danube on the southern side evolved in this way. The first, basic stage of river regulation and flood control development, aimed at reducing the losses caused by the river changing her bed continually over the Kisalföld talus cone and at improving navigation, was realized between 1759 and 1914. The main channel, which has been in use ever since, was created by regulation, started in 1831 and completed in the last years of the past century. This, however, could only be maintained by dredging gravel continuously from the channel at the rate of 7 million cubic metres per year.

A number of benefits accrued to the region from the vast project, which has alleviated but not eliminated the difficulties. Floods through breaches in the protected and reinforced levees have devastated large parts of the Hungarian Szigetköz area in 1954, then of the Slovakian Žitný Ostrov (Csallóköz) in 1965. To appreciate the proportions of the disaster, it should be noted that in 1954 one-half of the Szigetköz area was inundated and the water rose to the second-floor windows in the Bács district of Győr. The area flooded in 1965 was twice as large in the Žitný Ostrov area.



The rock ledge at Dömös is still a nightmare to the navigators of the Danube. Moreover, about forty fords and gravel bars over the Rajka—Gönyű stretch present obstacles to navigation as soon as the water level in the river drops below the mean stage. For this reason, navigation over the greater part of the year is possible during the daytime hours and in a single direction only with barges carrying reduced cargo. Even so, grounded barges awaiting cargo transfer to a rescue vessel are a common sight.

The Gabčikovo—Nagymaros Dam Project is intended to serve several purposes:

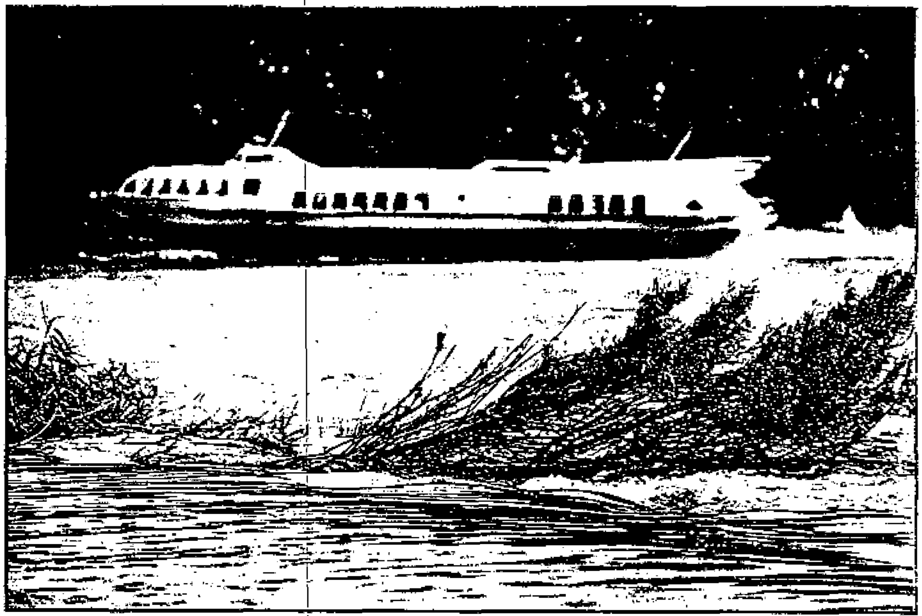
1. Generation of 3.6 thousand million kWh of electric energy in a normal year by harnessing the hydroelectric potential of the Danube section between Bratislava and Nagymaros. Moreover, 40 per cent of the output obtained by developing the non-polluting "white fuel" will be peak power produced for five hours daily. To generate the Hungarian share of this power in other power stations, the calorific value of 650—700 thousand tonnes of oil, or 2 million tonnes of brown coal, or 11 tonnes of uranium would needed.

2. Creation of an international waterway with parameters that comply—even over the worst section—with the recommendations of the eight-nation Danube Commission and which will meet the requirements even after the commissioning of the Danube—Main—Rhine Canal. Over the backwater reaches behind the dams the obstacles to navigation, such as narrows and sand bars will be drowned, navigation in both directions, even at night, with barges loaded to full capacity will become possible. The net time available to navigation will thus be extended by 40 per cent, the carrying capacity of the fleet will increase by 20 per cent while the fuel demand will be cut to one-half of the present. Tremendous advantages result thus from the multiple benefits of water transport, the power demand of which is lower by 30—50 per cent than that of other means of transport. The amount of gasoline or Diesel oil combustion products released into the atmosphere is accordingly smaller. The cost of vessels per ton of goods transported is also less by 60—70 per cent than of road, or rail vehicles.

3. The safety of national property in the region will be raised to a much higher level. The water masses impounded in the reservoir and in the river bed will be confined between embankments and levees capable of withstanding even the highest

loads. Moreover, it will become possible to split especially high floods to the existing Danube bed and the power canal presently under construction.

4. The ancillary projects realized by the concerted use of state and local resources will provide new impetus to development in the area. Piped water supply will be provided to a number of villages. The sewer network will be expanded, roads will be upgraded, opportunities will be created for recreation and water sports attracting a larger number of tourists. Consequently, the river dam project may be regarded as the most important infrastructure development project in the region.



HISTORICAL BACKGROUND

The ideas at developing the power potential of the flow in the Danube date back virtually to the early times of electrification in Hungary. A Swiss company obtained a lease for developing the Bratislava—Gönyü section of the river back in 1918. The Hungarian Soviet Republic of 1919 contemplated the production of 684 thousand kWh in a normal year according to the hydropower development programme and one-third of the capacity envisaged would have been installed in the river dams upstream of the Danube Bend.

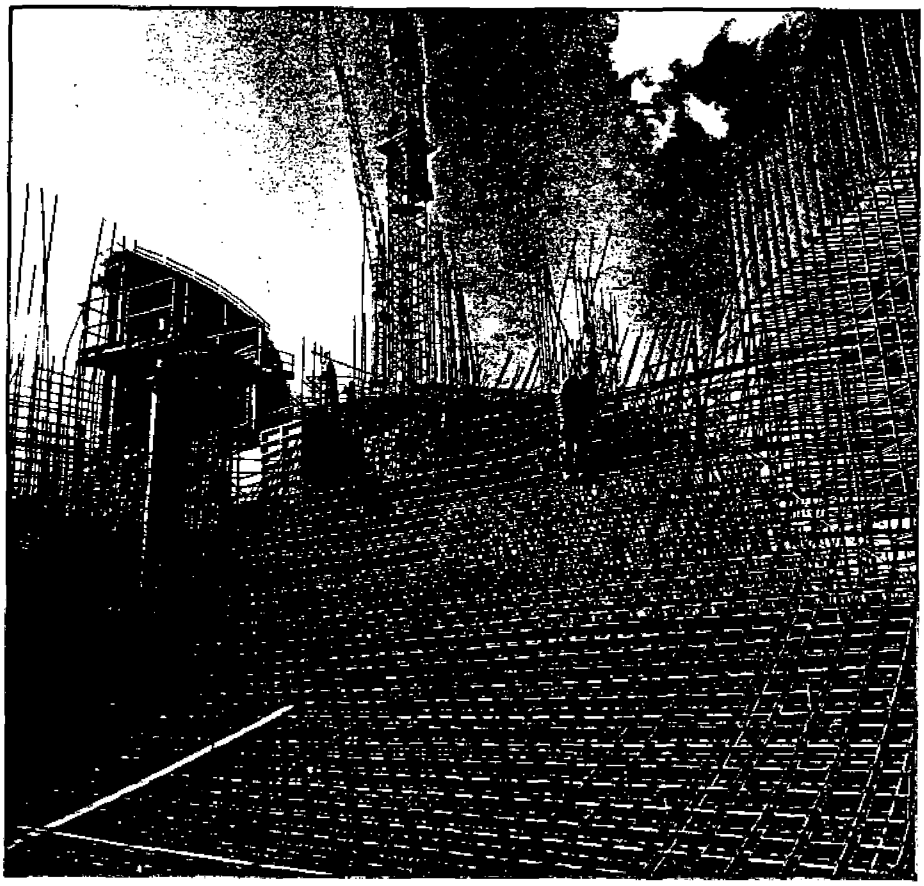
On the initiative of the Water Power Department the explorations for the dam contemplated in the Danube Bend were started in 1946. The geologic, flow pattern and geodetic surveys provided the basic data for the hydraulic model tests launched in 1952 at the Budapest University of Technology. Parallel thereto studies were started at VODOPROJEKT, Prague, Czechoslovakia, on the potential alternatives for developing the Danube stretch at Bratislava. The coordinated studies in Hungary and Czechoslovakia were started in 1951-52. The arrangement adopted eventually took shape over a period of two decades, during which over fifty (!) alternatives have been considered. The criteria have changed with the evolution of science and technology to meet the demands which grew in complexity over the years.

In order to obtain a complete picture about the natural conditions fundamental to project formulation, the full set of data on the region furnished by the disciplines of topography, geology, hydrogeology, hydrology (covering, for instance, stages, streamflows, ice and sediment transport and navigation), biology, soil mechanics, meteorology, seismology, etc., were taken into consideration. The basic survey data were used in broad hydraulic, seepage and engineering studies performed in the laboratories of several research institutes, universities and industries.

The technical and economic criteria were established by exploring the demands and possibilities of regional and communal development, power generation, navigation, environmental protection and nature conservation, water management (including flood control, land drainage, conservation of the quality of both surface- and groundwaters, regional water supply, etc.), coordinating these individually and comprehensively.

The international status of the Danube, the recommendations of the Danube Commission together with the fact that the Danube forms over a long part of the stretch the boundary between Hungary and Czechoslovakia provided a particular background to all these activities. It was a requirement always borne in mind that the dams on this stretch of the Danube should be adjusted to the dams situated upstream and downstream: the southernmost dam in Austria and the dams contemplated at Adony and Fajsz (Hungary) and the northernmost dam in Yugoslavia, so that they should form eventually an uninterrupted cascade.

A similar criterion observed consistently from the very beginning of the engineering studies was the protection of the natural en-



Mounting reinforcement at Dunakiliti

vironment. In analysing, and deciding on, the various alternatives during the sixties and the seventies, the professionals always adopted more stringent standards than those of the day. The need thereof was emphasized also in the agreement signed by Hungary and Czechoslovakia in 1977, and codified as a law-decree in 1978.

The studies concerned with the technical, economic, ecological, social, legal, political and aesthetic aspects of the project would fill a library. These have been discussed repeatedly, in detail and in their complexity by the competent political, public and scientific bodies and organizations. The number of plans, studies, analyses and other documents dealing also with environmental protection is near one hundred.

The diverse questions examined included also the possibility of *shifting the dam farther westward* on Hungarian territory, i.e., upstream of the proposed site at Nagymaros. Alternative sites at the villages of Pilismarót and Szob were also studied, but were later abandoned for several reasons. The cost of the alternative at Pilismarót would have been higher by several thousand million forints at a lower power output, thus at higher unit costs of construction. The alternative at Szob proved unfeasible for engineering considerations and would have made the safe passage of flood flows and ice runs questionable. The rock ledge at Dömös would have remained an obstacle to navigation in both alternatives.

Repeated studies and more recent analyses taking all aspects into account have thus confirmed the correctness of the original proposal, i.e., that the eastern end of the rock bed upstream of Nagymaros and Visegrád is the optimal site for the downstream dam. The results of both engineering and economic studies have demonstrated the superiority of this site, where the structures can be adjusted aesthetically into the landscape.

PROJECT DESCRIPTION

The four main components of the Gabčikovo—Nagymaros Dam Project are situated on Hungarian and Czechoslovakian territory and comprise:

1. The Dunakiliti Weir and the impoundment reservoir created thereby.

Construction under way on the Gabčikovo power station

Interception canal in the Szigetköz area

2. The power canal (headrace and tailrace) between Dunakiliti and Palkovičovo (Szap).
3. The power station at Gabčikovo (Bős).
4. The Nagymaros Dam.

1. The Dunakiliti Weir is one of the largest structures of the project on Hungarian territory. The steel gates between reinforced concrete piers founded securely, with a wide margin of safety, arrest the runoff arriving from the Alps and create an artificial lake with a 60 square kilometres large surface area—one-tenth of Lake Balaton.

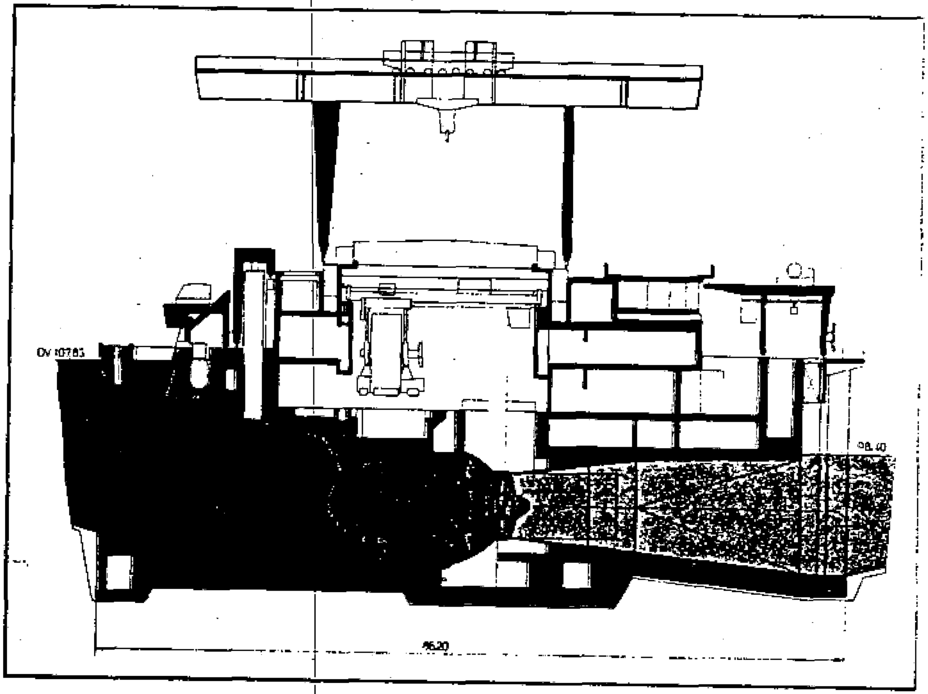
The weir impounds the flood plain between Dunakiliti and Bratislava confined already by flood levees. With a volume of up to 200 million cubic metres, it will have a capacity large enough to receive and store two days flow of the Danube, thus to supply — even at times of low flow — the discharge needed to generate power in the hours of peak demand.

The Dunakiliti Weir will control the water level in the reservoir, just as the flow diverted into the power canal and released into the present Danube bed and the branches in the Szigetköz area. The auxiliary shiplock incorporated into the weir will make the original Danube bed accessible to vessels.

2. The releases from the Dunakiliti Reservoir will be split among the artificial power canal and the original bed, of which the former will receive the major share and function also as the main navigation channel.

The 17 kilometres long and 300 to 700 metres wide canal, forming the common property of the two countries, will convey the flow to the power station and navigation locks at Gabčikovo. The height of the embankments will be 18 metres here; the water level in the canal will remain over the entire length [illegible] above the terrain in order to create as high a head as possible for power generation.

The 8 kilometres long tailrace downstream of the power station will discharge at Palkovičovo into the original river bed.



Cross section through the Nagymaros power station

A flow varying from 50 to 200 cubic metres per second will be released into the present main channel. This flow, though substantially lower than the natural streamflow, will still be sufficiently large to serve the various interests of the population and economy in the area. Navigation for recreation purposes with shallow-draft craft will remain possible. Together with the raised water level in the lateral branches and the water compensating network in the Szigetköz area, it will maintain a blanced groundwater budget and meet the requirements of nature conservation and irrigation alike.

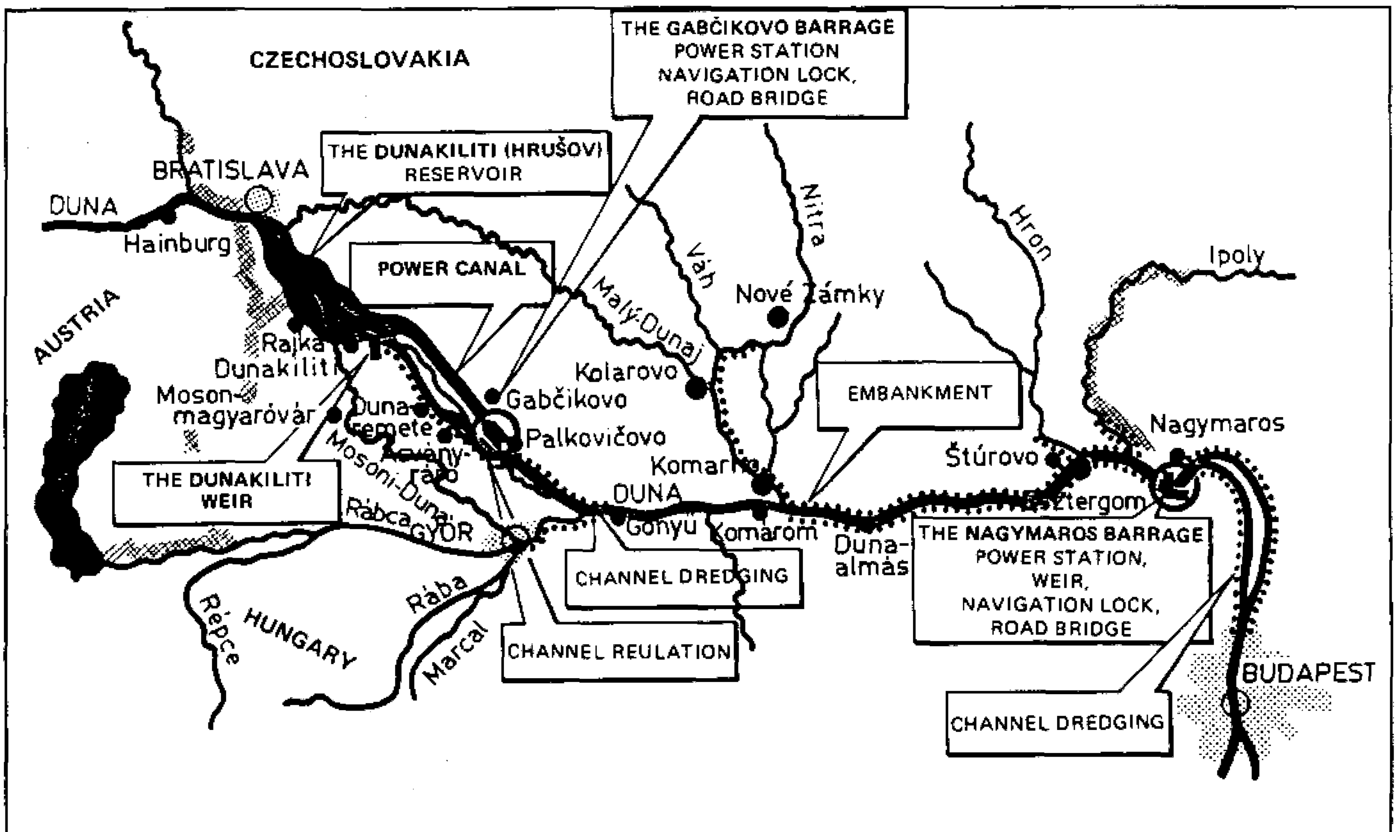
To illustrate the proportions involved, it should be sufficient to note that the water demands at Bratislava and Budapest are up to 8 and 15 cubic metres per second, respectively. The second largest stream of Hungary, River Tisza, carries a flow of 60 to [illegible] cubic metres per second at stages lower than the mean value.

The original bed between Dunakiliti and Palkovičovo will participate in conveying flood discharges and ice runs surpassing the capacity of the power canal.

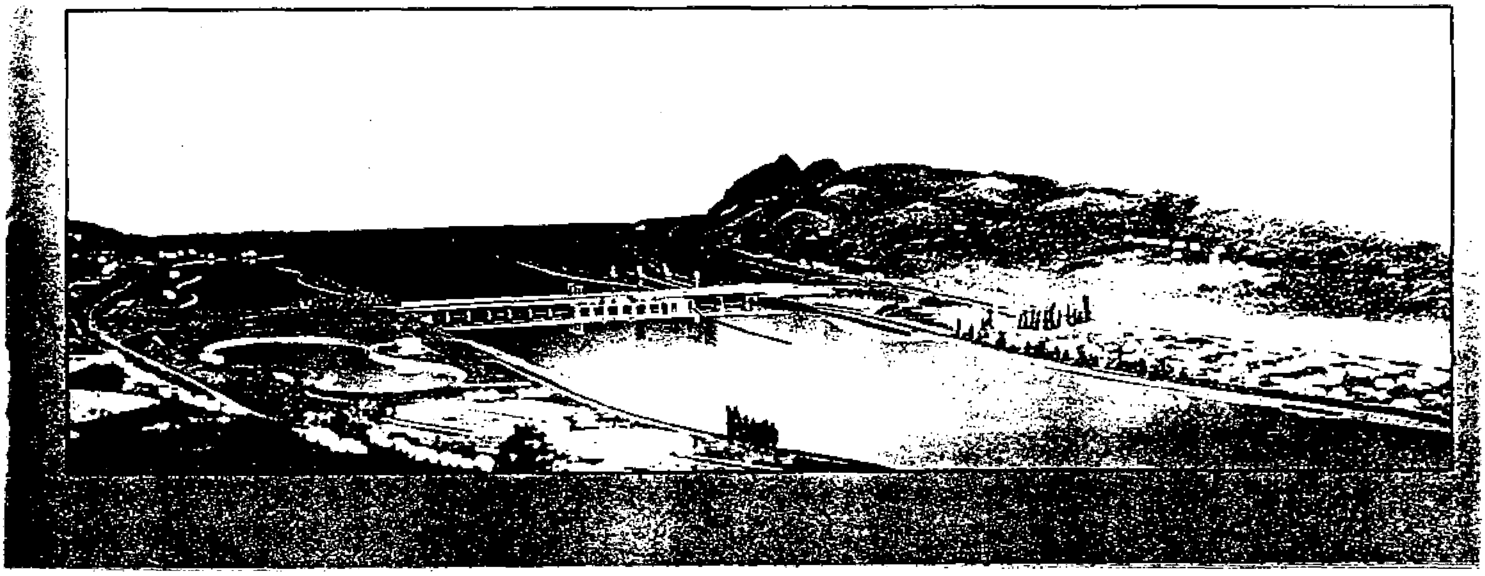
Even after completion of the project the "old" Danube will thus remain a live stream and the boundary between the Hungarian Peoples' Republic and the Socialist Republic of Czechoslovakia.

3. The power plant at Gabčikovo will comprise a powerstation of 720 Megawatts installed capacity and the set of shiplocks designed to allow the safe passage of river and seagoing vessels. The eight turbines of 90Megawatt capacity each will be operated in the morning and afternoon periods with the highest power demand, the peak periods.

This mode of operation will exploit the following advantage of hydroelectric stations: they can be connected to the network within a few minutes, whereas the other types of



General layout of the upper Danube project



power station—including nuclear plants—take a considerably longer time to increase power generation to the desired level.

4. The terminal downstream structure of the Gabčikovo—Nagymaros project serving the complex development of the Hungarian upstream Danube stretch is the Nagymaros Dam. Consisting of the power station, the weir and the twin navigation locks, it is intended to perform several functions:

- To even out the surge waves due to the intermittent (peak load) operation of the Gabčikovo power station.
- To create over the backwater reach extending to the tailwater at Gabčikovo the depth required for the unobstructed use of the waterway in periods when the released flow is insufficient.
- To feed continuously 160 Megawatts from the six turbines into the power grid.
- To help the vessels in negotiating the dam.
- As a road bridge to create a permanent link between the two communities: Visegrád and Nagymaros in the beautiful landscape of the Danube Bend.

The head created here will be substantially lower then that at Dunakiliti, exceeding by no more than 0.8 metres the highest flood level on record. The backwater curve will join the meanwater surface profile at Gönyü already. The embankments along the river will be reinforced sufficiently to withstand safely even the extraordinary flood waves or any earthquake load. Besides, in this region the probability of a major earthquake is very low, virtually zero.

The project will occupy 10 thousand hectares on Czechoslovakian and 4 thousand hectares on Hungarian territory, thus considerably less than contemplated originally. The area to be sacrificed was originally estimated at 16 thousand hectares for the Gabčikovo power station alone, but the engineers later succeeded in constructing it on only four thousand hectares.

CREATIVE CO-OPERATION

The Gabčikovo—Nagymaros Dam Project will be realized jointly by the Hungarian Peoples' Republic and the Czechoslovakian Socialist Republic as an integrated and interconnected hydraulic and power generation system, forming the common property of the two states.

Construction of the project started in 1978 and was scheduled for completion to 1986 and 1989 in the Hungarian—Czechoslovakian intergovernmental agreeement of 1977. From the outset the Czechoslovak side deployed considerable staff and equipment, whereas in the late seventies the diminishing resources available for developing its economy compelled Hungary to gradually restrict capital investment, abandon some major projects and establish priorities for those retained. Some construction jobs were therefore carried out by Czechoslovakian contractors, to be compensated for at a later date by the Hungarian side.

In the new situation several alternative solutions were considered. The consequences of abandoning the Hungarian section of the project altogether were weighed and the suspension of work for ten years was proposed. Eventually, taking into account the sums invested so far by the Czechoslovakian side as well as the Hungarian interests, the heads of the two governments agreed in 1983, following a Hungarian initiative, on delaying construction by four years and rescheduling the project accordingly.

The generating units of the project will thus be commissioned between 1990 and 1993. The first turbine of the Gabčikovo power station will deliver current around June 1990, followed by the other seven sets at three-month intervals.

Under the revised schedule, the first unit in the Nagymaros Dam will start generating in 1992. The remaining five units will be connected to the grid at the rate of one in every second month. The power station will thus attain full capacity in 1993. Completion of construction is scheduled for 1994.

Following the agreement on the revised schedule, project implementation received a new impetus and construction continued at an accelerated rate after 1985 in Hungary, too. The volume of construction performed in 1986 surpassed 3 thousand million Forints in value. A 9 kilometres long section of the Dunakiliti reservoir embankment was completed and the specially sealed construction pit of the weir was excavated 3 months ahead of schedule with Austrian co-operation.

The progress made ever since has been considered satisfactory and appears to guarantee that the ambitious project will be completed on schedule. The costs and benefits will be shared equally by the two countries.

According to the provisions of the bilateral agreement signed in 1977 and renewed in 1983, the two sides shall share equally the costs of the structures of common interest. They shall have equal proprietary rights to the main structures of the project and be entitled to one half each of the power generated by the hydroelectric stations. The main structures shall be operated jointly, regardless of the territory on which they are situated.

The Hungarian share of the project costs, estimated at the 1987 price level, amounts to 54 thousand million Forints. The major part thereof is devoted to power, the rest to river regulation and other purposes. Cost-benefit analyses have shown the cost allocated to power to be comparable with the construction and operating costs of thermal stations of similar capacity. Additional benefits include the absence of fuel costs and of emissions detrimental to the environment, moreover a service life three to four times that of thermal power stations.

The main structures (power stations, weirs, power canal, etc.) will form common property. Parallel thereto, other structures of common interest (such as bank revetments, pumping stations, etc.) will also be built and will form the property and responsibility of the state on whose territory they are located.

In addition to the structures serving common purposes, so-called national developments are also associated with the project. These serve the advancement of communities and the infrastructure, and are made possible, or more advantageous by the realization of the dam project. Similar developments will be implemented over the years following the commissioning of the dams, too, at rates depending on the actual financial situation. However, the majority thereof will be funded from other resources, although they will benefit from the outputs and improvements emanating from the principal project.

The complex development of the Hungarian—Czechoslovak Danube stretch, founded on bilateral agreements, has become a model example also of creative co-operation between two countries with different political systems. Upon the successful conclusion of preparatory negotiations in May 1986, mutually advantageous contracts were signed by Hungary and Austria in Vienna, under which Austrian contractors will participate in the construction and financing of the Hungarian components of the dam project in return for power deliveries at a later date.

The main contractor for the complete Nagymaros Dam is the Österreichische Donaukraftwerke AG—DOKW—Vienna, Austria. The company, which has already built and currently operates nine dams on the Austrian stretch of the Danube meets the requirements in all respects. Its professional staff and equipment are available to carry out the large job successfully. This is demonstrated among others also by the fact that the contractor has agreed to complete the dam and to commission the first turbine in only 33 months. The contractor has also agreed to deliver the generating units and other mechanical equipment of the dam to the site in preassembled, large units in order to cause the least possible inconvenience to the communities of Visegrád and Nagymaros.

The costs of construction and the interest on related credits will be advanced by the Österreichische Elektrizitätswirtschaft AG, with financial backing by a group of Austrian banks. Payment will be made in electric power, to be delivered between 1996 and 2015. Under this financial arrangement, the Nagymaros Dam will not appear as a separate item in the Hungarian budget. The Austrian side will in turn have access to 1,200 million kilowatt-hours of electric power yearly, which will obviate for it the need of building and operating a coal-fired power block of 200 Megawatts capacity. The job opportunities offered to the Austrian hydro-contractors and manufacturers of generating equipment, which improves the situation on the Austrian labour market, will be fringe benefits.

This, however, is only one among the aspects of the related international division of labour. The Hungarian project managers sought also other fields to locate partners with the best professional skills and the most reliable references for carrying out jobs which require special equipment and expertise. An Austrian contractor has thus been invited to excavate the construction pit for the Dunakiliti Weir and place the special sealing trough thereof. Other jobs have been awarded to Yugoslav companies after competitive bidding.

ENVIRONMENTAL IMPACT STUDIES

The funnel-shaped area extending from Bratislava to Nagymaros—Visegrád is to be influenced by the dam project on Hungarian territory. It sustains a population of about 500 thousand. The communities include an ancient royal residence, a present school town, frequented touristic attractions and important industrial centres.

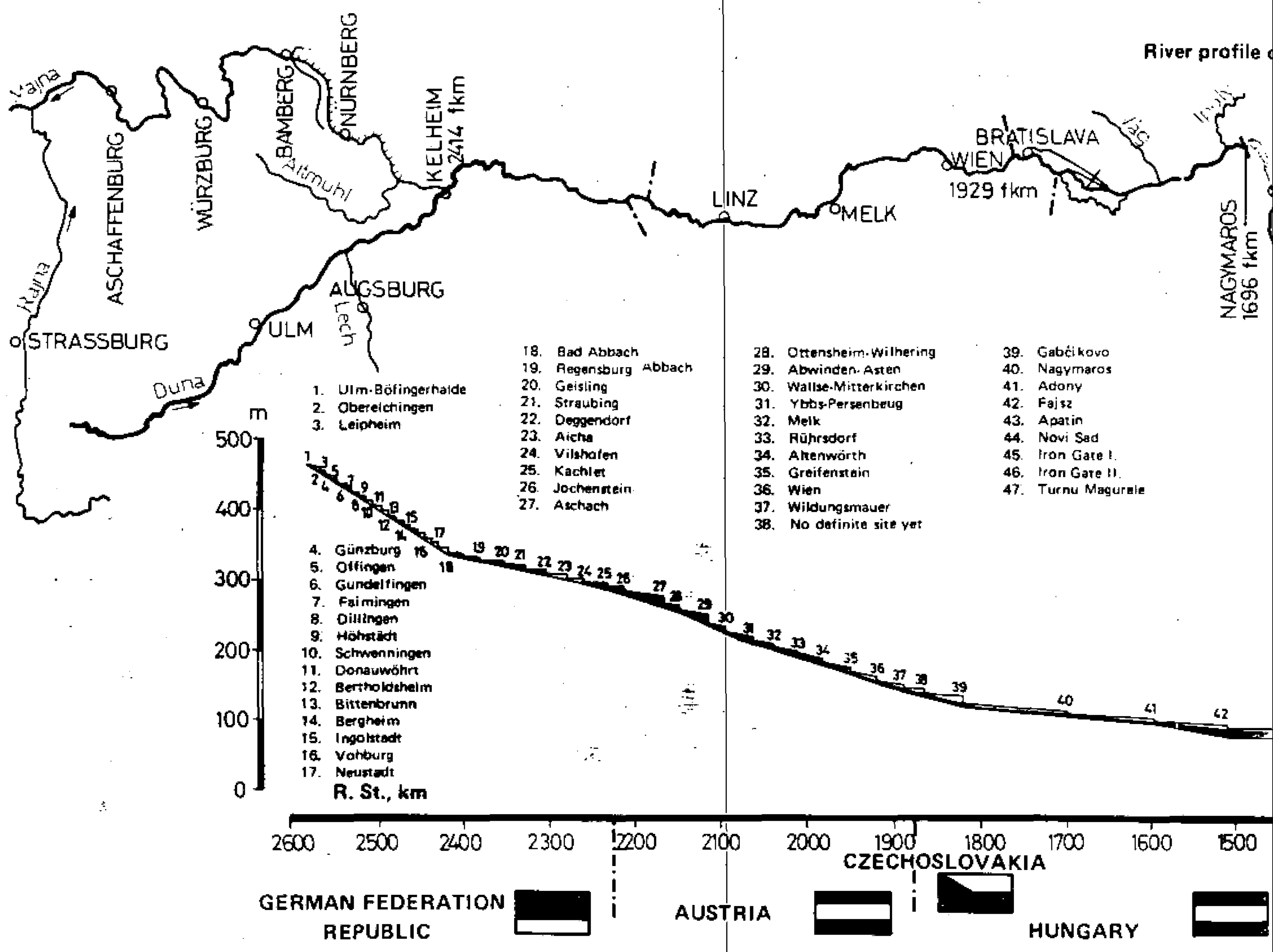
Fertile lands, rich pastures, modern industrialized farming operations and profitable private farms set into a landscape, which has retained her natural values regardless of the changes over the decades.

The gravel layers in the several hundred metres thick alluvial fan under the Szigetköz area hold an estimated ten cubic kilometres of potable groundwater. The forests in the region are claimed to produce the richest timber yield in Hungary.

Any irresponsible human interference jeopardizing, damaging or destroying these values would constitute not simply a mistake, a blunder, but an irreparable crime against future generations.

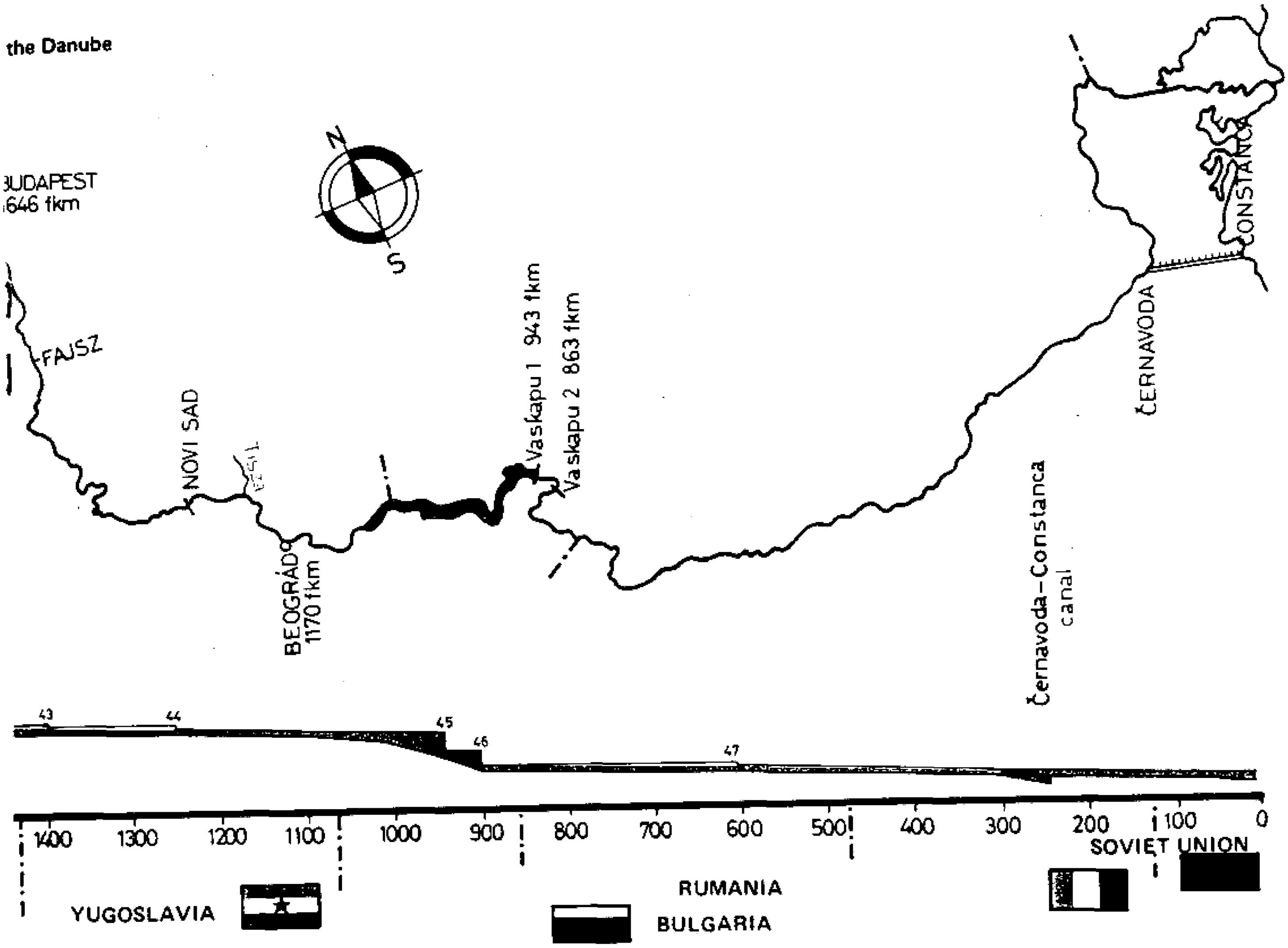
This consideration, which prompted extraordinary care and circumspection in all stages of preparatory work, received special

Stabilized regime in the Danube branches



emphasis. In the first half of the eighties, when construction proceeded at a temporarily reduced rate or was halted completely in Hungary. Following a proposal by the National Council of Environmental Protection and Nature Conservation, the consulting body to the government, the competent authorities ordered a complex environmental impact study to be compiled. Representatives of the disciplines and professions in this subject were called upon to examine the technological and ecological aspects of the project as an integrated system, taking into account all potential interactions, together with the risk factors, to synthetize in this way the various environmental, natural and social impacts of implementation. An inter-service committee was established to guide and monitor the work—pioneering even by international standards—of the scientific institutions and a large number of independent experts and scientists. Representatives of the Hungarian Academy of Sciences, the National Committee of Research and Development, the Ministries of Building and Urban Development, Industry, Transport, Food and Agriculture, the National Environmental Protection and Nature Conservation Authority, the National Planning Office, the National Water Authority and the National Development Bank were all invited to this committee. The critical review of earlier conclusions (just as of the more recent studies) had the aim of providing answers to the following cardinal questions:

the Danube



- Does the project comply with the current requirements of environmental protection?
- Do the various components of the project minimize effectively or eliminate completely the undesirable impacts?
- Is a modification of the plans and designs necessary or warranted?
- In what ways could the various sectors make even better use of the opportunities offered by the project?

In exploring the complex interactions between the project and the environmental elements, special attention was focussed on the problems associated with water quality, water supply in the region and protection of the groundwater resources under the Szigetköz plains. The anticipated consequences of peak-load operation, groundwater control and the actual operation of the groundwater recharging-interception system, the potential ways of maintaining and improving agriculture and forestry, the biological and pedological aspects of the flood-plain forests, the possibilities of regional development were studied together with the relevant economic implications.

The complex environmental impact statement summarizing the results of some fifty former and 33 recent studies arrived at the following conclusions:

The implementation of the Gabcikovo–Nagymaros Dam Project will not cause any irreparable damage to the environment.

(In other words: appropriate design and careful operation will eliminate undesirable consequences.)

At the same time, improvements were suggested to some of the original solutions in design and construction technology.

Prompted by these results, the government again reviewed the project. In compliance with the recommendations of the impact statement, decision was taken to adopt engineering solutions that protect and improve the environment, further, to operate the project by observing strictly the requirements of optimal ecological conditions.

The government commissioned further efforts for a more effective environmental protection. It also decided to continue research during construction and beyond the completion of the project.

The government also decided the installation of a complete regional observation network—referred to as the monitoring network—designed to provide accurate information on the condition of, and changes in, the environment. This network will be commissioned three years ahead of the project so as to establish a reliable basis of reference, against which any later change can be measured and assessed. At the same time, continued cooperation with the Slovakian Academy of Sciences was decided.

THE SCIENTISTS' VIEW

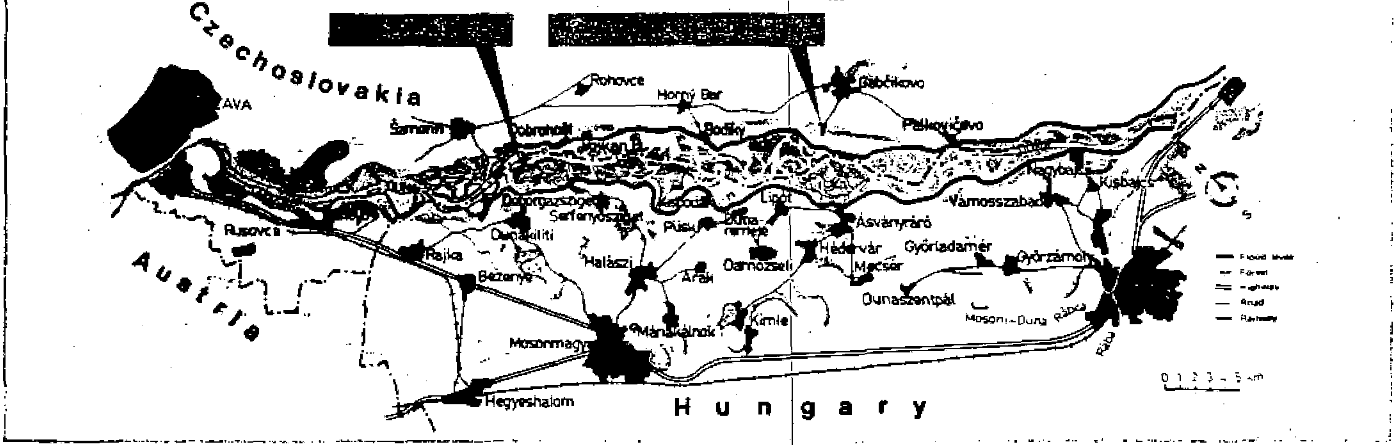
Besides the official statements, a number of prominent Hungarian scientists have voiced reassuring opinion on questions related to the dam project.

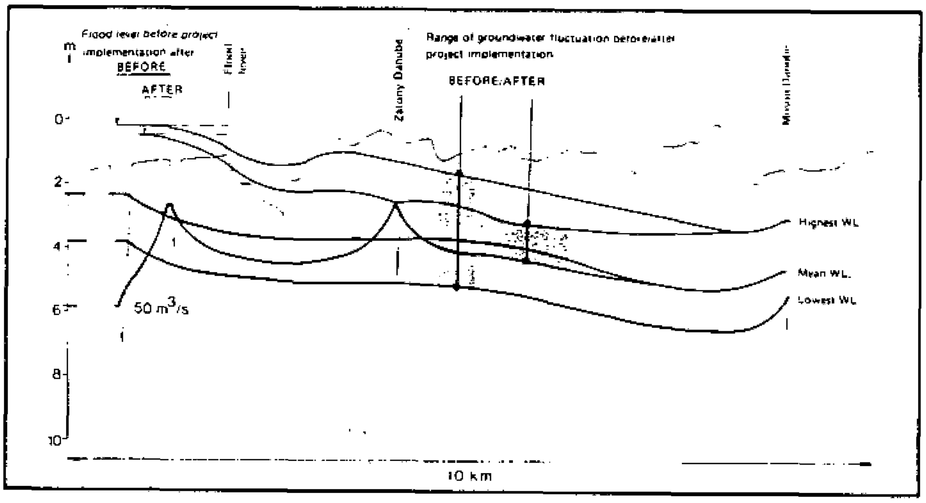
Mr. Bruno F. Straub, Vice-President of the Hungarian Academy of Sciences, past chairman of the National Council of Environmental Protection and Nature Conservation, which initiated the environmental impact statement, and presently acting chairman of the Communal Development and Environmental Protection Committee of Parliament, established in 1985, declared in an interview:

". . . I consider the problem from a scientific aspect, drawing on fifty years of experience in research. I have detected neither in the report, nor in the comments by third-party critics a single truly scientific objection to convince me about the inadvisability of the project.

Evidently, the construction of any river dam entails changes in the environment. Any interference is necessarily associated with changes, both adverse and beneficial. I believe the benefits from such a project should outweigh the detriments."

New structures in the Dunakiliti and Gabčikovo areas





Mr. György Kovács, Professor, Corresponding Member of the Hungarian Academy of Sciences, presently expert at the UN International Institute of Applied Systems Analysis, Laxenburg, Austria, wrote in a paper: "No more appropriate appraisal of the Gabčikovo—Nagymaros Dam Project and no more pertinent summary of the debates related thereto can be found than the conclusions arrived at by the professional committees convened to study and consider the subject between 1982 and 1984. These have detected no major hazard to the environment which had not been taken into consideration in devising the protective and control measures and which would compel us to abandon the construction work started or to change the designs radically. It should be noted in addition that neither a revision of the cost-benefit analysis would warrant any major modification of the plans.

Continued research work and scientific investigations, refinements to the environmental impact statement, modifications perfecting particular features in the engineering designs and the monitoring network registering the actual changes in the environment serve the purpose of better understanding and, as far as possible, controlling the dynamics of the new environmental situation developing as a consequence of the important interferences concomitant to river canalization. This understanding is expected to permit remedial measures to be taken in time, in the early stages of any undesirable process detected, but also to make the fullest possible use of any advantages offered by the changing situation.

The present generation of Hungarian hydraulic engineers need not be ashamed before the memory of Paul Vásárhelyi and the many other prominent predecessors when it submits after careful deliberations to the general public a solution to the problems of modern life."

Mr. Imre Petrasovits, Doctor of Agricultural Sciences, Professor at the Gödöllő University of Agriculture, wrote the following comments on the impacts of the project on the agricultural environment:

The anticipated natural and social impacts and significance of complex development along the Hungarian Danube stretch is reminiscent of the vast river regulation, reclamation, flood control and land drainage projects started and largely completed in the past century. Reclamation, flood control and drainage in the Great Plains in the nineteenth century created the opportunities for the capitalist development of agriculture in Hungary, but also for its present successes.

". . . no detriment has been identified to agriculture, or to the environment which would occur as a consequence of project implementation. In the upstream part of the Szigetköz area, the arable lands will increase in size after the commissioning of the Dunakiliti Weir, mainly because of the interception of the present underseepage waters. No reduction of the agriculturally productive area is anticipated in the Middle Szigetköz. The elimination of rising groundwaters by the control system will even permit a changeover to more intensive farming methods on round 1000 hectares. In the downstream Szigetköz area the water table is expected to rise, but the harmful consequences thereof can be avoided by operating properly the interception-drainage network envisaged.

In the Komárom, Esztergom and Pilismarót area, further, in the valley of the Ipoly river an estimated 2000 hectares were thus far excluded from any more intensive agricultural production owing to the annually recurring floods. The control measures will provide complete safety to production in the future. The higher level of flood safety and the resulting increase in the value of agricultural lands may be listed among the benefits in the Szigetköz area as well.

Forestry experts concur in the opinion that the risk of any change in the stands and productivity of the flood-plain forests in the Szigetköz area is virtually nil, except for a narrow riparian belt. Here new species may have to be planted, which adjust better to the new moisture conditions.

The hydrobiological conditions of fish life are expected to improve along the backwater reach above the Nagymaros Dam. Over the Szigetköz stretch, on the other hand, considerable changes in the species composition and in the aquatic ecology should be anticipated. Intensive research is under way to predict the quality and extent of these changes.

CHANGES IN WATER MANAGEMENT

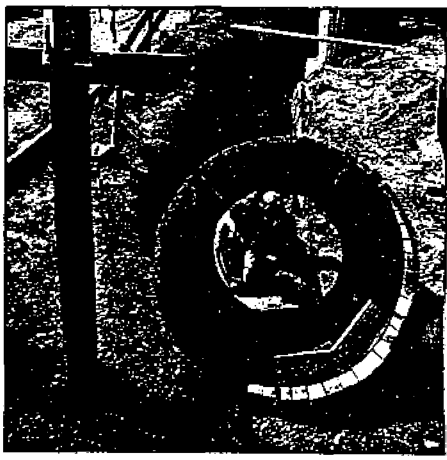
Parallel to the implementation of the Gabčikovo—Nagymaros Dam Project, the waters in the Szigetköz area will be regulated into an integrated system and a new network of groundwater control (recharging and intercepting) canals will be constructed. The 6 to 9 metres wide range of water table fluctuations caused by stage variations in the Danube will thus be eliminated. The water cycle in the area will be accelerated, water supply to the belt between the "Old" Danube and the Moson Danube will be improved and by computerized control the groundwater level will be raised and lowered as and when required by the interests of agriculture or the natural environment. As an interesting fringe benefit, stagnation frequently observable in the abandoned branches will be eliminated, the recharging-infiltration canals forming a network of live watersurface in the landscape.

In Hungary and Czechoslovakia alike, great efforts are devoted to reducing the volume of untreated wastewaters. The treatment plant relying on Japanese technology has already been commissioned for the oil refinery at Bratislava and construction work is under way on the municipal sewage treatment plant of 400 thousand cubic metres per day capacity. In the ecological programme adopted recently the construction of altogether 95 sewage treatment plant is envisaged. As a result, the sewage load in the Czechoslovak catchment of the Danube will reduce to one-tenth of the present value within the next ten years.

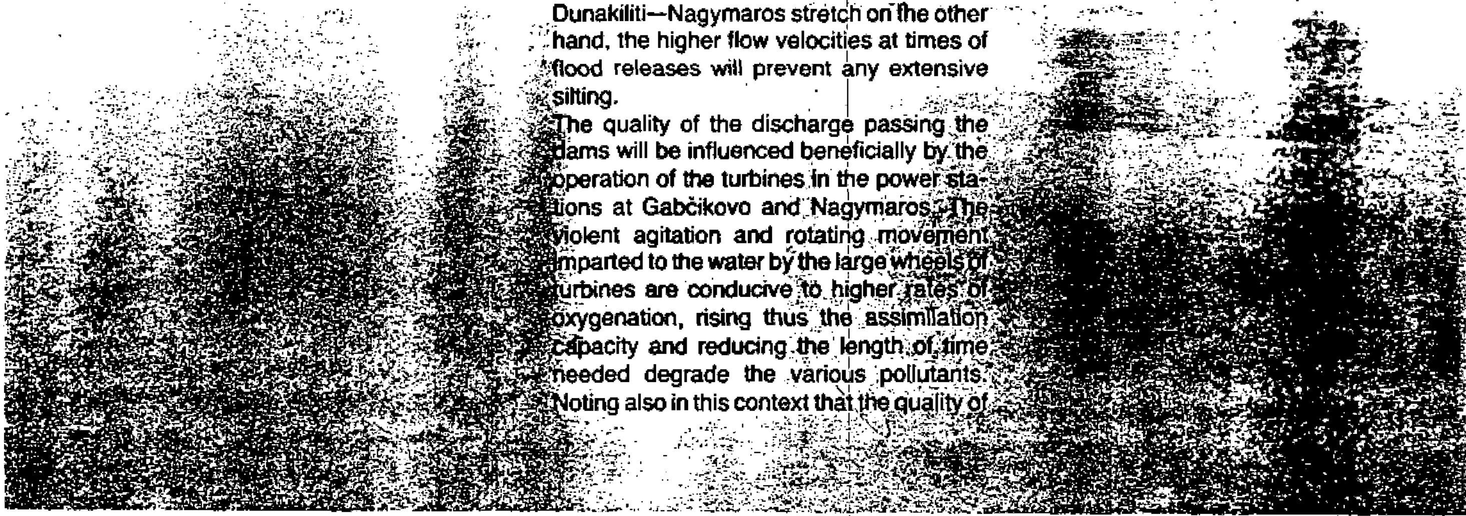
On Hungarian territory sewerage will be provided to 43 communities and industrial plants in the project area by 1995. Regional networks of water distribution and sewerage are envisaged at Visegrád and Nagymaros. Moreover, under a system combining state subsidies and local resources sewage and wastewater treatment will be provided at the major riparian towns, viz. Győr, Komárom, Esztergom, Tatabánya and Oroszlány. The sewer networks will be expanded and piped watersupply will be introduced in all villages in the Szigetköz area. Recent hydrogeological and hydraulic analyses have repeatedly confirmed that the dam project will cause higher recharge rates to the gravel aquifers under the Szigetköz area, adding not only more, but better water to this important source of supply.

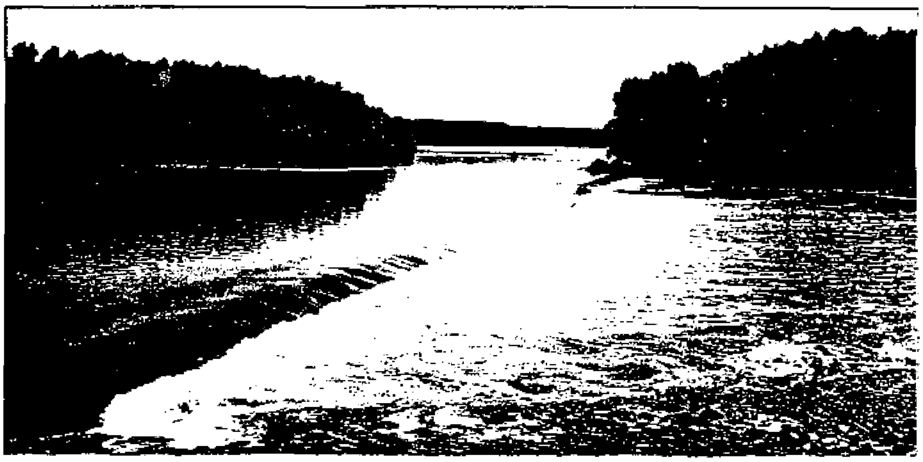
The sediment depositing over the backwater reach presents no pollution hazard. The water in the Dunakiliti reservoir will be exchanged in three to four day cycles, one of such cycles taking two years to complete in Lake Balaton. A fraction only of the suspended sediment is thus liable of settling out in the 60 million square metres large reservoir and of causing a potential annual silting rate of millimetre order. Over the Dunakiliti—Nagymaros stretch on the other hand, the higher flow velocities at times of flood releases will prevent any extensive silting.

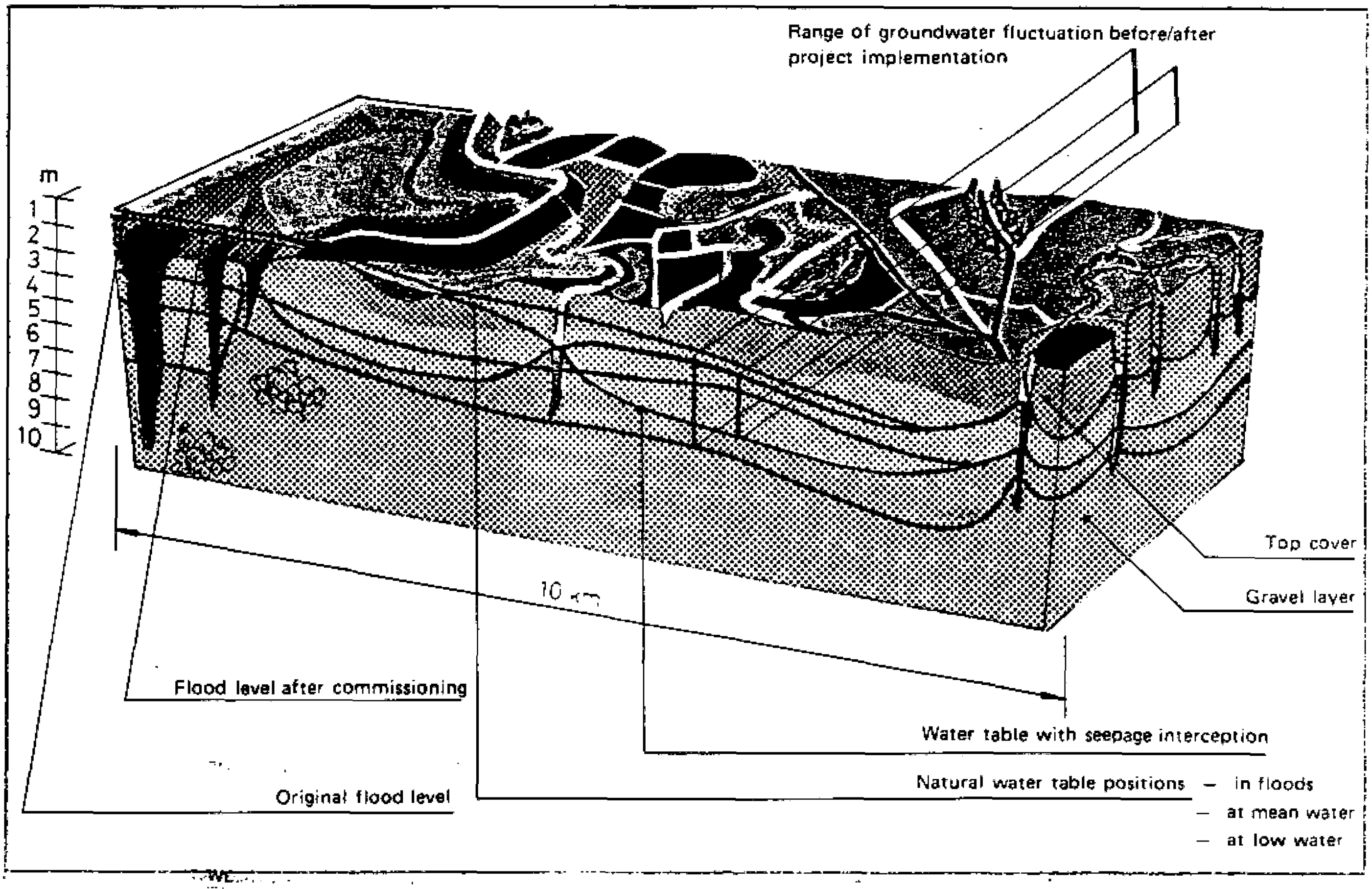
The quality of the discharge passing the dams will be influenced beneficially by the operation of the turbines in the power stations at Gabčikovo and Nagymaros. The violent agitation and rotating movement imparted to the water by the large wheels of turbines are conducive to higher rates of oxygenation, rising thus the assimilation capacity and reducing the length of time needed degrade the various pollutants. Noting also in this context that the quality of Danube water classified presently as of Category II (slightly polluted) has improved already in 1986 along the Szigetköz area and downstream of Gönyü alike, we feel justified in expecting favourable results from subsequent efforts.



Nor are the sources of supply downstream of Nagymaros endangered. The character of the river remains unchanged over this section of the Danube, the biological parameters of the water and the flow conditions following the present pattern. The recharge to, and the yield from, the bank-filtered wells sunk on Szentendre- and Csepel Islands, as well as the quality of the drinking water at Budapest are controlled by factors unrelated to the dam project.







Range of groundwater fluctuation before/after project implementation
m
1
2
3
4
5
6
7
8
9
10
10 km
Top cover
Gravel layer
Flood level after commissioning
Water table with seepage interception
Natural water table positions – in floods
– at mean water
– at low water
Original flood level

REGIONAL DEVELOPMENT PLANS

The Gabčikovo—Nagymaros Dam Project will change the face of a 150 kilometres long riparian strip on the Hungarian side between Rajka and Nagymaros. The range influenced is, however, a considerably wider one, so that the living conditions and welfare of hundreds of thousands of people are involved.

The benefits of the project and the fullest possible exploitation thereof have been explored in a comprehensive programme of regional development, the fundamental aim of which was to formulate a policy aimed at improving the situation of the people in the region.

The programme outlined by the concerted efforts of experts from the relevant disciplines and professions, perfected subsequently in a series of open, public debates has reviewed the possibilities of improving the infrastructure and summarized the actions required.

No Hungarian village or town will be inundated as a consequence of the project. Relative to the proportions of the project, the number of real estates expropriated—against equitable damages—will be negligibly small. Most of these houses are in areas

inundated more or less frequently and would be submerged by the backwater created. The basic principle observed in land clearing is and will remain to demolish houses only where absolutely essential.

The economy of the region will undergo no major changes on account of the dam project. The trades and professions indigenous to the region will thus have ample opportunities for flourishing and expanding. The projects of land clearing and regional development will be realized as national investment drawing on three sources for funding. For attaining certain objectives, state subsidies will be relied upon, whereas others will be realized with the financial resources of the local agencies of administration and the population. The ambitious programme was formulated expecting the attraction which the controlled waters, regulated banks and larger watersurfaces will exercise on those seeking recreation, tourism and water sports.

The Dunakiliti Reservoir offers ideal conditions for the organization of both domestic and international rowing and sailing events, while the willows and glades growing on the shores may become camping centres. The Danube branches at Koppánymonostor and Tát, further, the severed lakes at Pilismarót and Dömös—the latter in combination with the already popular thermal water bath at Lepence—may also prove attractive to many for touring, camping, rowing and sailing.

Parallel to the construction of the Dam Project, programmes will be implemented for developing the thermal water resources in the Szigetköz area. A sanatorium is contemplated in the western corner of the area, at Hédervár. Additional thermal baths can be built at Lipót, Mosonmagyaróvár and Győr. Recreation centres are contemplated in the vicinity of Győrújfalu and Győrzámoly. The expansion of village tourism is envisaged at Ásványráró, Dunasziget, Sokorópátka, further, along the Moson-Danube and Kimle, Dunaszeg and Dunaszentpál. A site for an international camping has been located at Likóc-puszta.

Considerable attention has been devoted to improving transport. A new international river port will be built at Győr. The southern motorway bypassing the town has also been included in the plans. The east—west road network in the area will be modernized and new roads will provide access to the growing recreation centres.

The need of expanding the network of shops, restaurants and other services of the catering trade parallel to the anticipated growth of tourism has also been recognized. The buildings erected to accommodate the work force on the project were thus designed to serve—in a form restored and reconditioned—as tourist or normal hotels after the completion of construction.

Special care has been devoted to preserving the aesthetical values and natural features, further, to developing the communities of the Danube Bend, which attracts many tourists already and is capable of accommodating 200 thousand visitors in summer. Anticipating a further expansion of the tourist trade, new excursion centres have been envisaged in the Visegrád—Nagymaros and Esztergom—Vaskapu areas. The existing small garden and shack lots, which deteriorate the landscape, will be changed into a more pleasing type of land use and work will be started on modernizing infrastructure.

A nationwide public competition has been announced, inviting architectural designs for the Nagymaros Dam and the ancillary structures, but only some of the proposals were considered acceptable by the evaluation committee. Contracts have thus been placed for new designs incorporating the best solutions submitted.

The architects were required to comply with stringent requirements. For acceptance, any design had to conserve the unique landscape of the Danube Bend and to avoid industrial structures.

The specifications for the dam comprising the weir, the powerhouse, the twin navigation locks and the road bridge on the crest linking Visegrád and Nagymaros required an unbroken trace, a horizontally articulated structure to fit in all respects harmonically into the landscape. The use of dark, or glaring colours was also declared undesirable. Lighting was to be solved by means of concealed fixtures with appropriate arrangements for floodlighting. Separate lanes were also required for vehicular and pedestrian traffic. The power generated had to be conveyed by underground cables out of the core of the region, viz. as far as the Szob plains on the left-hand bank and the Malom Creek at Dömös on the right-hand bank.

The best design submitted and adopted as a starting basis in preparing the final drawings proposes horizontal patterns to relieve the monotony of large concrete surfaces. Mixes of different shade and the use of vegetation on certain parts served to merge solid surfaces unobtrusively into the surroundings. A partly recessed solution has been adopted for the operation building and the other ancillary structures on the banks to make them less conspicuous.

Another public design competition preceded, and established the criteria for, the development plans and designs of the community center of Nagymaros. The team responsible for synthetizing the ideas presented in the award-winning designs received proposals of high professional standards concerning virtually all the criteria. The renewal of this community in a setting between the hills and the Danube will therefore preserve its particular atmosphere and make it more attractive.

PUBLIC INVOLVEMENT

Communication between the professionals preparing the decisions related to the Gabčikovo—Nagymaros Dam Project, on the one hand, and the people living and owning property in the area influenced by the development, on the other hand, has taken a wide variety of forms.

The public hearings at which the plans, their justification, objectives were presented and the potential benefits outlined started in the seventies and have continued to these days, growing in both attendance and depth of discussion.

The character of information flow always depended on the events and requirements of the particular period. At the first public hearings the professionals outlined the general aspects and features of the project. In the early eighties, in the months of uncertainty concerning the new deadlines and during the preparation of the environmental impact statement, the purpose of the debates was to review and screen impartially the various options and to confront diverging opinions. Then the debates intensified on the level of state agencies and scientific workshops. As demonstrated by the wealth of information gathered in recent years, these were fully successful also in this respect. On the other hand, in the subsequent stage of preparing the detailed designs, the discussions at the local public bodies focussed on the works and structures affecting directly the particular communities and on the consequences thereof.

Public involvement in, and control over, the project was further intensified by the establishment in 1985 of the Communal Development and Environmental Protection Committee of Parliament, to which the project managers were obliged to report regularly and which monitored progress on, and the environmental impacts of, the project continuously.

The growing public interest and activity is reflected also by the fact that whereas the number of public discussions on the dam project remained less than sixty during the five years between 1976 and 1981, the debates extending into the late night hours at the meetings of the local political and public bodies took place on thirty occasions in 1986 alone. The aim of the planners at these meetings was to find the optimal solutions with the co-operation and approval of the people affected in the region. The approach adopted was motivated by the realization that any ambitious landscape shaping project can only be implemented successfully with the consensus, approval and active participation of the people living in the project area.

Any comment made, opinion voiced or proposal submitted at these hearings has received careful consideration and scrutiny, and was incorporated into the plans, or rejected depending on its merits and drawbacks. A number of such proposals and initiatives have led to modifications in the original plans.

At Esztergom, for example, the original trace of the embankments has been changed as suggested by representatives of the population, reducing the area to be inundated from eighty hectares originally envisaged to no more than twelfe and excluding thus from the reservoir a strip of the flood plains which includes the entire Primás Island, a popular recreation spot of the town offering leisure time activity to up to ten thousand people.

At Nagymaros the debates prompted the engineers to change the trace originally contemplated for relocating the Highway No. 12 and the curvature of the road leading to the dam. The number of houses earmarked for demolition has been reduced. At Zebegény some of the properties will be returned to the original owners after filling the riparian zone.

Over the bank section along Szob and at Ipolynádasd the original engineering designs have been changed into more complicated ones in order to save several houses. An open competition has been announced for the recreation area developed in the area of Pilismarót. The alternative plans have been presented at a public exhibition, offering even the possibility of a public vote on them. The principle adhered to has been to continue the debates to the very last stage of planning and design with the aim of finding an optimal compromise between the requirements of the project and the local demands and interests.

This exchange of ideas does not replace, evidently, but supplements the nationwide flow of information on the project. Reports were regularly published in the press and broadcast on radio and television on the progress of construction. Also, these media have assumed an important role in representing the interests of the population living in the area of the project.

ARCHEOLOGICAL EXPLORATIONS

Measures aimed at exploring and preserving the treasures and major archeological monuments of ancient cultures in the project area were taken already in the earliest stages of the project preparations. Under the guidance and with the active co-operation of staff members of the Hungarian National Museum, archeological surveying of the Danube stretch involved started in 1959. Since it was soon realized that no important relics could be expected in the Szigetköz area, the surveys were concentrated on the region between Komárom and Nagymaros.

The explorations revealed that the slightly over 100 sites which will eventually become inundated, represent the history of the area from the Neolithic Age to medieval times, but differ widely in value.

A settlement in the Pilismarót—Szob area, from the Copper Age, a Neolithic one at Basaharc, Avar and Celtic graves at Pilismarót and near the Malom Creek a minor Roman fortress have been unearthed. The latter was one of the most valuable monuments. The remains of a medieval convent have been discovered on Primás Island at Esztergom.

Most of these relics have been transferred to the museums of Visegrád and Esztergom, but some are on display in the permanent archeological collection of the National Museum.

Excavations are currently under way in the areas Visegrád—Lepence and Neszmély—Nyergesújfalu. The former site is expected to yield monuments ranging from prehistoric to medieval times, whereas prehistoric relics are anticipated from the latter. Archeological work will be concluded at all sites before starting impoundment.

The absence of ancient relics is offset by the wealth of scenic and natural assets offered to the visitors of the Szigetköz area. Prompted by this recognition, work has been launched on the compilation of a live inventory with scientific thoroughness on this region of particular views and atmosphere before the flow regime in the present Danube is changed.

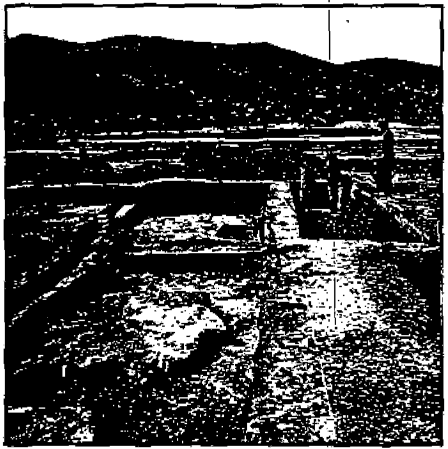
Commissioned by the National Council of Environmental Protection and Nature Conservation, a survey has been started to survey the components of the present flora and fauna, the habitats and frequency of occurrence of protected animal and plant species. In this way the knowledge available on the islands will be enriched, while laying the groundwork for studies over subsequent decades. The present will thus serve as an exact reference basis for the future.

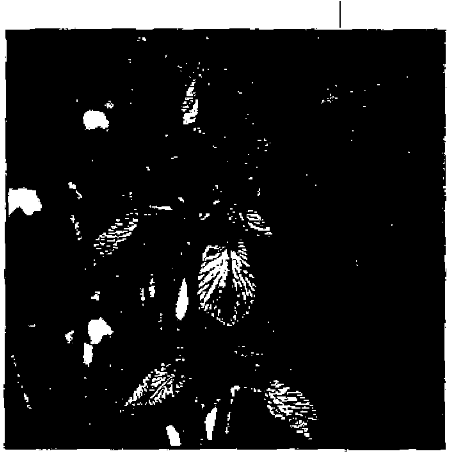
Care has also been taken at conserving the traditional scenic beauty of the region. Planning on the dam project and the early stages of implementation thereof resulted in declaring almost ten thousand hectares as the Szigetköz Nature Conservation District in 1986, thus providing protection to, and ensuring the preservation of, the scenic, botanic and zoological assets of the area.

The conservation district consists of two major parts, the first extending in the Danube flood plains from Dunakiliti to the Medve road bridge, the second forming a string of wet groves along the Moson Danube.

Vestiges of the former hardwood grove forests, white alder stands, subrelic waterbeach and oak forests, further, the precious grey poplars, which may play an important role as gene banks in the future, still thrive in this region. Alder marshes and wet meadow bogs indicate ancient severed meanders. The undergrowth is dotted with Siberian iris, hemerocallis, sword bifoliates, a wide variety of orchids.

The wonderful islands of the entwined Danube branches at Ásványráró, which shelter and feed a wide variety of waterfowl form part of the nature conservation district. The grove at Bordacs with a mixed stand of [illegible] ash, black oak, gray and black poplar is reminiscent of the ancient Szigetköz scenery, the old landscape, of which little has been preserved to these days and which will continue changing inevitably regardless whether the dam project is implemented or not.





Outlook For The Future

The overwhelming part — round 96 per cent — of the streamflow in the Hungarian rivers originates beyond the national boundaries and introduces an ever growing pollution load to the country. The flood waves rushing down the high mountains in the neighbouring countries overtake each other in the Hungarian Plains giving often rise to violent floods.

Wet years with ample flow are normally followed by dry ones bringing severe draught, the effects of which cannot be alleviated unless the water storage capacity is increased.

Careful management of all water resources available to the nation, including streamflow- and pollution control will thus remain imperative over longer terms.

The Gabčikovo—Nagymaros Dam Project has already reached implementation stage. To the general public it represents the immediate future, but the professionals responsible for managing the water resources of the nation think in terms of longer perspectives. They have identified two further potential dam sites over the Hungarian stretch of the Danube, one at Adony, the other at Fajsz, to complete the long-term development plan of the river. Moreover, studies have been started in Yugoslavia with the aim of selecting the most suitable site for the Dam at Újvidék (Novi Sad) and of preparing construction. The common driving force behind this exploration of future potentials is the recognition that the rational and circumspect development of the resources which nature has endowed upon us will continue to play an essential role in the steady and balanced progress of mankind.

Annex 6

English translation of Hungarian press report, 4 May 1989

ČTK - International redaction	ECS-1-
News from abroad	For information
Czechoslovakia	04 05 89

Ecological Agreement only after the solution of the Nagymaros problem

Budapest 4 May (APA) - Hungary will not sign the Agreement with Czechoslovakia on the protection of the environment and construction of seewage plants in relation to the Gabčíkovo-Nagymaros Project before the Hungarian Parliament decides about the possibility of referendum concerning this problematic Project. It was announced on Wednesday in Bratislava after two days discussions between the Deputy Prime Minister of Hungary Péter Medgyessy and his Czechoslovak colleague Pavol Hrivnák.

(...)

Annex 7

Updated list of recently completed sewage treatment plants on the Slovak side of the joint Slovak-Hungarian Danube section (including tributaries of the Danube)

Re:
Survey of wastewater treatment plants (WWTP) put into operation in the river basin of the Danube in the years 1989 - 1994.

Source of pollution	Planned date of finalization of construction	Real or supposed date of final. of construction
1. VK Bratislava A -left bank	12/1994	04/1995
2. Istrochem Bratislava-MCHČOV	1987	1987
3. Istrochem Bratislava BČOV	temporary solution connected on MCHČOV Slovnaft 1994	own WWTP planned1995 will not be fulfilled
4. VK Dunajská Streda MBČOV	-	1993
5. Juhocukor Dunajská Streda	-	1989
6. VK Šamorín (waste piping a.pumping station)	1994	1994
7. VK Bratislava-Petržalka MBČOV	1989	12/1993
8. MBČOV, Hamuliakovo-Kalinkovo (operating also for villages Rovinka and Dunajská Lužná)	-	05/1994
9. Medmilk Veľký Meder MBČOV	-	1989
10.MBČOV Šenkvice	-	1994
11.MBČOV Limbach	-	1992
12.MBČOV Kafiléria Senec	-	1993
13.MBČOV Dolný Štál	-	1993
14.MBČOV Zlaté Klasy	-	1994
15.MBČOV Kolárovo	1994	1994

Explanation:

VK - public sewerage system
ČOV - wastewater treatement plant
MCHČOV - mechanical and chemical wastewater treatement plant
MBČOV - mechanical and biological wastewater treatement plant
BČOV - biological wastewater treatement plant

Re: List of investment WWTP in the river
basin of the Váh finished in the years 1989 - 94

Source of pollution	Recipient	Type	Year of finalization
1. VK Liptovský Mikuláš	Váh	MBČOV	1989
		reconstr.,expanded	
2. VK Demänovská Dolina	Demänovka	reconstr.	1992
3. VK Liptovská Teplá	Váh	MBČOV	1989
4. SCP š.p.Celpap Ružomberok	Váh	MCHČOV	1991
5. VK Trstená-Tvrdošín-Nižná	Orava	MBČOV	1991
6. ZVL a.s. Dolný Kubín	Orava	MBČOV	1992
		neutralization stat.	
7. OFZ a.s. Široká	Orava	MBČOV	1991
8. VK Dolný Kubín	Orava	MBČOV	1993
		technol.ALFA BIO	
9. VK Sučany	Váh	MBČOV	1990
10.VK Martin-Vrútky	Váh	MBČOV	1993
		reconstr.,expanded	
11.VK Turček	Turiec	MBČOV	1993
12.VK Turčianske Teplice	Teplica	MBČOV	1989
13.SEZ - Tepláreň Martin	Turiec	MBČOV	1992
14.Psychiatr.liečebňa Sučany	Biely Potok	MBČOV	1992
15.Chemicelulóza Žilina		- connected to WWTP Žilina	1990
16.ZVL Diamon Rajec	Rajčianka	MBČOV	1992
17.VK Rajec	Rajčianka	MBČOV	1992
18.VK Žilina	Váh	(waste) ČOV	1992
19.VK Bytča	Váh	MBČOV	1989
20.VK Považská Bystrica	Váh	MBČOV	1989
		reconstr.,expanded	
21.Slovakofarma Hlohovec	Váh (VK)	BČOV	1992
22.VK Sereď	Váh	MBČOV	1994
		reconstr.,expand.	
23.Slovamyl a.s. Boleráz	Trnávka	MBČOV-intensif.	1993
24.Cukrovar Trnava	Trnávka	MBČOV	1993
25.VK Prievidza	Handlovka	MBČOV	1992
		reconstr.,expand.	
26.VK Lehota pod Vtáčnikom	Lehot.Potok	MBČOV	1990
27.Koželužne Bošany	Nitra	MBČOV	1991
28.Plastika Nitra	Stará Nitra	MBČOV	1990
29.VK Nové Zámky	Nitra	MBČOV	1992
		intensif.,expand.	
30.Cukrovar Šurany	Stará Nitra	MB ČOV	1993

Explanation:

VK - public sewerage system
ČOV - wastewater treatement plant
MCHČOV - mechanical and chemical wastewater treatement plant
MBČOV - mechanical and biological wastewater treatement plant
BČOV - biological wastewater treatement plant

H R O N

List of WWTP put into operation in 1989 - 1994

Town's WWTP

1. Brezno - Pálenica
2. Brezno - expanded WWTP
3. Banská Bystrica - expanded WWTP
4. Zvolen - intensification
5. Kremnica - Horná Ves
6. Nová Baňa
7. Levice - expanded WWTP
8. Žiar n/Hr. - up to the end '94
9. Hriňová
10. Žarnovica

Village's WWTP

11. Dolná Lehota
12. Čierny Balog
13. Polomka
14. Valaská
15. Tále
16. Krpáčovo
17. Slovenská Lupča
18. Kalná n/Hronom
19. Krahule
20. Očová

Industrial WWTP

21. Lesy Beňuš
22. Strojsmalt Pohorelá
23. Petrochema Dubová
24. OSC Lučatín
25. Kovo Ľubietová
26. Stredoslov.lesy Slov. Lupča
27. Mliekareň Selce
28. Cementáreň Banská Bystrica
29. SAD Banská Bystrica
30. Chemika Úľanka
31. Vojenský katastr.ústav Harmanec
32. Bučina Zvolen
33. VVO Budča
34. Sandrik - Hámre
35. Kovolesk Hodruša - Hámre
36. VVO Tekovská Breznica
37. PD Voznica - bitúnok
38. VVO Veľký Ďúr
39. LZ Žarnovica
40. Pivovar Vyhne
41. Syráreň Hriňová
42. ZŤS Detva
43. RD Hron, Slov.Lupča
44. Truckcentrum Zvolen
45. Lovčica - Trubín

Together: 45

I P E Ľ

List of WWTP put into operation in 1989 - 1994

Town's WWTP

1. Veľký Krtíš
2. Krupina (market hall + KD)
3. Krupina (Majeský rad)

Village's WWTP

4. Málinec
5. Lovinobaňa
6. Dudince (LÚ Diamant)
7. Dudince village (up to the end of 1994)
8. Štiavnické bane
9. Štiavnické bane (RZ Duslo Šaľa)
10. Pôtor
11. Ipeľské Predmestie (PS)
12. Slovenské Ďarmoty (PS)

Industrial WWTP

13. Sklárne Málinec
14. Novona - Fiľakovo
15. Kovosmalt (Energoc.Fiľakovo)
16. Bučina - Vinica
17. Práč. a čistiareň Lučenec
18. DZ Spojov - Lučenec (Lo)
19. ZŤS Krupina (ČOV)
20. KS III Veľké Zlievce
21. PD Plachtince
22. PD Litava
23. PD Hontianske Moravce
24. PD Terany
25. PD Mýtna

Together: 25

Annex 8

PHARE Project No. PHARE/EC/WAT/1, Danubian Lowland - Ground Water Model, Interim Report, Vol. 1, January 1995

Ministry of the Environment, Slovak Republic

Commission of The European Communities

DANUBIAN LOWLAND - GROUND WATER MODEL

PHARE PROJECT NO. PHARE/EC/WAT/1

Interim Report

Volume 1

Project Management Aspects and Summary of Technical Status

January 1995

Danish Hydraulic Institute,	Denmark
in association with	
DHV Consultants BV,	The Netherlands
TNO - Institute of Applied Geoscience,	The Netherlands
Water Quality Institute,	Denmark
I Krüger,	Denmark
The Royal Veterinary and Agricultural University,	Denmark

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Danubian Lowland - Ground Water Model
PHARE/EC/WAT/1
Interim Report

Client Ministry of the Environment, Programme Implementation Unit, Slovak Republic	**Client's representative** F. Kelbel, Director, PIU
Project Danubian Lowland - Ground Water Model	**Project N°** 8828
Authors Jens Chr. Refsgaard, DHI Henrik R. Sørensen, DHI DHV Consultants BV, NL TNO-Institute of Applied Geoscience, NL Water Quality Institute (VKI), DK I. Krüger Consultant AS, DK Royal Veterinary and Agricultural University, DK VUVH - Water Resources Research Institute VUZH - Research Institute of Irrigation GWC - Ground Water Consulting Ltd.	**Date** January 12, 1995 **Approved by** Jens Chr. Refsgaard Project Team Leader

0	Interim Report, Final Version	HRS/JCR		JCR	95.01.12
Revision	Description	By	Checked	App.	Date

Key words Danube, Water Resources Management, numerical modelling, river and reservoir, ground water, unsaturated zone, agriculture, sediment transport, ground water quality, surface water quality, ecology, geographical information system, field investigations, equipment, staff schedule, work plan	**Classification** ☐ Open ☐ Internal ☒ Proprietary

INTERIM REPORT

VOLUME 1

PROJECT MANAGEMENT ASPECTS AND SUMMARY OF TECHNICAL STATUS

TABLE OF CONTENTS

0 EXECUTIVE SUMMARY

The Danubian Lowland between Bratislava and Komarno is an inland delta formed in the past by river sediments from the Danube. The entire area forms an alluvial aquifer, which throughout the year receives infiltration water from the Danube in the upper parts of the area and returns it into the Danube via a network of drainage canals in the downstream part. The aquifer is an important water resource for municipal and agricultural water supply.

Various human activities have gradually changed the hydrological regime in the area. In particular a lowering of the water levels in the Danube has been observed between 1960 and 1990. In most of the area the Danube controls the ground water flow regime and hence a lowering of the general ground water level in the area has also been observed.

The Gabcikovo hydropower scheme was finalized in October 1992. The upstream reservoir and various hydraulic structures related to Gabcikovo have major impacts on the hydrological regime and the ecosystem of the region. The Gabcikovo hydropower scheme is the most important of the man induced impacts of the area and therefore it plays a key role in the project.

The immediate project objective is to develop, test and transfer an integrated mathematical modelling system including the most important aspects for water resources management in the Danubian Lowland. The ultimate project objective is that the transferred modelling system be used as the technical/scientific basis for future management decisions.

The consultant staff has spent about 70 man-month by the end of Phase I. Staff members from the following three Slovakian research organisations have participated actively in the project implementation:

- The Ground Water Consulting (GWC) with 6 persons,
- The Water Research Institute (VUVH) with 3 persons, and
- The Irrigation Research Center (VUZH) with 2 persons.

The work of these 11 persons have been funded by various Slovakian organisations and by the Ministry of the Environment. In addition various field- and monitoring programmes have been funded by Slovakian organisations.

Originally, GWC was a part of the Faculty of Natural Science, Comenius University (PRIF UK), but from the beginning of 1994 they established a private company.

The Project Manager is appointed by PRIF UK and until the end of 1994 professor Igor Mucha (GWC) was the Project Manager. A new Project Manager from PRIF UK is expected to be officially appointed soon.

Due to a delayed delivery of about 20 months of the major computer equipment, the project period has been extended with 6 months. The project termination is December 31, 1995.

In order to address the problems within the project area an integrated modelling system has been established based on the consultants mathematical modelling systems. These are:

- MIKE 11 which is a one dimensional river modelling system for hydraulics, sediment transport and morphology and water quality.
- MIKE 21 which is a two dimensional modelling system used for reservoir modelling, including hydrodynamics, sediment transport and water quality.
- MIKE SHE which simulates the major flow and transport processes within the hydrological cycle. MIKE SHE comprises modules for flow and transport on the ground surface, in rivers, in the unsaturated zone and in the ground water zone
- DAISY which is a one-dimensional root zone model for simulation of soil water dynamics and nitrogen transport and transformation.

Although these modelling systems are generalized tools with comprehensive applicability ranges, a few model modifications have taken place within the project, in order to accommodate the very special conditions in the area.

The integrated modelling system is formed by the exchange of data and the feedbacks between the individual modelling system. The structure of the integrated modelling system is illustrated in the figure below.

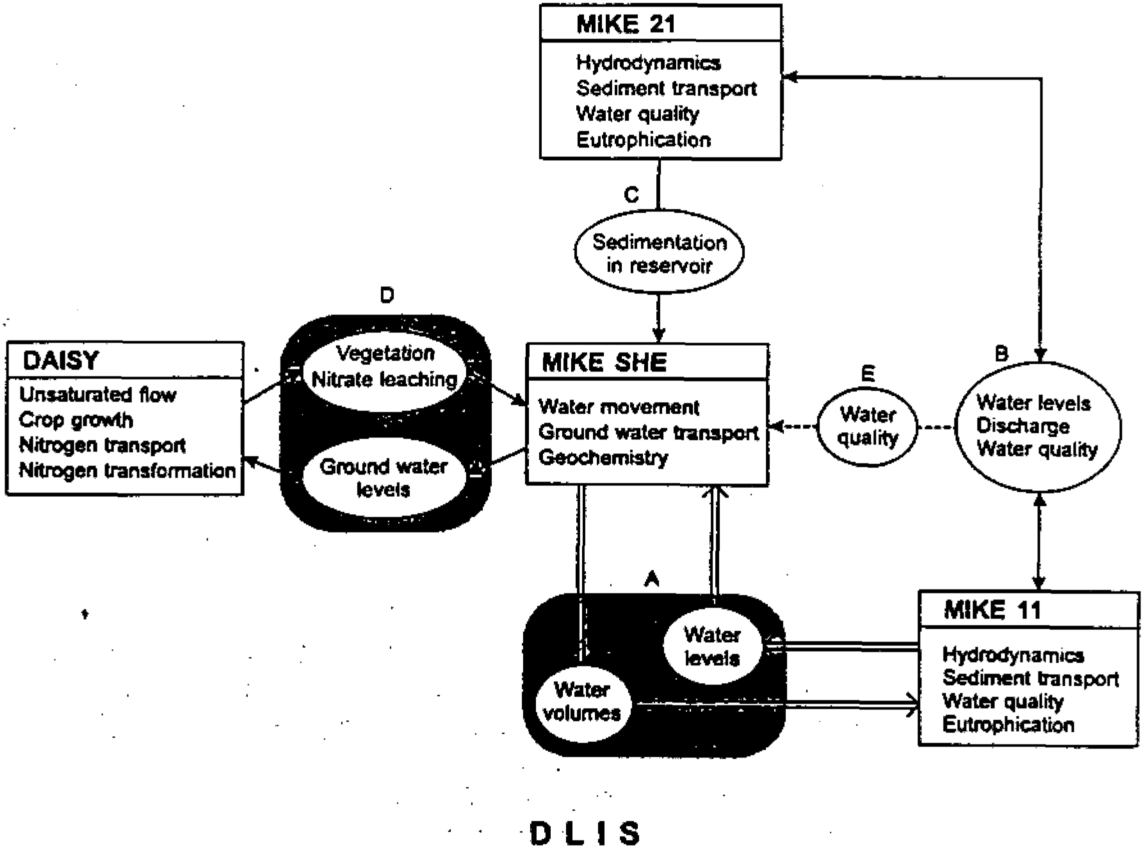


Fig. 0.1 Structure of the integrated modelling system.

The Danubian Lowland Information System (DLIS) is a combined data base and geographical information system that has been developed under this project. The DLIS is based on Informix (database) and Arc/Info (GIS) and provides a framework for data storage, maintenance, processing and presentation. In addition, an interface between DLIS and MIKE SHE allowing import and export of maps and time series files in MIKE SHE file formats has been made. A direct interface to the remaining models has not been developed, but files can easily be transferred from MIKE SHE file format to any other of the applied modelling systems.

The various mathematical models have been established using the three step approach below.

step 1) Model setup
step 2) Model calibration
step 3) Model validation.

The following models have been established:

- a MIKE 11 hydrodynamic model for the Danube
- a MIKE 11 water quality model for the Danube
- a MIKE 11 sediment transport and morphological model for the Danube.
- a MIKE 11 hydrodynamic model for the river branch system on the Slovak floodplain.
- a MIKE 11 eutrophication model for the river branch system.
- a MIKE 11 sediment transport model for the river branch system.

All the MIKE 11 models have been established in two versions reflecting the situation before and after the damming of the Danube.

- a MIKE 21 hydrodynamic model for the reservoir.
- a MIKE 21 eutrophication model for the reservoir.
- a MIKE 21 sediment transport model for the reservoir.

- a MIKE SHE regional ground water model for the entire project area (3500 km^2. (pre- and post-conditions)
- a MIKE SHE detailed model for the reservoir area (180 km^2).
- a MIKE SHE detailed model for the river branch system (60 km^2)
- a MIKE SHE geochemical transect model for a geochemical field site.
- a MIKE SHE geochemical model for the reservoir area (under preparation)

- a number of DAISY models (profiles) reflecting the different agricultural and hydrological conditions within the area.

During Phase I most of the models have been calibrated and validated, but some models still need final calibration and validation before they are ready for practical use.

Phase II is mainly dedicated to model application. The specific scenarios for which model simulations will be carried out will be decided jointly by the Slovak Ministry of the Environment and the Consultant.

The Consultant has suggested a scenario framework comprising the three Water Management Regimes listed below. The Water Management Regimes will be based on a measured discharge time series at Bratislava for the period 1986 to 1991. This period has an average discharge (2027 m^3/s) which is close to the long term average and furthermore contains high flow as well as low flow situations.

- Water Management Regime I is a reference situation reflecting the pre-dam situation.
- Water Management Regime II reflects a post-dam situation where 400 m^3/s are diverted from the reservoir to the Old Danube.
- Water Management Regime III reflects a post-dam situation where 800 m^3/s are diverted from the reservoir to the Old Danube.

- Water Management Regime IV will be decided based on the results from the model simulations for the above three Water Management Regimes.

A more comprehensive summary of the technical status is provided in Chapter 4.

1 INTRODUCTION

1.1 Background

The Danubian Lowland between Bratislava and Komárno is an inland delta formed in the past by river sediments from the Danube. The entire area forms an alluvial aquifer, which throughout the year receives infiltration water from the Danube in the upper parts of the area and returns it into the Danube and the drainage channels in the downstream part. The aquifer is an important water resource for municipal and agricultural water supply.

Human influence has gradually changed the hydrological regime in the area. Construction of dams upstream of Bratislava together with exploitation of river sediments has significantly deepened the river bed and lowered the water level in the river. These changes have had a significant influence on the ground water regime as well as the sensitive riverside forests downstream of Bratislava. The hydraulic structures related to the hydropower plant at Gabcikovo have major impacts on the hydrological regime and the ecosystem of the region.

Industrial waste and municipal sewage from Bratislava and its surroundings together with the diffuse sources of agricultural fertilizers and agrochemicals are polluting the rivers, soil and ground water.

These physical and biochemical changes may reduce the atmospheric oxygen transport to the ground water and at the same time increase the supply of organic matter which will change the oxidizing conditions to reducing conditions and thereby seriously deteriorate the ground water quality.

To address these urgent water resources problems in the area the project "Danubian Lowland - Ground Water Model" has been defined in 1991 within the PHARE programme agreed upon between the Commission of the European Communities and the Government of the Czech and Slovak Federal Republic.

To understand and analyze the complex relationships between physical, chemical and biological changes in the surface- and subsurface water regimes requires multidisciplinary expertise in combination with advanced mathematical modelling techniques. The overall project objective is to establish a reliable impact assessment model for the Danubian Lowland area, which enables the authorities to formulate optimal management strategies leading to a protection of the water resource and a sound ecological development for the area.

1.2 Project Objectives

The objective of the project is to provide technical/scientific based management tools for the Slovakian authorities and through interaction with decision makers to apply these tools for addressing selected problems. Thus, on the one hand, the role of the project is not to define management objectives nor to establish a management decision framework for water resources. On the other hand, the project shall in accordance with the Terms of Reference prepare expert suggestions for the government to be used for technical decisions as well as for policy making.

The water resources problems in the project area are so complex, the number of relevant studies already carried out so high, and the amount of available data so large that it is not possible within the framework of the project to fully process all this data and provide optimal technical solutions to all the problems. However, the modelling system being established during the project shall be able to address the most important types of water resources problems, the performance of the models shall be verified and the models shall be applied to a selected number of practical problems demonstrating their applicability for the large range of problem types.

The ultimate objective of the project is that the models provided during the project be used as the technical/scientific core for the future management decisions. It is noted that this objective can only be fulfilled through close cooperation with Slovakian specialists, who by the end of the project must be able to fully utilize the models.

1.3 Project Relation to the Gabcíkovo Hydropower Scheme

For a clarification of the role of the present PHARE project in relation to the international political discussions between Slovakia and Hungary on the Gabcikovo hydropower scheme it is noted that the project in accordance with its Terms of Reference is limited to the pure technical and scientific aspects. Furthermore, the following two points may be noted:

- The project deals with the water resources problems in the entire Danubian Lowland area (the area between Bratislava to the west and Komarno to the east and between the Danube to the south and the Karpathians to the north). The Gabcikovo is only one, although at present the largest, of the man induced impacts which has to be studied.
- The project deals with modelling of the water resources on the Slovakian side of the Danube. No recent data is available to the project from the Hungarian side, and the project can therefore only make predictions dealing with the effects of the Gabcikovo scheme for Slovakian areas. Thus, the project cannot address questions regarding e.g. the ecological consequences of the Gabcikovo scheme for Hungarian areas.

1.4 Project Relation to other Water Resources Activities in the Region

Due to the very significant water resources problems in the area comprehensive activities are currently being carried out both with regard to monitoring and to studies. Thus many professional organizations are involved in various aspects of water resources activities in the project area. The purpose of the project is to cooperate with all these activities in order to avoid duplication of work and to ensure maximum dissemination of project outputs to Slovakian organizations.

1.5 Purpose and Content of Report

According to the Terms of References the results of Phase I of the project shall be reported in an Interim Report. The Interim Report is divided in two volumes, namely the present Summary Report (Volume 1) and the Technical Status Report (Volume 2).

The present report summarizes the management aspects, which have been currently reported in six-monthly Progress Reports. Furthermore, a summary of the Technical Status Report is provided in the report.

Chapter 2 contains a summary of the project staffing, both in terms of Consultant staff input and input from Slovakian specialists associated to the project.

Chapter 3 deals with the project management issues during the Phase I, including the Steering Committee and the cooperation with local organizations.

In Chapter 4 a summary of the technical status of the project is given. This chapter can be seen as an executive summary of Volume 2 of the Interim Report.

Chapter 5 contains the Consultant's proposal for the application scenarios to be carried out in Phase II.

A work plan for the remaining project activities under Phase II is given in Chapter 6.

2 PROJECT STAFFING

2.1 Consultant

The assignment of Consultant staff at the project office in Bratislava during Phase I, July 15 1992 through January 15 1995, is listed in Table 2.1

Table 2.1 Project staff members working in Bratislava during Phase I between July 1992 and January 1995.

Staff member	Periods	Comments
J.C. Refsgaard Team Leader	2/9 - 11/9 92 25/11 92 21/1 - 29/1 92 8/3 - 12/3 93 19/4 - 28/4 93 3/6 - 16/6 93 1/9 - 7/9 93 20/10 - 4/11 93 19/1 - 7/9 94 10/2 - 15/2 94 20/4 - 26/4 94 24/5 - 3/6 94 12/7 - 14/7 94 9/9 - 16/9 94 23/11 - 1/12 94	
B. Storm Deputy Team Leader Chief MIKE SHE Modeller	22/3 - 14/4 92 6/5 - 12/5 92 1/6 - 23/6 92 10/1 - 26/1 94 24/10 - 4/11 94	Replaced by H.R. Sørensen, February 1994
H.R. Sørensen Deputy Team Leader Chief MIKE SHE Modeller	10/2 - 23/2 94 7/3 - 11/5 94 24/5 - 10/6 94 20/6 - 8/7 94 15/8 - 2/9 94 7/9 - 30/9 94 20/10 - 4/11 94 21/11 - 1/12 94	
T. Clausen MIKE SHE Modeller	10/1 - 28/1 94 20/6 - 8/7 94 15/8 - 2/9 94 19/9 - 30/9 94 24/10 - 4/11 94	
A. Refsgaard MIKE SHE Modeller	11/4 - 22/4 94 24/5 - 2/6 94	
J. Griffioen Hydrogeochemist	18/8 - 28/8 92 3/11 - 23/7 92 12/4 - 20/4 93 3/8 - 10/8 93 25/5 - 3/6 94 26/8 - 2/9 94	

Staff member	Periods	Comments
P. Engesgaard Hydrogeochemical Modeller	15/1 - 21/1 94 18/4 - 26/4 94 20/5 - 2/6 94 15/8 - 26/8 94	Temporarily substituted by A. Bruun
M. Styczen Agronomist	6/6 - 16/6 93 15/9 - 19/9 94	Replaced by M.Thorsen, November 1994
M. Thorsen Agronomist	21/11 - 1/12 94	
M. Madsen Hydraulic Engineer	19/4 - 28/4 93 15/7 - 23/7 93 27/9 - 30/9 93 7/3 - 15/3 94	
J.T. Kjelds Hydraulic/sediment Engineer	15/7 - 6/8 92	
J.K. Jensen Surface Water Quality Specialist	30/8 - 4/9 92 18/7 - 23/7 93 22/9 - 1/10 93 27/5 - 2/6 94 7/9 - 16/9 94 21/11 - 24/11 94	9/9 not spend on this project
F. Deckers Information System Analyst	7/3 - 25/3 94 14/5 - 1/6 94 14/11 - 18/11 94	
F. Werdenburg Information System Analyst	7/3 - 25/3 94 14/5 - 1/6 94 14/11 - 18/11 94	
J.L. Fiselier Flood Plain Ecologist	26/5 - 8/6 94 25/11 - 29/11 94	
M.W. de Haan Limnologist	26/5 - 6/6 94	
Hans G. Enggrob Sediment Transport Modeller	24/5 - 11/6 94 9/9 - 19/9 94 14/11 - 23/11 94	
S. Hansen Agricultural Modeller	19/4 - 4/5 93 7/2 - 18/2 94 25/5 - 3/6 94	
A. Bruun Geochemical Modeller	19/8 - 26/8 94 15/10 - 20/10 94 26/11 - 1/12 94	
L.C. Larsen Computer System Specialist	21/1 - 22/1 93 31/1 - 3/2 93 26/4 - 30/4 93 15/11 - 18/11 94	

In addition, some of the Consultant staff members have worked on the project at their respective home offices.

In total the Consultant has spent about 70 man-months (m.m.) by the end of Phase I.

2.2 Local Organizations

Staff members from the following three Slovakian research organisations have participated actively in the project implementation:

- The Ground Water Consulting (GWC). This group was in 1992 and 1993 part of the Faculty of Natural Sciences, Comenius University (PRIF UK). In 1994 the group established itself as a private company. The following staff members have received training and subsequently participated in the modelling activities under the project:

  - Professor, Dr. Igor Mucha
  - RNDr. Eva Paulikova
  - RNDr. Dalibor Rodak
  - RNDr. Zoltan Hlavaty
  - RNDr. Lubomir Bansky
  - Mr. Matej Gideon

  Furthermore, GWC staff members have conducted field studies as well as collected and processed data for the project. The staff input from GWC to the project corresponds to about six persons full time during 1992 and 1993. For reasons discussed in Section 3.3 GWC's staff input has in 1994 only been equivalent to in average about three persons full time.

- The Water Research Institute (VUVH). The three key persons from VUVH, which have contributed with modelling work for the project are:

  - Ing. Jelica Klucovska
  - Ing. Jana Topolska
  - Ing. Zdena Kelnarova

  These three modelling specialists have been allocated in total for about 40 man-months during Phase I. Furthermore, other VUVH staff members have conducted field studies and corresponding analyses on hydrodynamics, sediment and water quality aspects for the project. From November 1994 Zdena Kelnarova changed job position from VUVH to Ministry of Environment. From January 1995 Jelica Klucovska and Jana Topolska changed job position from VUVH to GWC.

- The Irrigation Research Institute (VUZH). The two key persons from VUZH, which have contributed with modelling work for the project are:

  - RNDr. Jozef Takac
  - Ing. Vladimir Kosc

These modelling specialists have been allocated in total for about 24 man-months during Phase I. Furthermore, other VUZH staff members have contributed with field studies and corresponding analyses.

The Slovakian modelling specialists have received training abroad under the PHARE project as summarized in Table 2.2.

Table 2.2 Training abroad for Slovakian specialists under the project.

Staff member	Periods	Comments
I. Mucha, GWC PRIF UK	18/9 - 18/10 92	SHE training at DHI, Denmark
E. Paulikova, GWC PRIF UK	18/9 - 18/10 92	SHE training at DHI, Denmark
D. Rodak, GWC PRIF UK	3/10 - 25/10 92 14/11 - 5/12 92	Training in geochemical modelling at TNO and Free University of Amsterdam, NL Study tour to University of Kassel, Germany
Z. Hlavaty, GWC PRIF UK	19/4 - 22/4 92 19/7 - 3/8 93 11/8 - 25/8 93	HydroGIS conference, Austria GIS training, USA GIS training at TNO, Netherlands
L. Bansky, GWC PRIF UK	19/7 - 3/8 93	GIS training, USA
J. Klucovska, VUVH	2/11 - 30/11 92	MIKE 11/21 training at DHI and VKI, Denmark
J. Topolska, VUVH	2/11 - 30/11 92	MIKE 11/21 training at DHI and VKI, Denmark
Z. Kelnarova, VUVH	2/11 - 30/11 92	MIKE 11/21 training at DHI and VKI, Denmark
J. Takac, VUZH	19/10 - 15/11 92	DAISY training at Agricultural University, Denmark
V. Kosc, VUZH	19/10 - 15/11 92	Daisy training at Agricultural University, Denmark

3 PROJECT MANAGEMENT ISSUES

3.1 Project Organizational Framework

The PHARE project was during the first project year, 1992, executed by the Federal Committee for Environment, Government of the Czech and Slovak Federal Republic. From the beginning of 1993 the project was transferred to the Programme Implementation Unit (PIU) at the Ministry of the Environment, Slovak Republic.

The Project Manager is appointed by the Faculty of Natural Science, Comenius University (PRIF UK). From the beginning of the project until the end of 1994 professor Igor Mucha was the Project Manager. A new Project Manager has not officially been appointed.

Originally, professor Igor Mucha and his team of ground water specialists belonged to PRIF UK, but in 1994 they established a private company, Ground Water Consultants Ltd (GWC). Important Slovakian contributions to the project are provided by specialist staff from GWC, Water Research Institute (VUVH) and Irrigation Research Institute (VUZH).

A Danish-Dutch consortium of six organizations was selected as Consultant for the project. The Consultant is headed by Danish Hydraulic Institute (DHI) and comprises the following associated partners: DHV Consultants BV, The Netherlands; TNO-Applied Institute of Geoscience, The Netherlands; Water Quality Institute (VKI), Denmark; I Krüger Consult AS, Denmark; and the Royal Veterinary and Agricultural University, Denmark.

3.2 Steering Committee

In order to facilitate coordination between the project and important cooperation partners as well as key end users of project results a Steering Committee has been established. The committee comprises representatives of the following organizations:

- Programme Implementation Unit (PIU), Slovak Ministry of the Environment
- Slovak Ministry of the Environment
- The Project Manager

- Water Research Institute (VUVH)
- Research Institute of Irrigation (VUZH)
- Centre of Monitoring, Slovak Hydrometeorological Institute (SHMU)
- Faculty of Natural Sciences, Comenius University (PRIF UK)
- Ministry of Soil Management
- Water Economy Construction (Vodohospodarska Vystavba)
- Danube Catchment Authority (Povodie Dunaja)
- Danish Hydraulic Institute on behalf of the Consultant group.

The Steering Committee held four meetings during Phase I, namely on

- 10. March 1993
- 7. September 1993
- 26. January 1994
- 29. November 1994

The Progress Reports prepared by the Consultant in January 1993, July 1993, January 1994 and July 1994 were submitted to the Steering Committee and formed the basis for information and discussions of general project status and work plans. Furthermore, the technical progress and preliminary results were presented and discussed at several of the meetings.

3.3 Project Manager and End User Organisation

According to the Terms of References the core Slovakian group in the project is the Ground Water Division of the Faculty of Natural Sciences (PRIF UK) headed by Professor Igor Mucha. This group is described as having three key functions, namely providing the Project Manager, providing technical input to the project, and becoming the future user of the modelling system, equipment, hardware and software.

As discussed in the Inception Report from July 1992 and the four Progress Reports submitted since then these issues have been subject to continuous discussions during the project period. A main reason for this may be that since the start of the project radical changes occurred with respect to many fundamental conditions of importance for the project implementation and the "after project situation". These changes include creation of Slovakia as an independent nation, major new legislation and new administrative procedures, changed financial conditions for public sector institutions, creation of a private sector, changed conditions for access to data owned by public sector institutions.

During 1992 and 1993 Professor Mucha and his group received funding for their project activities from the Ministry of Soil Management and Povodie Dunaja through PRIF UK. However from the beginning of 1994 no funds were available through PRIF UK. Therefore the group established a private firm, Ground Water Consulting Limited (GWC), in April 1994. Throughout 1994 no funds at all were made available to GWC for providing the project input specified in the Terms of References. In spite of no payments GWC provided some work to the PHARE project to ensure that the computer system was maintained and running, and to enable the main project activities to continue. GWC has during 1994 provided staff input to the project corresponding to in average about three persons full time.

This situation with too less input from the core Slovakian group during 1994 has been a major concern and has therefore been subject for many discussions also involving the Consultant. A concluding meeting in this regard was held on 24. November 1994 with representatives from PIU, PRIF UK, EC and DHI. The key conclusions of this meeting were that the future status should be as follows:

- PRIF UK nominates a new Project Manager.

- Professor Mucha's group (now privatized in the name of Ground Water Consultants) continue to provide technical input to the project under direct subcontract with DHI.

- All equipment formally continues to be the property of the Ministry of Environment, but PRIF UK in practise becomes the end user. Thus by the end of the project the equipment and the integrated modelling system will be moved to suitable office facilities at PRIF UK. As a new activity PRIF UK will establish a new group of specialists, which after proper training, shall be ready to utilize the equipment and the integrated modelling system.

3.4 Project Extension by Six Months

The tendering process and delivery of the major computer equipment was after consultation with PIU (Prague) during the Inception Phase estimated to take about seven months. Instead, it turned out to take 15 - 20 months for the two major computer workstations including the ARC/INFO and INFORMIX data base software systems. This delay has created subsequent delays in many project activities, which were dependent on this equipment.

On this basis the Project Manager and the Consultant had requested that the project period was extended by six months. PIU has approved this request, so that the key timings have been modified as follows:

-	*Phase I*:	16 July 1992 - 15 January 1995
-	*Phase II*:	16 January 1995 - 15 September 1995
-	*Final Report*:	15 November 1995
-	*Project Termination*:	31 December 1995.

3.5 Access to Existing Data

A very large amount of relevant data from the project area exist. The major part of this data is collected by and available through the Centre of Monitoring, which is a separate organization under SHMU specifically responsible for the collection of data for the Danubian Lowland area.

The question of the availability of this data for the project and the associated conditions has been subject to comprehensive discussions at several separate meetings as well as at Steering Committee meetings.

The project has now been promised access to all relevant existing data without costs to be charged to the project in this regard. Subsequently, the necessary approvals and other formalities have been made and the data collection is almost completed.

3.6 Support Projects Financed by Slovakian Funds

The PHARE project has been supported in kind by Slovakian financing of associated projects. The key elements in this regard are:

- Project input from Professor Mucha's group (GWC):
    - staff input for data collection, data processing, field work, modelling and management, 1992 - 1994; and
    - field work and laboratory analyses for the Kalinkovo geochemical field site, 1994.

The activities in 1992 and 1993 were in accordance with the Terms of References and funded by the Ministry of Soil Management partly through PRIF UK and partly through Povodie Dunaja. The 1994 staff input, for which no funding was made from anywhere, amounted to about half the input specified in the Terms of References. The 1994 support project related to the Kalinkovo geochemical field site was financed by the Ministry of Environment.

- Project input from VUVH
    - staff input for modelling work, 1992 - 1994;
    - a sediment transport field programme, 1992 - 1993; and
    - a water quality field programme, 1992 - 1993.

  The activities in 1992 were funded by Water Economy Construction, while the 1993 and 1994 activities were funded by the Ministry of the Environment.

- Project input from VUZH
    - staff input for data collection, processing and modelling work, 1992 - 1994.

  The 1992 activities were funded by VUZH, while the activities in 1993 and 1994 were funded by the Ministry of the Environment.

In addition, the PHARE project has through cooperation with other projects obtained access to field data obtained under other projects. An important example in this regard is a major project on reservoir eutrophication conducted by VUVH and financed by the Ministry of the Environment during the second half of 1994. The PHARE project has given recommendations for the field programme, will make use of the data in connection with calibration of the reservoir eutrophication model and will subsequently provide model calculation results for the Ministry of the Environment under the forthcoming Phase II.

These support projects and cooperation with other projects have been very valuable for the PHARE project. Without this support and cooperation it would still have been possible to develop and apply the integrated modelling system as described in the Terms of References. However, with this support it has been possible to establish, calibrate and validate the models to a much higher level of refinement and accuracy than it would otherwise have been possible. Consequently, the direct practical applicability of the project outputs by the end of the project period will have improved significantly.

4 SUMMARY OF TECHNICAL STATUS

This chapter provides a brief summary of the various technical activities that have been carried out during project Phase I.

4.1 Introduction

The Danubian Lowland between Bratislava and Komarno is an inland delta formed in the past by river sediments from the Danube. The entire area forms an alluvial aquifer, which throughout the year receives infiltration water from the Danube in the upper parts of the area and returns it into the Danube in the downstream part. The aquifer is an important water resource for municipal and agricultural water supply.

Various human activities have gradually changed the hydrological regime and affected the ground water quality within the study area. This study mainly concentrates on the man induced impacts on:

- ground water regime
- ground water quality
- surface water quality
- sediment transport
- agriculture, and
- flood plain ecology

The Gabcikovo hydro power scheme is the largest of the man induced impacts within the study area, and hence it plays a central role in this project.

The immediate project objective is to develop, test and transfer an integrated mathematical modelling system including the most important aspects for water resources management in the Danubian Lowland. The ultimate project objective is that the transferred modelling system be used as the technical/scientific basis for future management decisions.

4.2 Equipment

The core of the computer system is two Hewlett Packard workstations (HP Apollo 9000/735). Via a local area network these workstations have been interconnected to a number of personal computers and X-terminals providing a total number of 9 work places.

In addition various field- and laboratory equipment and a project car have been procured. Table 4.1 provides an overview of the equipment procured under this project.

Table 4.1 Status of Project Equipment by January 1995.

Supply No	Description	Supplier	Price ECU	Status
Minor supplies				
MS 01	Copy machine + telefax	CZ & CZ	9,200	Delivered, April 1993
MS 02	PC equipment	BSP	26,130	Delivered, July 1992
MS 03	PC equipment	Zecco	6,360	Delivered, July 1992
MS 04	PC equipment	APS	12,600	Delivered, July 1992
MS 05	MODFLOW (software)	Scientific Software group	1,200	Delivered, May 1993
MS 06	Car	Kama	10,400	Delivered, Feb. 1994
MS 07	Field equipment - tensiometers and cer. cups for sampling of NO_3 leaching	Eijkelkamp	9,123	Delivered, April 1993
MS 08	Field equipment - measurements of chemical parameters directly in obs.wells	Venika	19,700	Delivered, August 1993
MS 10	GPS	Gravquick	46,900	Delivered, May 1993
MS 11	Laboratory equipment - retention curves and gulph hydraulic conductivity	Eijkelkamp	7,801	Delivered, July 1993
MS 12	Laboratory equipment - measurements of N-components in soil, water and plants.	Skalar	40,725	Delivered, August 1993
MS 13	2 X-terminals	DIGIS	10,000	Delivered, August 1994
MS 14	2 X-terminals, Computer memory upgrade, additional hard disk,UPS	DIGIS	30,630	Approved, delivery expected early 1995
MS 15	Arc/Info upgrade, UPS	ArcGEO	12,370	Approved, delivery expected early 1995

Supply No	Description	Supplier	Price ECU	Status
International tender - major computer supply				
Lot 1	Modelling computer	DIGIS	64,246	Delivered, Apr. 1994
Lot 2	Info server system	ARC data	239,198	Delivered, Dec. 1993
Lot 4	A1 elstat plotter	MATRA	45,541	Delivered, Oct. 1993
Lot 6	Local area network	EDICO	3,816	Delivered and installed, April 1994
GRAND TOTAL			595,940	

The total budget for equipment is ECU 630,000, but no further procurements are planned for 1995.

4.3 Danubian Lowland Information System

The Danubian Lowland Information System (DLIS) has been developed, and is now ready for practical use, providing a central database and Geographical Information System (GIS) with facilities for data storage, maintenance, processing and presentation. In addition, data can be imported and exported in file formats readable for the applied modelling system.

DLIS is based on two software resources, the Informix relational database and the Arc/Info GIS. All non-spatial data is stored in Informix and all spatial data in Arc/Info.

The non-spatial data that is stored in Informix may be any kind of data that is related to a certain location. For instance time series of measurements ground water levels, concentration of oxygen in rivers, river discharge etc. It may also be information on soil horizons in a soil profile in terms of water retention curves and hydraulic conductivities. For all kind of information some additional information may also be stored. It could for instance be a description of soil horizons or name and address of the organisation that owns a certain observation well for ground water observations.

Spatial data stored in Arc/Info (GIS) could for instance be surface topography, geological layer boundaries, cropping and land use, river geometry etc. Spatial data may be displayed together with other spatial data (e.g. cities, roads, rivers etc.) or with point information like location of water supply production wells etc. Some examples on different types of spatial data are given in Fig. 4.1.

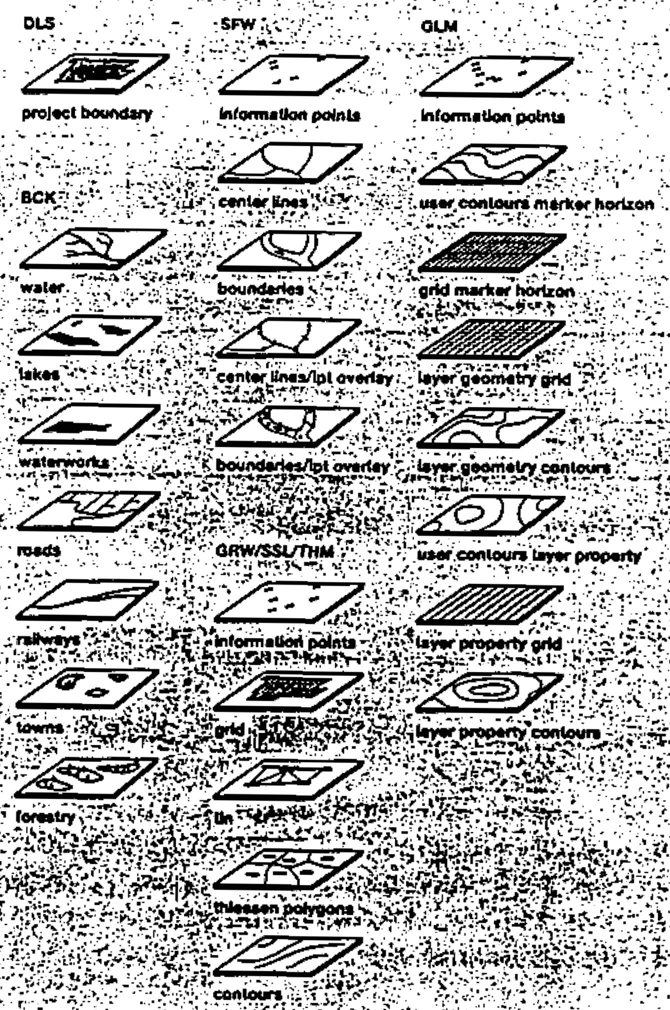


Fig. 4.1 Different spatial data stored in Arc/Info.

A large part of all relevant data within the project area has been collected and implemented into the DLIS. However, a substantial amount of data still needs to be collected, processed and stored in the DLIS. This work will continue during project Phase II mainly to be carried out by Slovak staff members.

An interface between DLIS and MIKE SHE has been developed enabling exchange and presentation of data in MIKE SHE file format. In that way MIKE SHE results may be displayed together with any other data stored in the DLIS. A direct interface to the remaining modelling systems has not been implemented. However, data can easily be transferred from MIKE SHE file formats to any other of the relevant modelling systems.

4.4 Modelling Approach

A number of individual modelling systems have been applied within this study:

- **MIKE 11** which is a one dimensional river modelling system used for hydraulics, sediment transport and morphology and water quality.

- **MIKE 21** which is a two dimensional modelling system used for reservoir modelling, including hydrodynamics, sediment transport and water quality.

- **MIKE SHE** which simulates the major flow and transport processes of the hydrological cycle. MIKE SHE comprises the following main components which are fully coupled allowing for feedbacks and interactions between the components:

    - 1D flow and transport in the unsaturated zone
    - 3D flow and transport in the ground water zone
    - 2D flow and transport on the ground surface
    - 1D flow and transport in rivers.

- **DAISY** which is a one-dimensional root zone model for simulation of soil water dynamics and nitrogen transport and transformation.

4.4.1 Further development of modelling systems

Although the above mentioned models are generalized tools with comprehensive applicability ranges, some model modifications were needed in order to accommodate the very special conditions in the area. The following model modifications have been made as part of the project:

Daisy
a new crop growth and nitrogen module for maize has been developed.

Coupling of MIKE SHE and MIKE 11
A fully dynamic coupling of MIKE SHE with the hydraulic module of MIKE 11 has been developed. The two modelling systems are running simultaneously exchanging data in the computer memory.

Geochemical Model
A geochemical model describing chemical/microbiological processes related to transformations of nitrogen species, organic matter, oxygen and manganese. This model is linked to the solute transport module of MIKE SHE.

Simplified Unsaturated Zone Description in MIKE SHE
A simplified unsaturated zone description only accounting for gravity flow has been implemented in MIKE SHE.

4.4.2 The integrated modelling system

The integrated modelling system is formed by the exchange of data and the feedbacks between the individual modelling systems. The structure of the integrated modelling system and the exchange of data between the various modelling systems are illustrated in Fig. 4.2.

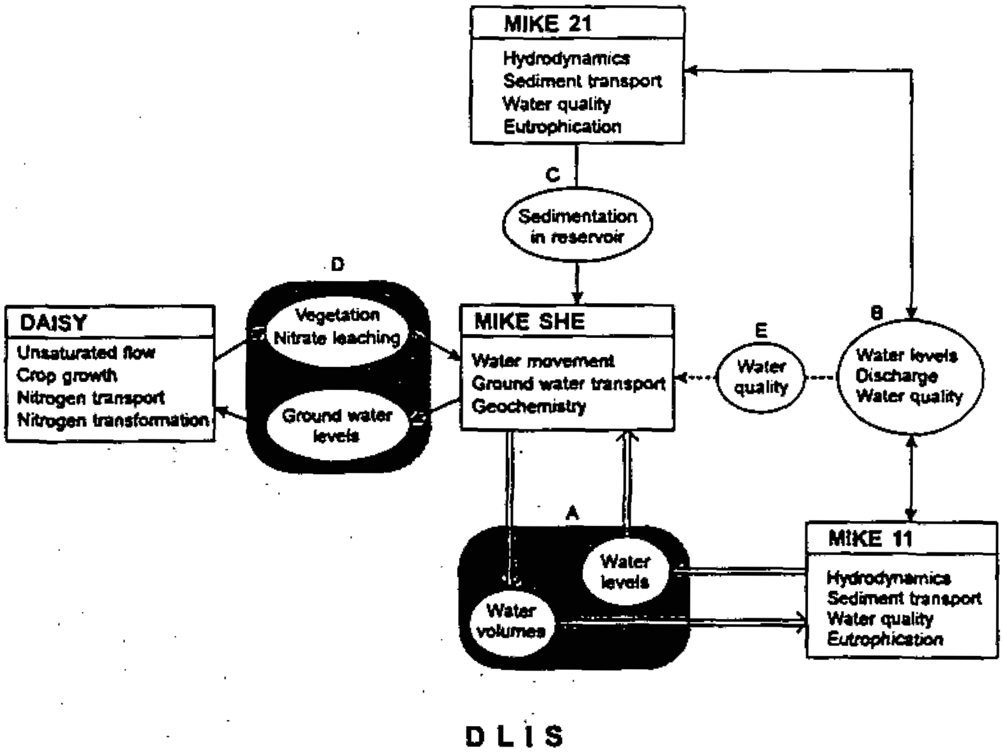


Fig. 4.2 Structure of the integrated modelling system.

The interface (A-E) between the various models are briefly described below:

A) MIKE SHE forms the core of the integrated modelling system having interfaces to all the individual modelling systems. The coupling of MIKE SHE and MIKE 11 is a fully dynamic coupling where data is exchanged after each computational time step.

The remaining modelling systems are coupled in a more simple manner involving a sequential execution of various models and subsequently a transfer of boundary conditions from one model to another. Some examples are listed below.

B) Results of eutrophication simulations with MIKE 21 in the reservoir are used to estimate the concentration of various water quality parameters in the water that enters the Danube downstream of the reservoir to be used for water quality simulations for the Danube using MIKE 11.

C) Sediment transport simulations in the reservoir with MIKE 21 provide information on the amount of fine sediment on the bottom of the reservoir. This information is used to calculate leakage coefficients which are used in ground water modelling with MIKE SHE.

D) The DAISY model calculates vegetation parameters which are used in MIKE SHE to calculate the actual evapotranspiration. Ground water levels calculated with MIKE SHE act as lower boundary conditions for DAISY unsaturated zone simulations. Consequently, this process is iterative and requires a few model simulations.

E) Results from water quality simulations with MIKE 11 and MIKE 21 are used to estimate the concentration of various species in the water that infiltrates to the aquifer from the Danube and the reservoir. This is being used in the ground water quality simulations (Geochemistry) with MIKE SHE.

4.4.3 Approach of model application

The procedure that has been applied in the model applications involves three steps:

1) **Model setup**; involves that the geometry of the system and some physical characteristics are implemented in the model. For instance river cross-sections, surface topography, soil physical parameters, land use, vegetation parameters and hydraulic conductivities in the ground water zone.

2) **Model calibration**; involves that a number of model simulations is carried out and model results are compared with measured data, until a satisfactory correspondence is obtained. All the applied modelling systems are physically-based implying that all input data can be assessed directly frpm field data. Thus, the model calibration has been limited to adjustment of a few physical parameters within a narrow ranges.

3) **Model validation**; involves that the model demonstrates the ability to reproduce measured data outside the calibration period.

4.5 Regional Ground Water Modelling

The main objectives of the regional ground water modelling are to study the impacts of the damming of the Danube on the hydrological regime within the project area, in particular in terms of ground water levels and dynamics, and to provide reliable boundary conditions for local ground water models.

The applied modelling systems are MIKE SHE, MIKE 11 and the coupled version of the two. All the modules of MIKE SHE have been applied implying that the major flow processes in the hydrological cycle are described.

Three ground water models have been established :

- a regional ground water model for pre-dam conditions
- a regional ground water model for post-dam conditions, and
- a local ground water model for an area surrounding the reservoir.

The regional model area covers about 3500 km^2 but the main area of interest is the Žitný Ostrov which is the area between the Danube, the Little Danube and the Vah. The model area is shown in Fig. 4.3.

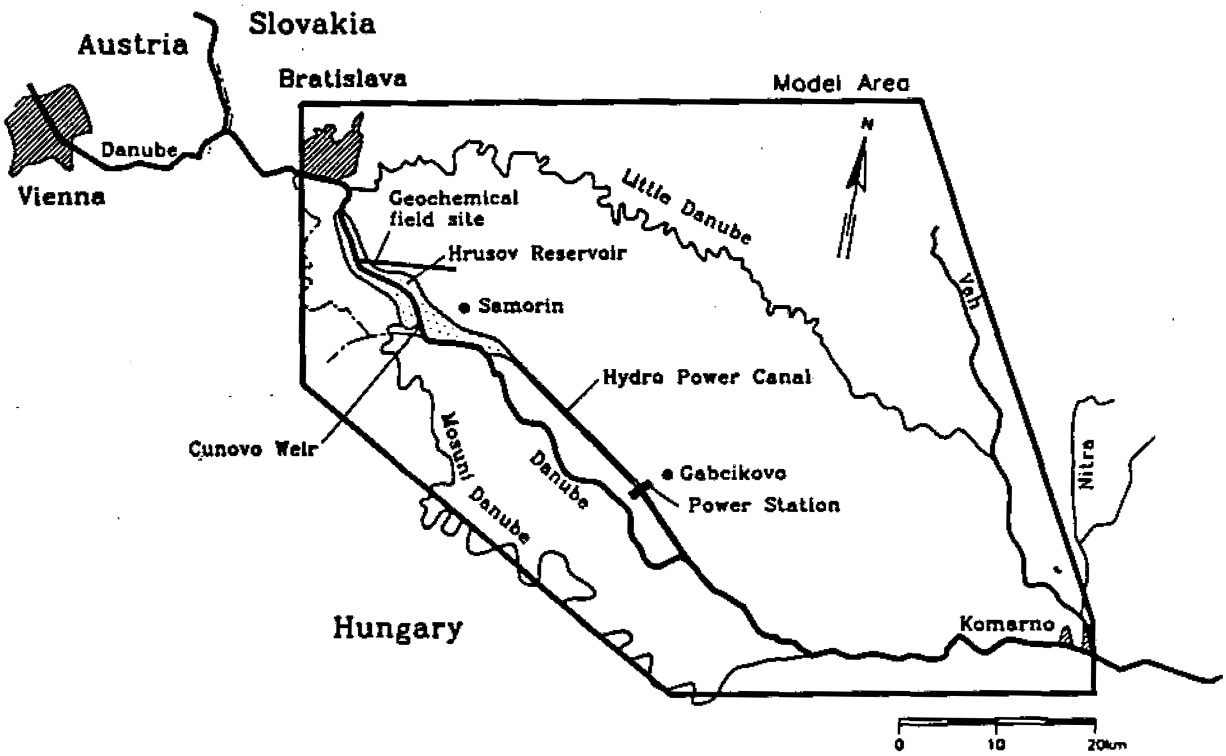


Fig. 4.3 Extent of the regional model area.

The model setup is based on information on location of river systems and cross sectional geometry, surface topography, climatology, land use and cropping pattern soil physical properties and hydrogeology. The setup for the two regional models reflecting pre- and post dam conditions is basically the same. The only difference is that the post-dam model includes the Hrusov reservoir and related hydraulic structures and canals.

The ground water flow regime on Žitný Ostrov is to a large extent controlled by the water level dynamics of the river. Time series of ground water levels measured at locations close to the Danube show a high degree of correlation with the water level fluctuations in the Danube. In general, precipitation does not affect the ground water dynamics significantly.

In order to model the ground water flow regime within the model area it is therefore of the utmost importance that the river models are simulating the water level dynamics in the Danube correctly. The river model that are used in the ground water modelling is identical to the MIKE 11 river model of the Danube, which has been successfully validated.

The regional ground water models apply a horizontal discretization of 1000 m and in the vertical the aquifer has been divided into geologically determined computational layers.

The pre-dam model was calibrated against measured ground water levels, discharge and water levels for the three year period from 1989 to 1991. In general, the simulated ground water levels are close to the measured levels, and in areas that are highly influenced by the Danube the ground water level fluctuations are also very well simulated (see well no. 718 and no. 7154). In the more inland eastern areas the ground water levels are controlled by the relationship between precipitation and evapotranspiration. In such area a seasonal behaviour is observed with low ground water levels during the summer and higher levels in the winter and the spring. This seasonal behaviour is not simulated by the model (see well 616). The main part of the model is considered as calibrated but some minor adjustment will be made in the beginning of project Phase II. A comparison between simulated and measured ground water levels for three typical wells is shown in Fig. 4.4.

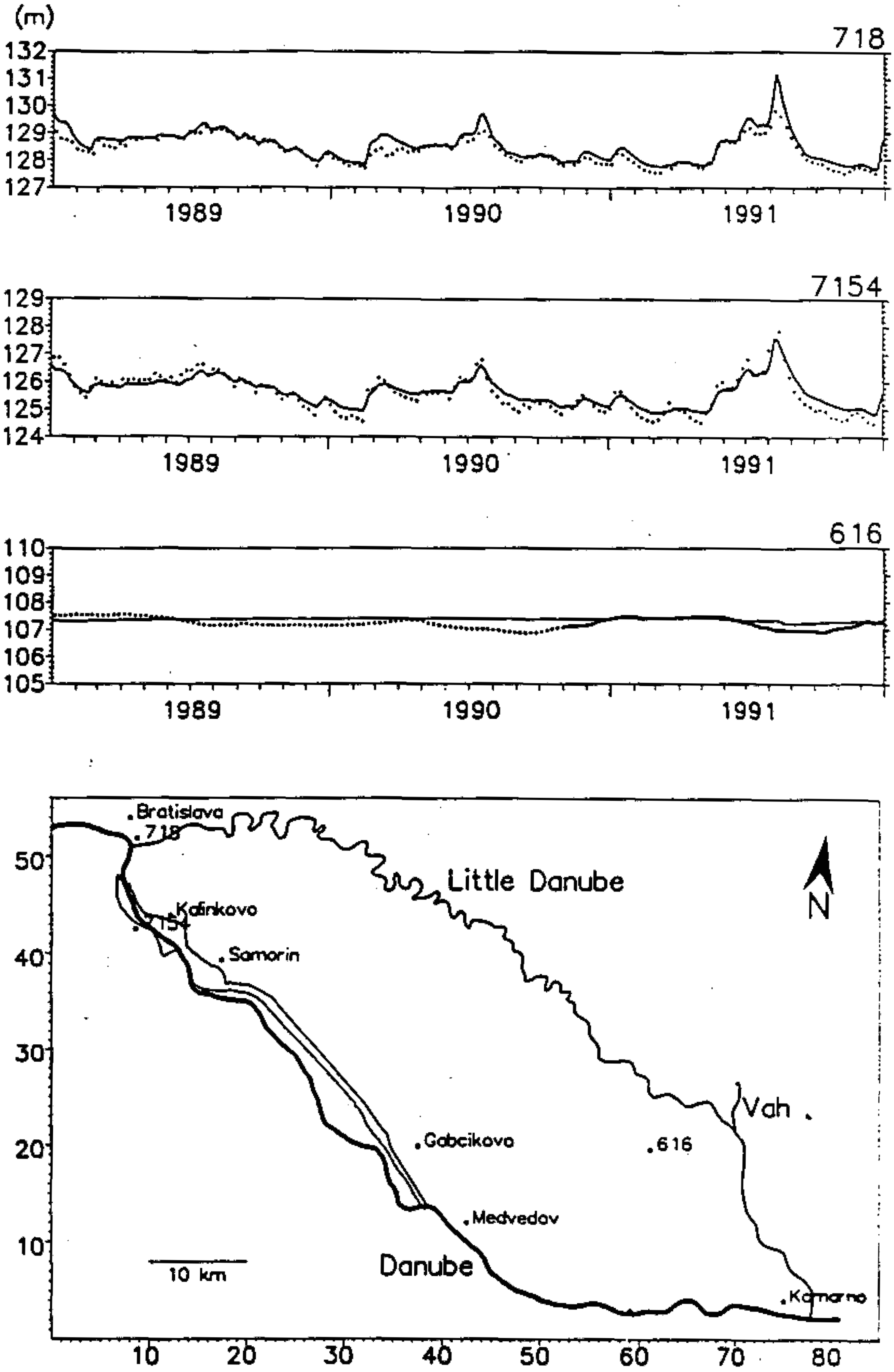


Fig. 4.4 *Location of wells and comparison of simulated and measured ground water levels in well no. 718, 7154 and 616. Model calibration, pre-dam conditions.*

The ground water model will be validated by demonstrating the ability to reproduce measured ground water levels after the damming of the Danube. In this regard the only change from the pre-dam model is the inclusion of the Hrusov reservoir and related canals and hydraulic structures. The validation cannot be finalized before the pre-dam model is finally calibrated, but some preliminary validation runs indicate that the post-dam conditions can be simulated without further calibration of the calibrated pre-dam model. A comparison between measured and simulated ground water levels for well no. 7154 is shown in Fig. 4.5. Well no. 7154 is located close to the Hrusov reservoir where the largest changes has occurred after the damming of the Danube.

The final model validation will be carried out for a longer period comprising 1993 and 1994.

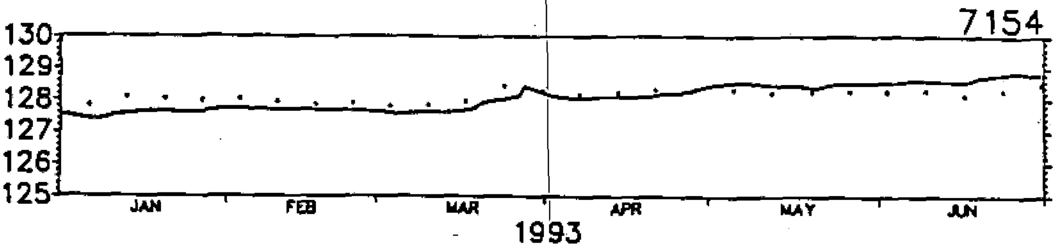


Fig. 4.5 *Comparison of simulated and measured ground water levels in well no. 7154. Model validation, post-dam conditions.*

The ground water model for the reservoir area is a sub-model to the post-dam regional model and the setup of the local model is identical to the setup for the regional model. The only change is that the local model applies a horizontal discretization of 250 m.

The local model receives time varying ground water levels from the regional post-dam model as boundary condition and therefore it cannot be finalized until the validation of regional model has been accomplished.

The local model provides a more detailed description of the ground water flow regime in the vicinity of the reservoir which will be used for the geochemical modelling activities around the major water supply installations at Kalinkovo and Samorin.

The calibration of the pre-dam model will be finalized in the beginning of project Phase II. Subsequently the validation of the post-dam model and finalization of the local reservoir model will be accomplished.

4.6 Pollution Status of Reservoir Sediments

A geochemical field investigation focusing on the pollution status of flood plain sediments which are now an inundated part of the reservoir has been carried out.

Shallow soil samples were collected and analyzed for some soil bulk parameters comprising seven metals, and a selected set of organic variables like PAH's, VOC's, etc. Total contents and oxides-extractable contents were measured for the metals, respectively. The latter is used to estimate the release of trace metals from oxides following potential reductive dissolution of (Fe-)oxides in association with enhanced infiltration of DOC after filling the reservoir.

The data show that relatively high contents of PAH's are found along the Danube river. High contents are also found for Ni and it seems that Ni can behave mobile. Calculations on the release of trace metals by reductive dissolution of Fe-oxyhydroxides, suggest that concentrations above Slovak drinking water limits may happen for Ni if infiltrating Danube river water has high DOC contents. The risk for high Cu concentrations in the ground water is much smaller because Cu binds strongly to organic matter present in the sediment.

4.7 Ground Water Quality

4.7.1 Geochemical field investigations at Kalinkovo

A geochemical field investigation has been carried out in a cross-section north of the reservoir near Kalinkovo (see Fig. 4.3).

This investigation was directed towards the development of groundwater quality during infiltration of Danube river water into the aquifer. It has been suggested that a change in groundwater quality may happen after damming the Danube due to enhanced infiltration of dissolved organic matter in the gravel aquifer.

Eleven multi-screen wells were installed forming a 7.5 km long cross-section close to the water supply wells at Kalinkovo.

The multi-screen wells have been sampled frequently to investigate the ongoing (bio)geochemical processes during infiltration of Danube river water into the aquifer.

A seasonal fluctuation in the concentrations of various species with a delay compared to the fluctuation of the Danube river water was observed for the screens that are close to the Danube.

Interpretation of collected data indicates slow denitrification by both solid and dissolved organic matter and reductive dissolution of Mn-oxides, possibly manganite. It is not known whether or not the two redox processes interact.

4.7.2 Ground water quality model

A mathematical model has been developed that includes kinetic denitrification by solid organic matter coupled to reductive dissolution of Mn-oxides. The model consists of three components:

1) advective/dispersive transport of all chemical components
2) kinetically-controlled denitrification, and
3) (pseudo) equilibrium-controlled speciation and equilibrium-controlled inorganic chemistry.

The denitrification module is a simple, empirical first-order denitrification model, having two parameters. These parameters are a rate parameter and an apparent equilibrium constant for the redox couple NO_3/NO_2. The rate parameter determines the rate of denitrification and the equilibrium constant determines the occurrence of NO_2 as intermediate denitrification product.

The model has been tested for a simple geohydrological system based on geochemical data from Kalinkovo. These tests have shown that the geochemical model behaves qualitatively correct. It is planned that the denitrification model will be extended with the option for denitrification under consumption of dissolved organic carbon in addition to consumption of solid organic matter.

Conservative transport of $\delta^{18}O$ in the Kalinkovo cross-section and reactive transport has been modelled. The setup of a cross-sectional ground water flow model was based on the setup for the regional model ground water model. An example of a model simulation is given in Fig. 4.6 which shows simulated distribution of $\delta^{18}O$ in the Kalinkovo cross-section in April 1994 and a comparison of measured and simulated $\delta^{18}O$ in one of the wells at Kalinkovo.

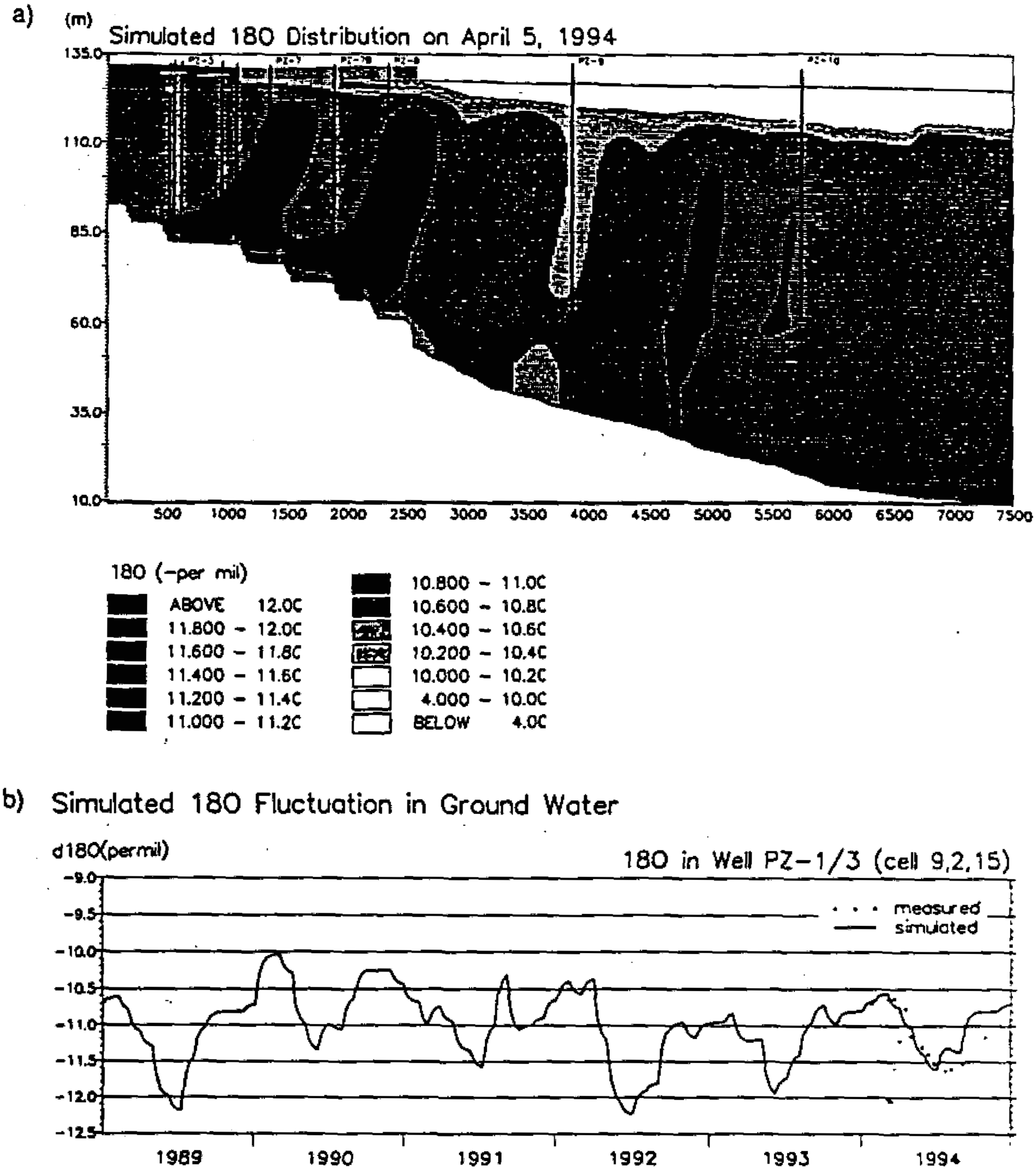


Fig. 4.6 Model results from the Kalinkovo cross-section. a) Modelled distribution of $\delta^{18}O$ in April 1994 and b) Comparison between measured and modelled $\delta^{18}O$ in one of the wells in the cross-section.

$\delta^{18}O$ can be used as a conservative tracer since the Danube river shows a seasonal fluctuation for that compound. The patterns found for $\delta^{18}O$, nitrogen-species and manganese can roughly be reproduced by the models. However, further improvement of the model on spatial variation in geohydrological as well as geochemical variables is necessary.

4.8 Unsaturated Zone and Agricultural Modelling

The objectives of the agricultural studies were to evaluate the impact on agricultural potential and nitrate leaching risk on Žitný Ostrov, due to the damming of the Danube.

The applied modelling system is the DAISY model which simulates crop growth, water flow in the unsaturated zone and nitrogen transport and turnover.

The model was calibrated on the basis of data from field experiments carried out during the years 1981-1987 at the experimental station in Most near Bratislava. During this process the crop parameters used in the model were adjusted to Slovak conditions.

After the initial setup and calibration, the model performance was evaluated through preliminary simulations using data from a number of plots located on an experimental field site at Lehnice. On the basis of comparisons between measured and simulated values of nitrogen uptake, dry matter yield and nitrate concentration in soil moisture, the model performance under Slovak conditions was considered satisfactory.

Modelling of the pre-dam and post-dam conditions regarding agricultural potential and nitrate leaching risk was carried out using a representative selection of soil units, cropping pattern and meteorological data covering the area of Žitný Ostrov. The simulations were conducted with a one year warming up period followed by a four-year period with climatological data representing an average, a dry, a wet and an average year, respectively.

The results of the DAISY simulation did not indicate a significant change in the agricultural production.

A minor reduction in the irrigation requirements from 32.5 mm (pre-dam) to 30.5 mm (post-dam) were simulated. These are average values for the entire Žitný Ostrov.

The simulated nitrate leaching was generally low and only minor changes from pre- to post-dam conditions were simulated. The nitrate leaching was 2.2 kg N/ha year (pre-dam) and 2.3 kg N/ha year (post-dam), respectively.

The DAISY simulations only comprised three different crops whereas the actual situation in the area is far more diverse. In addition, the lower boundary conditions (ground water levels) in the soil columns were held constant during the simulations.

In reality the ground water levels are, in some areas, highly fluctuating, which may play a role for the amount of nitrate leaching as well as for the irrigation requirements and the agricultural production.

The DAISY modelling to be carried during project Phase II will be based on time varying ground water levels simulated with the regional MIKE SHE ground water model as lower boundary condition.

Simulations will also be carried out for a more realistic cropping pattern including more crops providing a more precise picture of the conditions on Žitný Ostrov.

4.9 River and Reservoir Hydrodynamic Modelling

The main objectives for the hydrodynamic modelling are to provide calibrated and validated flow models to be used in relation to water quality, eutrophication and sediment transport modelling.

The applied modelling systems are the hydrodynamic module of MIKE 11 and MIKE 21.

The following models have been setup, calibrated and validated:

- one-dimensional MIKE 11 model for the Danube from Bratislava to Komarno
- one-dimensional MIKE 11 model for the river branch system at the Slovak floodplain.
- two-dimensional MIKE 21 model for the Hrusov reservoir.

The MIKE 11 models have been established in two versions reflecting post- and pre-dam conditions, respectively.

MIKE 11 on Danube
The setup of the MIKE 11 model for the Danube is based on river cross sections measured in 1989 and 1991.

The applied boundary conditions were measured daily discharge at Bratislava (upstream) and a Q-h relation at Komarno (downstream).

The model was initially calibrated for two steady state situations reflecting a low flow situation (905 m^3/s) and a flow situation close to the long term average (2390 m^3/s), respectively. Subsequently, the model was calibrated against water levels and discharges measured at Bratislava, Medvedov and Komarno in 1991.

The model was finally validated by demonstrating the ability to reproduce measured data from 1990. Fig. 4.7 shows the results of the model validation from Medvedov.

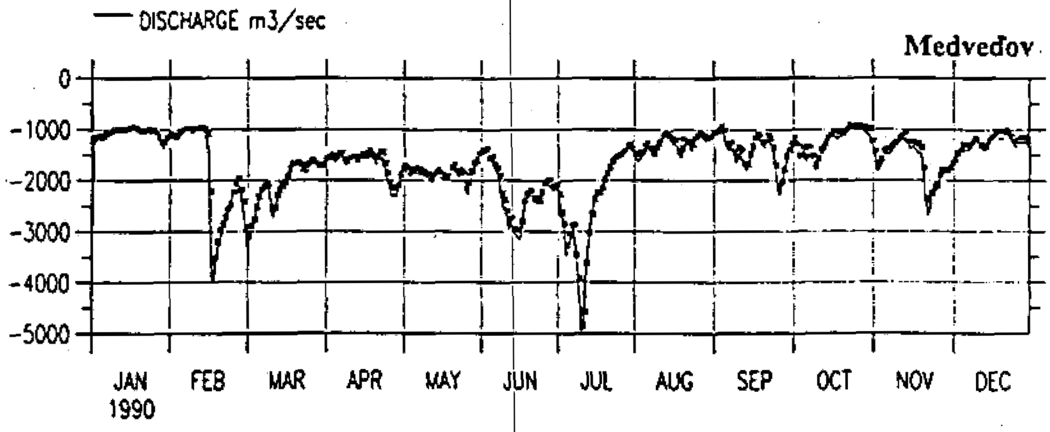


Fig. 4.7 Validation of MIKE 11 model for the Danube for pre-dam conditions.

For the post-dam model some river reaches were updated with cross-sections measured in 1993. In addition the reservoir and related hydraulic structures and canals were included. The model was validated against measured data from November 1992 to March 1993.

MIKE 11 on river branch system

The Slovak and Hungarian floodplain are at many locations characterized by a complex system of river branches. The area referred to as the river branch system covers about 20 km of the Slovak flood plain between the Old Danube and the hydro power canal. A layout of the river branch system is shown in Fig. 4.8.

This area is of major ecological interest and is one of the key areas for the ecological studies in this project (cf. Section 4.12).

The cross-sections in the river branch system were measured during the 1960's and 1970's.

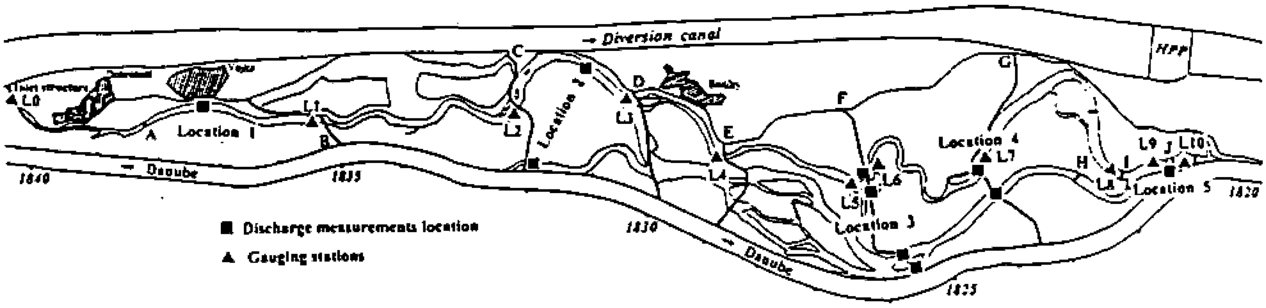


Fig. 4.8 Layout of the river branch system.

In the post-dam situation the branch system is fed by an inlet structure with water from the hydro power canal (on the figure denoted diversion canal). The system consists of a number of compartments separated by small dikes (lines C-D). On each of these dikes combined structures of culverts and spillways are located enabling some control of the water flows in the system.

Only very scarce and not very reliable data on flow and water levels in the river branch system was available. Therefore, a programme comprising measurements of discharges and water levels at a number of locations was carried under this project during the summer 1994. Fig. 4.9 shows results of the model calibration against these data.

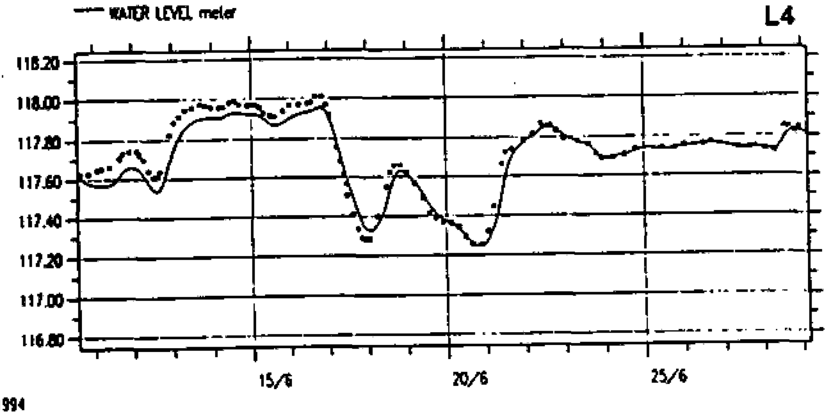


Fig. 4.9 Comparison of measured and simulated water levels with in the calibration period, at one location in the river branch system.

This is closely related to eutrophication, sediment transport, and ecological modelling of the river branch system.

MIKE 21 on the reservoir

A MIKE 21 hydrodynamic model for the Hrusov reservoir has been established. The model has not been finally calibrated and validated. There are two main reasons for that:

1) Flow velocities in the reservoir were not available for model calibration.

2) A new reservoir bathymetry has recently been measured but some data processing needs to be done in order to incorporate the new bathymetry in the model.

Some simulation runs and have been made with the existing model setup. An example of the flow field in the reservoir is given in Fig. 4.10.

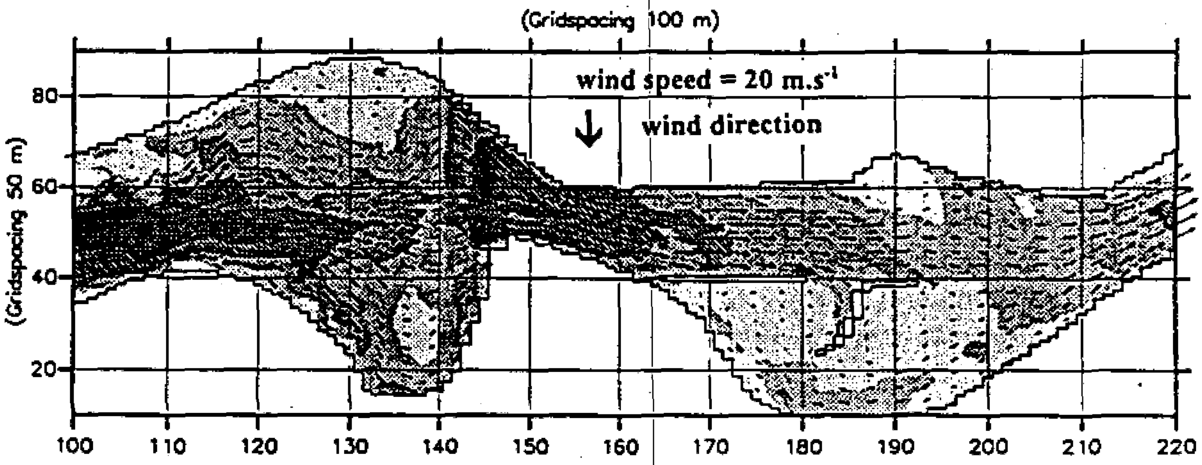


Fig. 4.10 Flow field in the reservoir simulated with MIKE 21.

It is expected that only limited model calibration will be necessary and the model will be finally calibrated and validated early in 1995.

4.10 River and Reservoir Sediment Transport Modelling

The sediment transport modelling was based on the use of existing data on the sediment transport processes prevailing in the Danube river. Few additional measurements were carried out to complement these data. Different sediment transport models covering both the fine suspended sediment (cohesive sediment and fine sand) and the bed load sediment (coarse sand and gravel) were established.

Measurements of concentration of suspended sediment at different cross-sections showed that the suspended load has decreased significantly from the 50'ties to the 90'ties due to construction of new reservoirs and treatment plants upstream of Bratislava. By comparing the grain size distribution of suspended sediment and fine deposited sediment, respectively, representative fall velocities of each class of grain sizes of fine sediment could be estimated.

Based on these measurements and established sediment rating curves, both one-dimensional and two-dimensional sediment transport models of transport of fine (suspended) sediment were established for the Danube river, the reservoir and for the river branch system on the Slovak flood plain between the hydro power canal and the Old Danube. The period from November 1992, when the reservoir was taken into operation, to August 1993 was simulated in the two-dimensional MIKE 21 model. Sedimentation rates in the correct order of magnitude (approximately 10 cm in the sedimentation areas) was simulated.

Various grain sizes (six fractions totally) were included in the mathematical model enabling prediction of the grain size distribution of the new sediment deposits in the reservoir. This information was used together with the simulated thickness of the deposited sediment layer to calculate leakage coefficients for water exchange between the surface water in the reservoir and the groundwater beneath it. Sediment rating curves were estimated at different cross-sections based on the simulated sediment transport rates. Siltation as function of upstream discharge was subsequently derived. From November 1992 to August 1993, the simulated siltation rate (kg/day) was 42% of the total suspended load at Bratislava. Simulated sedimentation in the reservoir during November 1992 to August 1993 is shown in Fig. 4.11.

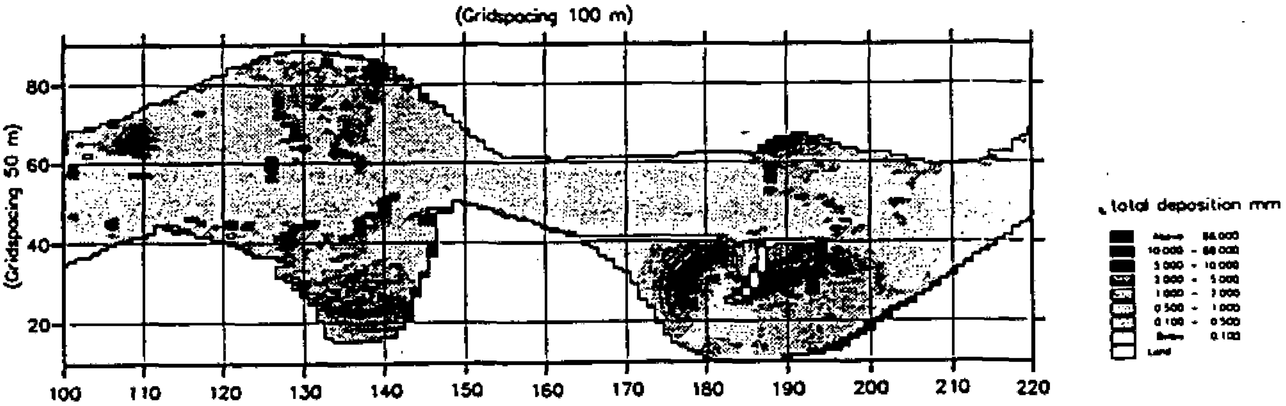


Fig. 4.11 Simulated sedimentation in the reservoir from November 1992 to August 1993.

Alluvial channel bed material was investigated with respect to grain sizes and exhibited significant scatter due to the natural grading of the sediment inside the cross-sections with bars, pools etc. In order to avoid difficulties in determining accurate mean grain sizes for the mathematical model, the change in mean water level over a decade rather than changes in bed elevations was compared between observations and simulations. By using such an approach, perturbations in bed levels from one cross-section to another did not destroy the picture of the overall trends in aggradation and degradation of the river bed. The morphological model predicted the observed erosion downstream Bratislava during the last decades to a very satisfactory degree. The reach between rkm 1820 and rkm 1840 (Old Danube) is characterized by a very complex flow pattern because the Danube interacts with the river branch system. These interactions are not properly described in the hydrodynamic model and consequently the morphological development cannot be properly simulated either.

Simulated and measured erosion of the river bed is shown in Fig. 4.12 which also illustrates the effects of dredging.

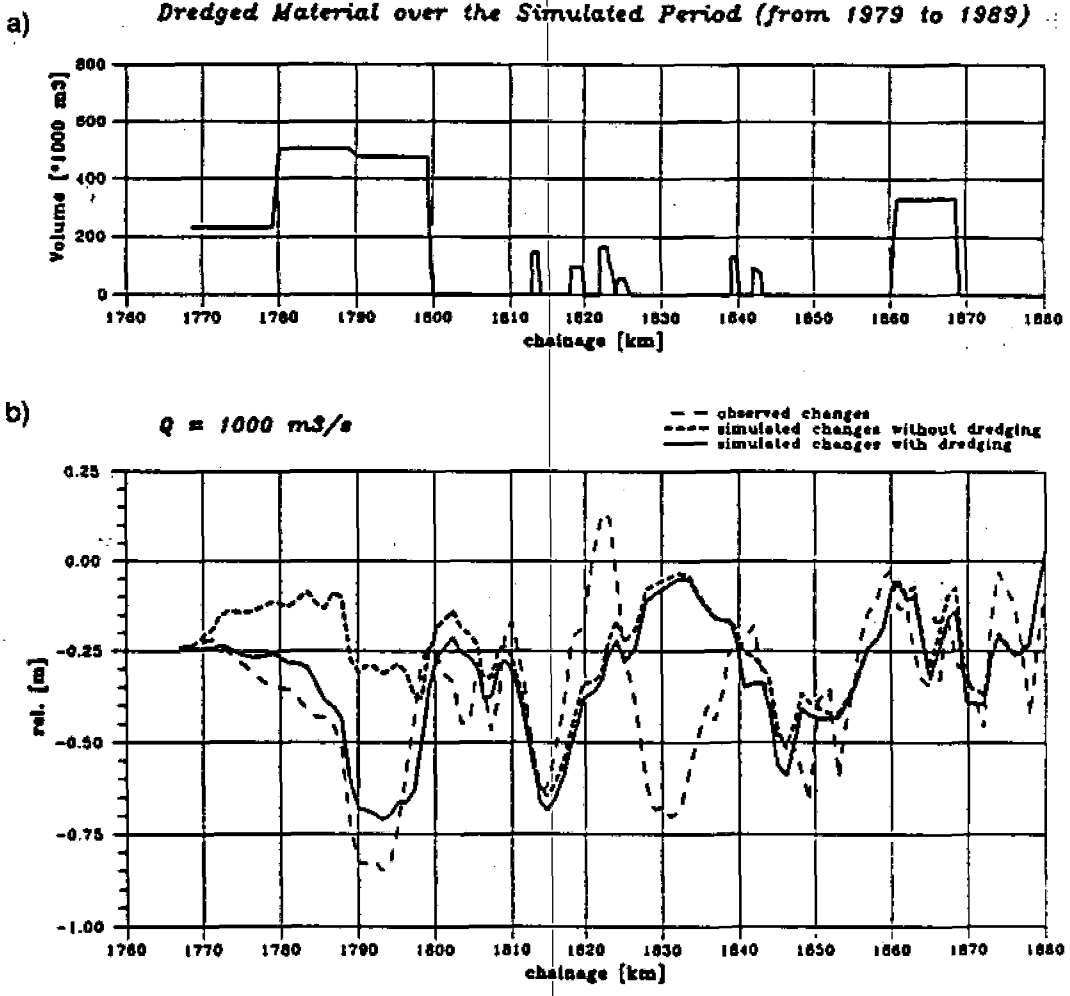


Fig. 4.12 Amount of dredging and the effect of dredging for the morphological development of the river bed.

Subsequently, the morphological model was used to see the effect of the dredging which has been going on over the years. Also the effect of the Gabcikovo Dam was investigated with respect to changes in bottom elevations and mean water levels in the new course of the river as well as in the Old Danube.

4.11 Surface Water Quality Modelling

The goal of the surface water quality modelling was to establish models describing the water quality in the main stream of the Old Danube before and after damming, in the reservoir, and in the river branches, respectively.

A BOD-DO model (MIKE 11 WQ) has been used to describe the water quality in the main stream of the Danube in the pre-dam situation and in the main stream of the old Danube in the post-dam situation. This model describes oxygen concentration (DO) as a function of the decay of organic matter (BOD), transformation of nitrogen components, re-aeration, oxygen consumption by the bottom and oxygen production and respiration by living organisms.

The river branches were simulated with a eutrophication model (MIKE 11 EU), in which the algae production is the driving force. The algae growth in this model is described as a function of incoming light, transparency of the water, temperature, sedimentation and growth rate of the algae and of the available inorganic nutrients.

In the reservoir the driving force is also the algae growth and hence a eutrophication model (MIKE 21 EU) was applied. This model is, in principle, the same as the MIKE 11 EU, but operates in two-dimensional (horizontally) whereas the MIKE 11 EU operates in one-dimensional.

To provide the basis for the modelling existing field data on water quality have been evaluated.

The field measurements show no significant changes in oxygen level in the Danube river from Bratislava to Komarno. The measurement has shown differences in oxygen concentration of up to 1 - 2 mg O_2/l in the river. This difference can be ascribed to the diurnal variation created by oxygen production and respiration of the algae in the river water. Oxygen concentration in the outlet canal from the reservoir have been observed to be 4 mg O_2/l higher than in the upstream river. This may also be due to oxygen production of the algae.

No vertical stratification of the water masses in the reservoir was observed during August and September 1994. The measured data do not indicate increases in BOD-level through the reservoir.

The BOD-DO model (MIKE 11 WQ) has been calibrated and validated to a satisfactory level both for pre-dam and post-dam condition. The model furthermore describes the diurnal variation satisfactorily. A comparison of simulated and measured oxygen concentrations in the Danube is shown in Fig. 4.13.

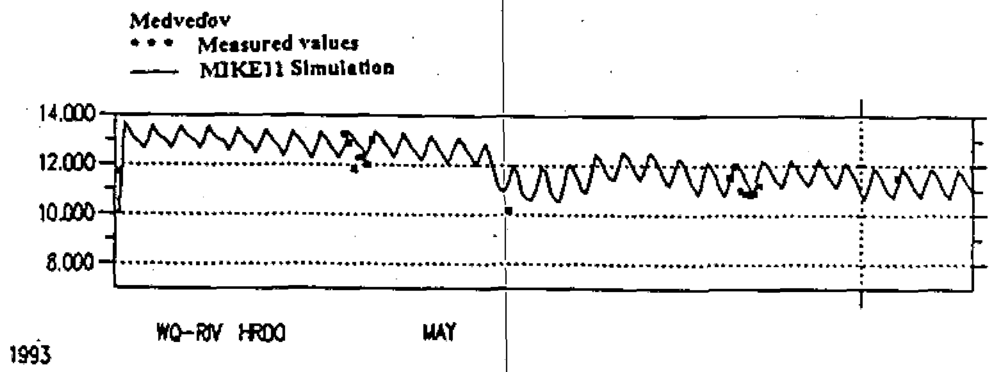
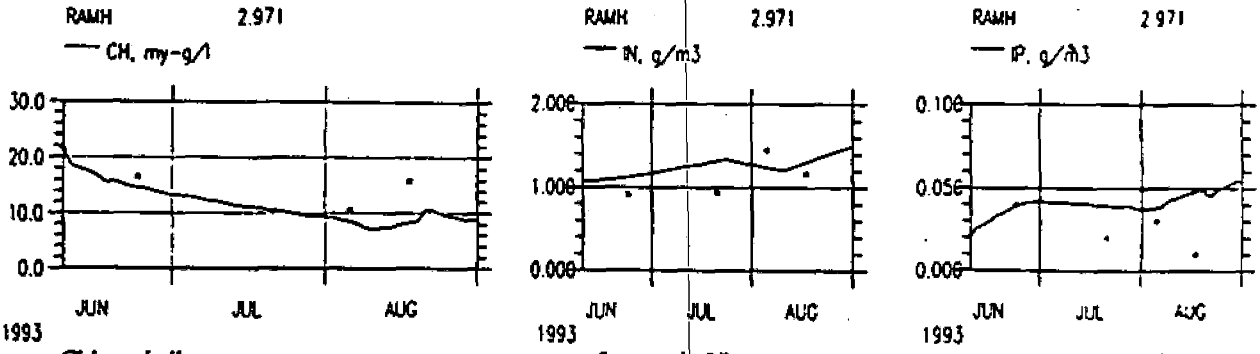


Fig. 4.13 Comparison of simulated and measured oxygen concentrations in the Old Danube. Post-dam situation. Calibration.

The conditions from pre-dam to post-dam have changed significantly, and hence a recalibration of the pre-dam model was necessary to obtain a well calibrated model for the post-dam situation. The pre-dam model was calibrated against data from October 1991 and validated against data from April and August/September 1991 The post-dam situation was calibrated against data from May 1993 and validated against data from June 1993

The calibrated and validated BOD-DO model (MIKE 11 WQ) is now ready for practical use in project Phase II.

Results from a preliminary calibration of the eutrophication model for the river branch system against data from June-August 1993 (MIKE 11 EU) is shown in Fig. 4.14.



Chlorophyll a ***Inorganic Nitrogen*** ***Inorganic Phosphorus***

Fig. 4.14 Comparison of simulated and measured water quality data for the river branch system, (Baka branch).

The simulated phytoplankton production (0.9-1.2 g C/m^2/day) is at the same level as the measured one and algae concentrations have been simulated correct within a difference of few micrograms chlorophyll. A little to high nutrient concentrations are at the moment simulated. Smaller adjustment through a continued short calibration procedure in the first quarter of 1995 is expected to bring this model to a stage where it is ready to use for simulation of different scenarios.

The calibration procedure for the eutrophication model of the reservoir (MIKE 21 EU) has just been initiated and will be finalized in the beginning of project Phase II.

4.12 Floodplain Ecology and Modelling

The ecological studies mainly puts focus on the Hrusov reservoir, the Danube river and the river branch system on the Slovak floodplain between the hydropower canal and the Old Danube.

An ecological management tool has been developed. It is based on output from the established integrated modelling system and a number of criteria that links model results to a number of different ecotopes.

The integrated modelling system provides data regarding:

- water quality and eutrophication
- sedimentation regime
- surface water flow regime, and
- subsurface flow regime

The ecological criteria are directly comparable with processed model results. The criteria are, for instance, expressed in terms of:

- frequency, duration and depth of floodings
- minimum depth to ground water table
- variations in ground water table
- flow velocities in rivers
- primary production

A detailed model of the river branch system on the Slovak floodplain has been established. This model is based on the coupled version of MIKE 11 and MIKE SHE and describes the complex network of river branches, their interactions with the subsurface flow regime and the Old Danube.

The model setup is based on the MIKE 11 model for the river branch system and the MIKE SHE regional ground water model for post dam conditions. The model was setup in a network of 100 m grid squares.

The model has not yet been finally calibrated but even without any calibration the model results corresponds rather well to measured data. Measured data indicates that about 80% of the water that enters the system is lost in the river branch system. The simulated water losses, during July and August 1993, corresponds very well to that amount. Therefore, it is expected that only very limited model calibration is required.

An example of model results is given in Fig. 4.15 which shows the extent and depth of flooding in the river branch system in July 1993.

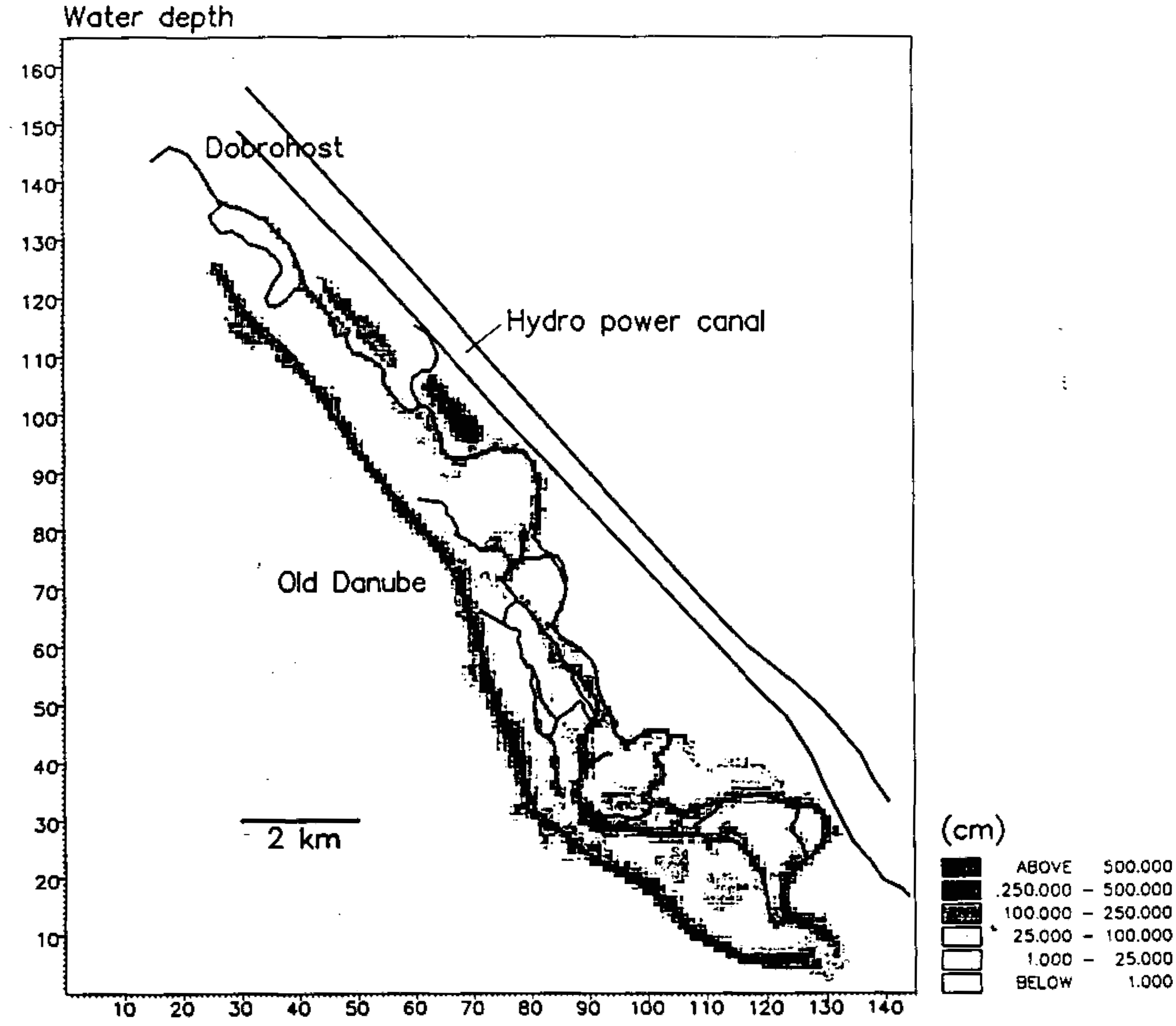


Fig. 4.15 Simulated areal extent and depth of flooding on 25 July 1993.

The established model of the river branch system reflects the conditions after damming of the Danube. A model for the pre-dam conditions will be established in the beginning of project Phase II.

5 PROPOSED APPLICATION SCENARIOS

5.1 Objectives

One of the primary objectives of the PHARE project is to prepare an integrated modelling system that can support management decisions within the following fields:

- *Ground water* with emphasis on safeguarding the ground water quality at the existing well fields.
- *Agriculture* with emphasis on water supply from ground water, irrigation practice and efficient use of fertilizers.
- *Ecology* with emphasis on the conditions in Danube, the river branch system and the reservoir and the management aspects in this regard.

Such an integrated modelling system has been developed during Phase I of the project and is now ready for practical use. Realizing that the management possibilities are numerous and that the entire system is very complex, only a limited number of scenarios can in practise be carried out under Phase II of the project. Therefore, the aim of the scenario calculations to be made under Phase II is to give relevant examples of the application of the integrated modelling system for prediction of environmental impacts of alternative management decisions.

The specific scenarios for which model calculations will be carried out in Phase II will be decided jointly by the Slovak Ministry of the Environment and the Consultant. The following is a first suggestion from the Consultant in this regard.

5.2 Terminology and General Framework for Formulation of Scenarios

The following terminology is used:

- A *Water Management Regime* is here defined by the operation rules for the major structures at Cunovo, Dobrohost and Gabcikovo for the post-dam conditions and no regulation for the pre-dam conditions. Thus, given a hydrological time series of Danube inflow at Bratislava, the overall discharge regime can be explicitly calculated. Hence, the selected Water Management

Regime defines the water management as far as the overall discharges are concerned.

- *Management Options* are here defined as options for management of the system under a given Water Management Regime, e.g. all management possibilities except for changes in the prespecified discharges at the three major structures that define the Water Management Regime.
- A *Scenario* is defined as calculations of conditions for groundwater, agriculture or ecology under a given Water Management Regime and one management option. Two fundamentally different types of scenarios are defined, namely *Reference Scenarios* and *Management Scenarios*.
- A *Reference Scenario* describes past conditions and is used for comparing impacts of present and future management options.
- A *Management Scenario* describes present or possible future conditions resulting from alternative management options. Hence, a Management Scenarios may comprise several sub-scenarios describing alternative management options.

The following general conditions have been assumed for the management scenarios:

- Scenarios will be limited to areas on Slovak territory.
- The presence of the Gabcikovo-Cunovo structures and the Hrusov reservoir (Variant C) forms the framework for all post-dam scenarios.
- Scenarios should be directed at key areas from an ecological or management perspective.
- The different scenarios should differ significantly from each other in order to show impacts of importance for the decision making.

5.3 Outline of Water Management Regimes

The following four water management regimes will be considered:

I. Pre-dam 1990.
The water management regime in 1990 will serve as a reference for the pre-dam situation for ground water conditions, agriculture and ecology. This regime is characterized by no regulation at Cunovo, Dobrohost and Gabcikovo and by the river topography from around 1990.

II. Post-dam (400 m³/s).
This regime is represented by the water management which has taken place since the filling of the side branches, i.e. since summer 1993. The discharge regime is characterised by an average annual discharge at Cunovo to the Old Danube of about 400 m³/s and an average intake to the river branches at Dobrohost of about 40 m³/s.

III. Post-dam (800 m³/s).
An allocation of 800 m³/s and 40 m³/s as average annual discharge to the Old Danube and intake to the river branches, respectively.

IV. Still to be decided.
Based upon the evaluation of the various management scenarios on groundwater conditions, agriculture and ecology, which will be done for water management regimes II and III it may be decided to define a new water management regime and carry out a few management scenarios.

In order to enable direct comparison of the scenarios under different water management regimes the model calculations must be carried out using the same basic Danube discharge time series at Bratislava. Therefore, a time series of measured daily discharges at Bratislava for a 5 - 10 years period will be selected and used in all calculations. This period will be selected so that it is adequately representative for the Danube discharge regime with respect to average flow as well as to low flows and high flows.

5.4 Outline of Selected Management Fields and Options

The fields which have been selected for describing the impacts of the different water management regimes are listed below together with a description of those management options, which are intended to be studied in the management scenarios:

A. Ground water

A.1 General ground water levels and dynamics in the project area.

A.2 Water quality at Kalinkovo.
Management options: Alternative locations of wells.

A.3 Water quality at Samorin.
Management options: Alternative locations of wells.

B. Agriculture

B.1 Agricultural potential production, irrigation requirements and nitrogen leaching in Žitný Ostrov.
Management options: Irrigation, fertilization and cropping pattern.

C. Ecology

C.1 Danube main river.
Management options: Underwater weirs, fish passes, sediment management.

C.2 Dobrohost floodplain.
Management options: Underwater weirs in the Old Danube or other measures to improve the hydraulic connectivity between the main river and the side branches.

C.3 Hrusov reservoir.
Management options: Reservoir operation (water levels, internal flow pattern) aiming at furthering ecological functioning and preventing water quality problems such as eutrophication, oxygen depletion, sedimentation in areas where the main infiltration for the water works occurs.

5.5 Overview of Scenarios

Combining the water management regimes described in Section 5.3 and the management fields and options described in Section 5.4 an overview of the model calculations for the scenarios is provided in the "scenario matrix" in Table 5.1.

The pre-dam 1990 water management regime forms the basis for the reference runs A.1 - C.2, whereas C.3 is not relevant because the reservoir did not exist at that time.

For the post-dam water management regimes II + III the management options for the respective areas are indicated. It is envisaged that a couple of model simulations are carried out for each management scenario.

Table 5.1 Scenario matrix describing the combination of water management regimes I-IV and management fields A.1 - C.3.

	A. Ground Water			B. Agriculture	C. Ecology		
	A.1 General	A.2 Kalinkovo	A.3 Samorin	B.1 Production Irrigation req Nitrogen leach	C.1 Danube channel	C.2 Floodplain	C.3 Reservoir
Water Management Regime							
I. Pre-dam 1990	Reference	Reference	Reference	Reference	Reference	Reference	-
II. Post-dam ($400\ m^3/s$)	SC	LW	LW	IR, FE, CR	UW, SM	UW	RO
III. Post-dam ($800\ m^3/s$)	-	-	LW	-	UW, SM	UW	RO
IV. To be decided later	?	?	?	?	?	?	?

Legend for management options under water management regime II-IV:

-	No scenario
SC	Operation of water level in seepage canal
LW	Well location
IR	Irrigation
FE	Fertilization
CR	Cropping pattern
UW	Underwater weirs
SM	Sediment management
RO	Reservoir operation
?	Not yet decided

5.6 Detailed Description of Water Management Regimes

5.6.1 General assumptions

As the hydrological basis for the calculations of the different water management regimes the time series comprising daily values of measured discharges at Danube, Bratislava for the period 1986 - 1991 will be used. This period has an average discharge of 2027 m^3/s, which is very close to the long term average.

For pre-dam conditions the inflow to Little Danube has been assumed to be 10 m^3/s, while the inflow to Mosoni Danube between Cunovo and Dunakility has been assumed to be 0 m^3/s. These two discharges are assumed to be constant in time.

For post-dam conditions the inflow to Little Danube has been assumed to be 30 m^3/s, while the intake to Mosoni Danube at Cunovo has been assumed to be 25 m^3/s. These two discharges are assumed to be constant in time.

As the river branch system on the Hungarian side of the Danube is not included in the modelling system the inflow to Mosoni Danube is here treated as a loss term.

The assumed operation rules for separation of the discharge at the three main hydraulic structures at Cunovo, Dobrohost and Gabcikovo is described in the following subsections. A summary of the resulting discharge regimes is provided in Table 5.2.

Table 5.2 Discharge characteristics (in m^3/s) of the four different water management regimes described in Subsections 5.6.2-5.6.5.

	I. Pre-dam 1990	II. Post-dam (400 m^3/s)	III. Post-dam (800 m^3/s)	IV. Still to be decided
Average flows for 1986-91 period				
- Danube at Bratislava	2027	2027	2027	2027
- Little Danube	10	30	36	36
- Mosoni Danube	0	25	25	25
- Old Danube at Cunovo	2017[2]	393	732	?
- Intake at Dobrohost	-	45	45	?
- Gabcikovo[1]	-	1469	1130	?
Maximum flows over period[3]				
- Danube at Bratislava	9032	9032	9032	9032
- Old Danube at Cunovo	9022[2]	5598	5598	?
- Intake at Dobrohost	-	234	234	?
- Gabcikovo	-	3080	3080	?
Minimum flows over period				
- Danube at Bratislava	755	755	755	755
- Old Danube at Cunovo	745[2]	100	133	?
- Intake at Dobrohost	-	7	7	?
- Gabcikovo[1]	-	480	284	?

Notes:

1) The resulting discharge at Gabcikovo is not fully correct as the interaction with the groundwater system has not been considered in the present table. More accurate figures will be calculated as output from the models.
2) The resulting discharge in the Danube is not fully correct as the interaction with the groundwater system has not been considered in the present table. More accurate figures will be calculated as output from the models.
3) The maximum flows are approximate only, as no routing has been considered in the present table.

The discharges for water management regimes II and III for the hydrological year 1991 is illustrated in Figs. 5.1 and 5.2.

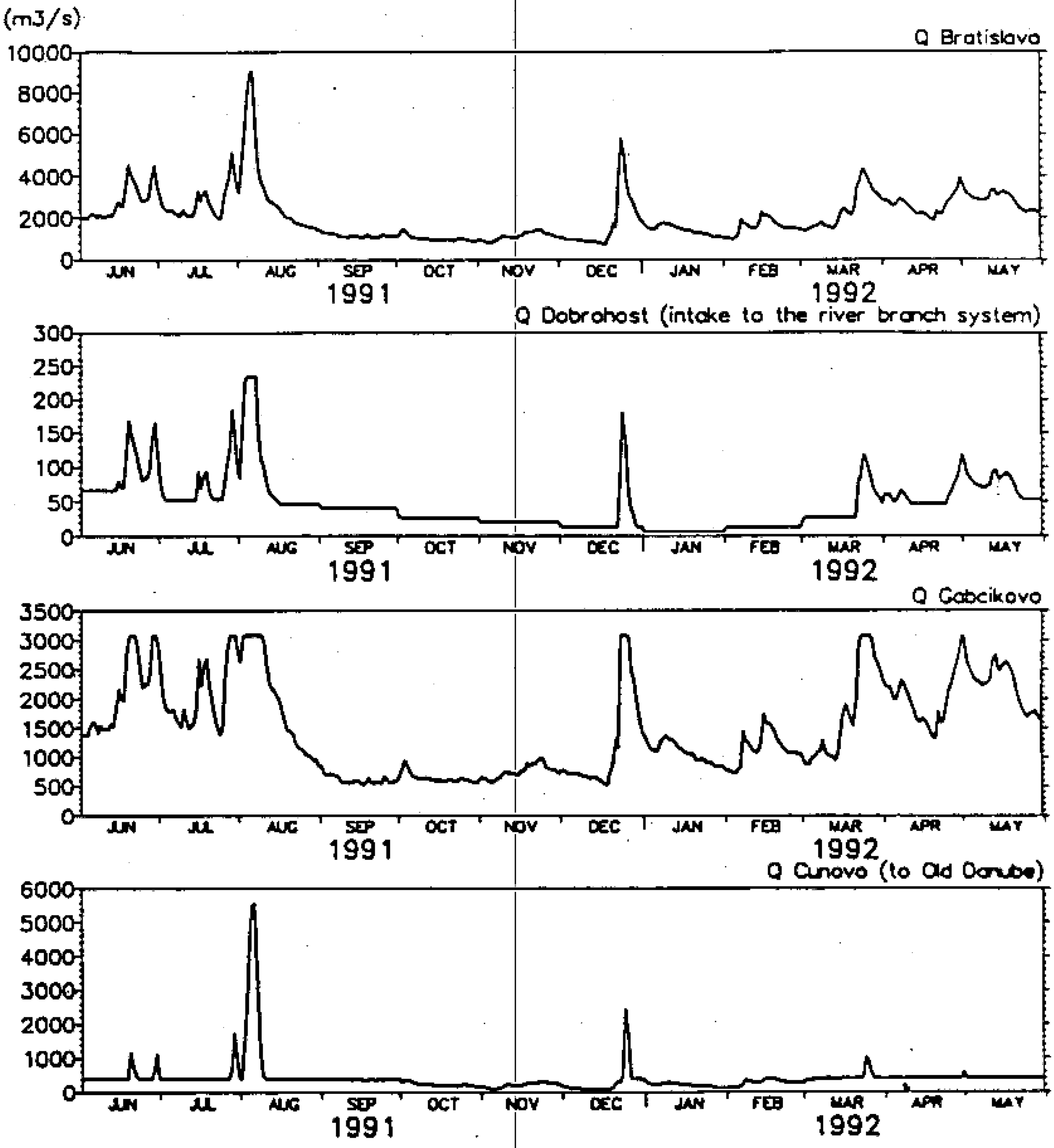


Fig. 5.1 *Discharge for the 1991 hydrological year as it would be for water management regime II.*

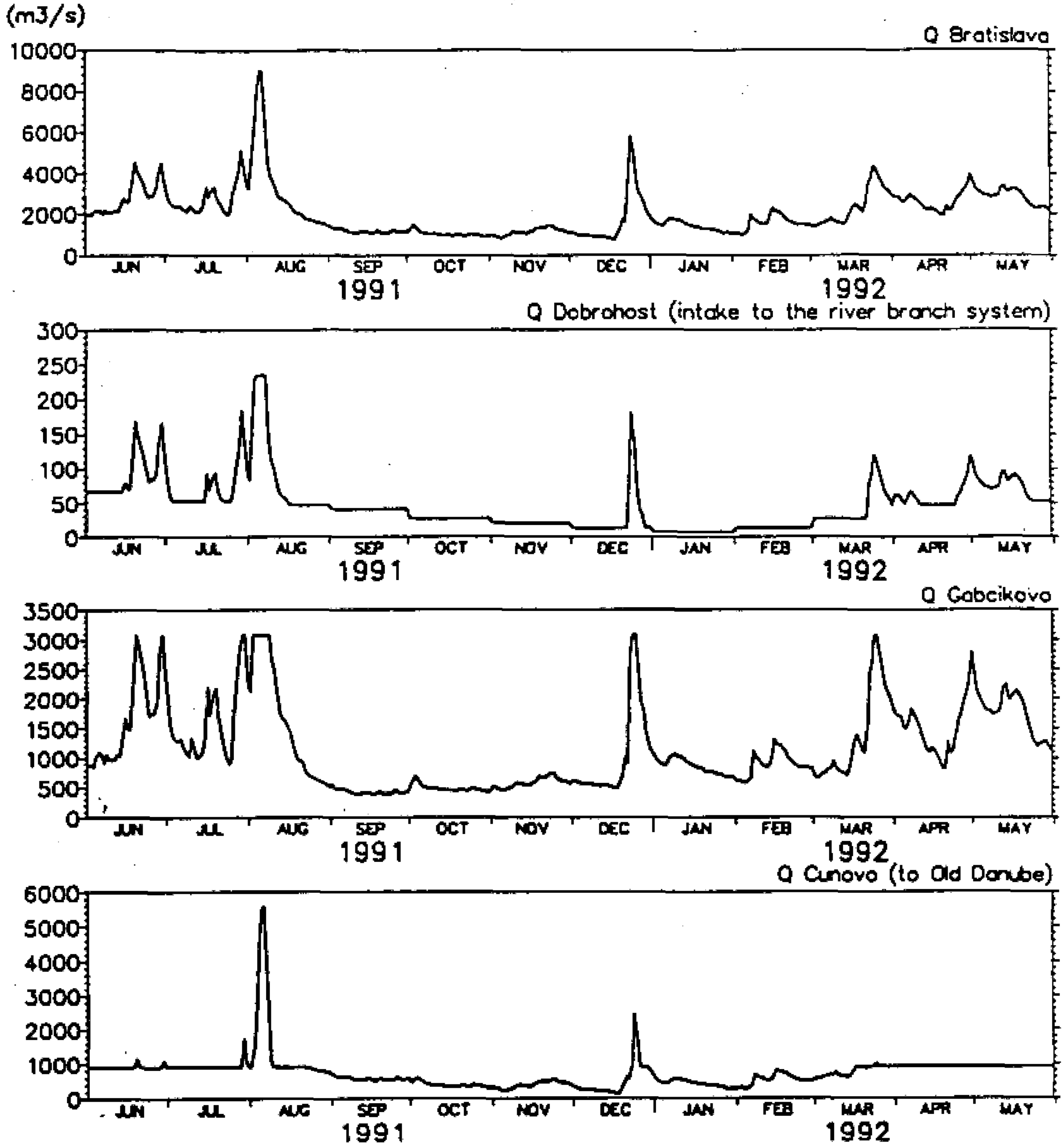


Fig. 5.2 Discharge for the 1991 hydrological year as it would be for water management regime III.

5.6.2 I. Pre-dam 1990

For this water management regime the river morphology existing around 1990 are used. The Danube discharges are determined as the discharge at Bratislava minus the inflow to Little Danube minus the inflow to Mosoni Danube.

5.6.3 II. Post-dam 1990 (400 m³/s)

For this water management regime the river morphology existing in 1994 are used. The Danube discharges (in m³/s) are governed by the following rules, STEP1 - STEP5:

STEP 1: Calculate discharge through bypass weir, $Q_{Bypass\ weir}$:

(a) For discharges in Bratislava, $Q_{Bratislava}$, less than 1200 m³/s:

$$Q_{Bypass\ weir} = 0.45 * Q_{Bratislava} - 120 + Q_{season}$$

(b) For discharges in Bratislava, $Q_{Bratislava}$, larger than 1200 m³/s:

$$Q_{Bypass\ weir} = Q_{Bratislava} - ((Q_{Bratislava} - 1200) * 0.8 + 660) - 120 + Q_{season}$$

where the 120 m³/s comprises the 55 m³/s inflows to Little Danube and Mosoni Danube plus estimated leakages from the reservoir to seepage canals, ground water and Old Danube. Q_{season} is a seasonal modification given in Table 5.3. The minimum and maximum discharges through the bypass weir are 100 m³/s and 400 m³/s respectively.

STEP 2: Calculate the discharge inlet to the river branch system at Dobrohost, $Q_{Dobrohost}$:

(a) For discharges in Bratislava, $Q_{Bratislava}$, less than 2500 m³/s:

$$Q_{Dobrohost} = 40 + Q_{season}/7.5$$

(b) For discharges in Bratislava, $Q_{Bratislava}$, larger than 2500 m³/s:

$$Q^{Dobrohost} = 40 + Q^{season}/7.5 + (Q_{Bratislava} - 2500) * 0.05$$

The maximum discharge through the intake structure at Dobrohost is 200 m³/s.

STEP 3: Calculate the discharge in the power canal downstream of Dobrohost, $Q_{Gabcikovo}$:

$$Q_{Gabcikovo} = Q_{Bratislava} - Q_{Dobrohost} - Q_{Bypass\ weir} - 120$$

The maximum discharge through the power canal, corresponding to full use of five turbines and the shiplocks, is 3080 m³/s.

STEP 4: Calculate the discharge through the inundation weir at Cunovo, $Q_{Inundation\ weir}$:

$$Q_{Inundation\ weir} = Q_{Bratislava} - Q_{Bypass\ weir} - Q_{Dobrohost} - Q_{Gabcikovo} - 120$$

$Q_{Inundation\ weir}$ is always larger than or equal to zero.

STEP 5: Calculate the discharge through the structures at Cunovo to the Old Danube, Q_{Cunovo}:

$$Q_{Cunovo} = Q_{Bypass\ weir} + Q_{Inundation\ weir}$$

Table 5.3 Seasonal modification of discharge, Q_{season} (in m^3/s).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-250	-200	-100	+50	+100	+200	+100	+50	0	-100	-150	-200

5.6.4 III. Post-dam 1990 (800 m³/s)

This water management regime is identical to water management regime II except for the calculation of the discharge through the bypass weir. Thus STEP 1 is replaced by the following:

STEP 1: Calculate discharge through bypass weir, $Q_{Bypass\ weir}$:

(a) For discharges in Bratislava, $Q_{Bratislava}$, less than 1200 m³/s:

$$Q_{Bypass\ weir} = 0.60 * Q_{Bratislava} - 120 + Q_{season}$$

(b) For discharges in Bratislava, $Q_{Bratislava}$, larger than 1200 m³/s:

$$Q_{Bypass\ weir} = Q_{Bratislava} - ((Q_{Bratislava} - 1200) * 0.6 + 480) - 120 + Q_{season}$$

The minimum and maximum discharges through the bypass weir are 400 m³/s and 900 m³/s. It is realized that discharges larger than 500 m3/s are beyond the hydraulic capacity of the present structure. Thus, in order to achieve higher daily discharges a considerable amount of construction work will be required. This will be possible through the new weir planned for construction as part of Phase II of the Cunovo structures.

5.6.5 IV. Still to be decided

The specific content of this water management regime will be decided at a later stage after having evaluated results from II and III.

5.7 Description of Scenarios

For each of the water management regimes listed in Table 5.1 a number of scenarios will be carried out under different water management options. Each of these scenarios involves exchange of data among the various established models. This Section provides an overview of the model simulations that are required for each scenario. Data exchange among the modelling systems will be described and the type and amount of model output will be listed.

5.7.1 Ground water

The ground water flow regime on Žitný Ostrov is mainly controlled by the water levels in the Danube. After damming of the Danube the water levels as well as the dynamics in Danube have been significantly altered and consequently the ground water flow regime has changed. The aim of the model scenarios is to study the impacts of the different water management regimes on the general ground water flow regime within the project area and on the ground water quality at the two large water supply installations at Kalinkovo and Samorin.

A changed flow regime in the reservoir may also change the sedimentation regime. An increased sedimentation in certain areas within the reservoir will affect the amount of infiltrating water. In addition, an increased sedimentation of fine particles will also increase the load of organic matter to the reservoir bottom. This organic matter will degrade under consumption of oxygen which may change the conditions in the reservoir sediment from being oxic to being anoxic. Consequently, the flow regime in the reservoir may be important for the ground water flow regime as well as for the ground water quality. The sedimentation regime in the reservoir will be calculated using the established MIKE 21 HD and MIKE 21 sediment transport models for the reservoir.

The infiltration of water from the reservoir to the ground water and the ground water flow regime will be calculated using the MIKE SHE regional ground water for pre-dam conditions and the coupled versions of MIKE SHE and MIKE 11 for post-dam conditions on local reservoir modelling scale as well as on regional scale.

A.1) General ground water levels and dynamics in the project area

Scenarios
The following three scenarios will be carried out:

A.1.I Reference scenario (Water Management Regime I)

A.1.II Management scenario (Water Management Regime II, post-dam 400 m^3/s)

In order to study the impacts of the operation of the seepage canals on the ground water regime two sub-scenarios will be carried out:

A.1.II.1 The water level in the seepage canals will be kept at the highest operational level by keeping the crest elevations of the weirs in the seepage canals at the maximum level.

A.1.II.2 The water level in the seepage canals will be kept at the lowest operational level.

Model output
For each scenario maps illustrating the ground water dynamics and the ground water levels will be produced. The ground water dynamics will be characterized by the annual sum of ground water level fluctuations (Pegelweg).
The ground water level will be characterized as mean ground water table over the entire simulation period produced from daily values. In order to compare the post-dam scenarios with the reference scenario maps that shows the difference between the reference scenario A.1.I and the sub-scenarios A.1.I.1 and A.1.II.2 will be produced.

Required model simulations and exchange of data among models

MIKE 21
A.1.1) hydrodynamic simulation for water management regime II.
A.1.2) sediment transport simulation for water management regime II.

Maps of leakage coefficients of the reservoir bottom will be produced based on simulation 2. These will be used as input data for the ground water flow simulations (4 and 5). The leakage coefficients will be calculated based on information on simulated areal distribution of sediment, thickness of sediment layer and grain size distribution curves of the sediment, respectively.

MIKE SHE

A.1.3) Water movement simulation for water management regime I.

A.1.4) Water movement simulation for water management regime II, sub-scenario A.1.II.1.

A.1.5) Water movement simulation for water management regime II, sub-scenario A.1.II.2.

Simulation A.1.4 and A.1.5 will be carried out using the coupled version of MIKE SHE and MIKE 11.

A.2) Ground Water Quality at Kalinkovo

Scenarios
In order to study the development of the drinking water quality and the geochemical conditions around the large well field at Kalinkovo the following scenarios will be carried out:

A.2.I Reference scenario (Water Management Regime I, Pre-dam)

A.2.II Management scenario (Water Management Regime II, Post-dam 400 m^3/s).

If the results of the model simulations indicate problems in relation to ground water quality a couple of sub-scenarios may be carried out suggesting alternative locations of the water supply production wells.

Model Output
For each sub-scenario, the ground water quality around the well field at Kalinkovo will be mapped, in terms of concentrations of various nitrogen species (NO_3,NO_2) in the ground water. Results from management scenario A.2.II will be compared with the reference scenario (A.2.I) in order to assess the changes in ground water chemistry due to the damming of the Danube.

Required model simulations and exchange of data among models

MIKE 11

A.2.1) hydrodynamic simulation for water management regime I for the Danube (pre-dam).

A.2.2) water quality simulation for water management regime I for the Danube.

MIKE 21

A.2.3) hydrodynamic simulation for water management regime II.

A.2.4) sediment transport simulation for the reservoir for water management regime II.

A.2.5) eutrophication simulation for the reservoir for water management regime II.

As explained under A.1 results from the sediment transport simulation in the reservoir (A.2.4) will be used to calculate leakage coefficients in the sediment on the reservoir bottom.

Water quality and eutrophication simulations (A.2.2 and A.2.5) will be used to estimate the concentrations of various species (NO_3, oxygen, organic matter) in the water that infiltrates to the ground water from the Danube (pre-dam) and from the reservoir (post-dam), respectively.

Results from DAISY nitrate leaching simulations (simulation B.1.1 and B.1.2) will be used to estimate the concentrations of NO_3 in the water that infiltrates from the ground surface to the ground water.

MIKE SHE

A.2.6)	water movement simulation for water management regime I, scenario A.2.I, regional model.
A.2.7)	water movement simulation for water management regime II, scenario A.2.II, regional model.
A.2.8)	water movement simulation for water management regime I, scenario A.2.I, local model for the area around the reservoir.
A.2.9)	water movement simulation for water management regime II, scenario A.2.II, local model for the area around the reservoir.
A.2.10)	geochemical simulation for water management regime I, based on the flow regime from simulation A.2.8.
A.2.11)	geochemical simulation for water management regime II, based on the flow regime from simulation A.2.9.

The supply wells at Kalinkovo is located adjacent to the upper part of the reservoir. The flow regime in this part of the reservoir will not change significantly from water management regime II to III, and hence the ground water quality will not change either. Therefore, the ground water quality at Kalinkovo is only studied for water management regime I and II.

For the post-dam MIKE SHE simulations (A.2.7 and A.2.9) the water level in the seepage canals will be kept constant reflecting the typical water levels in the canals.

A.3 Ground Water Quality at Samorin

The ground water quality at the well field at Samorin will be subject to the same studies as the ground water quality at Kalinkovo. However, the well field at Samorin is located at the downstream part of the reservoir where the flow regime will be different for water management regimes II and III. Therefore the same simulations as listed above will also be carried out for water management regime III (post-dam, 800 m^3/s).

5.7.2 Agriculture

The depth to the ground water is an important parameter for the agricultural production potential on Žitný Ostrov. The construction of the Hrusov reservoir have, in some areas, significantly altered the ground water flow regime in terms of ground water levels and dynamics. This, may have some affects on the agricultural production potential, in the needs for irrigation and in the amount of nitrate leaching to the aquifers.

B.1 Agriculture

Scenarios
The scenarios listed below will be carried out assuming the same cropping pattern and application of fertilizers as within the period 1986-1991.
The following scenarios will be carried out:

B.1.I Reference scenario (Water Management Regime I, pre-dam)
B.1.II Management scenario (Water Management Regime II, post-dam 400 m^3/s.

Model output
The agricultural production, the irrigation requirements and the nitrate leaching for the two scenarios will be mapped, and specific areas where changes have occurred will be identified.

Required model simulations and exchange of data among models

B.1.1) DAISY unsaturated flow simulations including crop growth for water management regime I, scenario B.1.I.
B.1.2) DAISY nitrate leaching simulations for scenario B.1.I.
B.1.3) DAISY unsaturated flow and crop growth simulations for water management regime II, scenario B.1.II.
B.1.4) DAISY nitrate leaching simulations for scenario B.1.II.

In order to describe the spatial variability within the project area in cropping and application of fertilizers and in amount of irrigation, each of the four points listed above involves a sequence of DAISY simulations that describes different crops, different fertilization policies, different depths to the ground water table and different ground water table dynamics.

Simulated ground water tables from MIKE SHE (simulation A.2.6 and A.2.7) will be used as the lower boundary condition for the DAISY simulations.

5.7.3 Ecology

The ecological studies within this project mainly concentrates on the Danube river, the Hrusov reservoir and the river branch system on the Slovak floodplain between the hydro power canal and the Old Danube, respectively. The damming of the Danube and the construction of the Hrusov reservoir have induced a number of ecological problems but also created possibilities for new ecological developments for instance in the Hrusov reservoir.

Scenarios

With regard to ecology the reference scenarios (pre-dam, 1990) reflects the more or less degraded conditions before the damming of the Danube. If time and data availability allow, the 1960 situation in the Danube and the river branches may also be studied and used as reference scenario. At that time there was still conductivity between the Danube river and the river branch system and the river branches carried a substantial part of the flow in the Danube (about 20%)

In order to characterize the ecological conditions within the Danube, the reservoir and in the river branch system the following scenarios and sub-scenarios will be carried out:

Danube river

C.1.I Reference scenario (Water Management Regime I, pre-dam)

C.1.II Management scenario (Water Management Regime II, post-dam 400 m^3/s).

In order to study the effects of establishing under water weirs in the Old Danube the following two sub-scenarios will be carried out for water management regime II.

C.1.II.1 Without under water weirs in the Old Danube.
C.1.II.2 With under water weirs in the Old Danube. The exact location and geometry of the under water weirs has not yet been decided.

C.1.III Management scenario (Water Management Regime III, post-dam 800 m^3/s)
C.1.III.1 Without under water weirs in the Old Danube.
C.1.III.2 With under water weirs in the Old Danube.

River branch system

C.2.I Reference scenario (Water Management Regime I, pre-dam)

C.2.II Management scenario (Water Management Regime II, post-dam 400 m^3/s).

The water levels and dynamics of the Old Danube significantly affects the ground water levels within the river branch system. In order to study these effects the following sub-scenarios will be carried out:

C.2.II.1 Without under water weirs in the Old Danube.
C.2.II.2 With under water weirs in the Old Danube.

C.2.III Management scenario (Water Management Regime III, post-dam 800 m^3/s)
C.2.III.1 Without under water weirs in the Old Danube.
C.2.III.2 With under water weirs in the Old Danube.

Hrusov Reservoir

C.3.I Reference scenario (Water Management Regime I, pre-dam)

C.3.II Management scenario (Water Management Regime II, post-dam 400 m^3/s)

C.3.III Management scenario (Water Management Regime III, post-dam 800 m^3/s)

Model Output

The ecological conditions in the Danube, the river branch system and the Hrusov reservoir, respectively, will be characterized based on results from water quality modelling, sediment transport modelling and ground water modelling, supported by available field data.

For the Danube river maps describing flow velocities, water quality and sedimentation regime in the river will be produced. These will be provided by various MIKE 11 simulations of the Danube.

For the reservoir the same information as for the Danube is required and will be provided by MIKE 21 simulations.

For the river branch system the necessary data concerning eutrophication and sedimentation regime will be provided by the MIKE 11 model for the river branch system. The coupled version of MIKE SHE and MIKE 11 will be used to predict minimum ground water levels, ground water dynamics (Pegelweg), areal extent of floodings as well as frequency and duration of floodings.

Ecotope mapping

By linking a number of ecological criteria with model simulation results (flow velocities, water quality, sedimentation, ground water dynamics and levels etc.) an ecotope map will be produced for the Danube, the river branch system and the reservoir, respectively.

Connectivity
Flow velocities in the Danube, in the river branch system and on the individual weirs are provided by MIKE 11 hydrodynamic simulations. By combining flow velocities with ecotope maps the possibilities for fish species to migrate between various ecotopes will be described.

Bio-diversity of the river branch system
Based on ecotope maps and a characterisation of flood frequency and peak flows the potential bio-diversity of the river branch system will be described. The bio-diversity of the aquatic component of the system can only be expressed as a combination of ecotopes and connectivity.

Required Model Simulations and exchange of data among models

MIKE 11 (Danube river)

C.1.1) Hydrodynamic simulation for the Danube for water management regime I (pre-dam).
C.1.2) Water quality simulation for the Danube for water management regime I.
C.1.3) Sediment transport simulation for the Danube for water management regime I.
C.1.4+5) Hydrodynamic simulation for the Danube for water management regime II, with and without under water weirs.
C.1.6+7) Water quality simulation for the Danube for water management regime II, with and without under water weirs.
C.1.8+9) Sediment transport simulation for the Danube for water management regime II, with and without under water weirs.
C.1.10+11) Hydrodynamic simulation for the Danube for water management regime III, with and without under water weirs.
C.1.12+13) Water quality simulation for the Danube for water management regime III, with and without under water weirs.
C.1.14+15) Sediment transport simulation for the Danube for water management regime III, with and without under water weirs.

MIKE 11 (River branch system)

C.2.1) Hydrodynamic simulation for water management regime I (pre-dam).
C.2.2) Water quality simulation for water management regime I.
C.2.3) Sediment transport simulation for water management regime I.
C.2.4) Hydrodynamic simulation for water management regime II.
C.2.5) Water quality simulation for water management regime II.
C.2.6) Sediment transport simulation for water management regime II.
C.2.7) Hydrodynamic simulation for water management regime III.
C.2.8) Water quality simulation for water management regime III.
C.2.9) Sediment transport simulation for water management regime III.

MIKE SHE-MIKE 11 (River branch system)

C.2.10) Water movement simulation (ground water, unsaturated zone, overland flow, evapotranspiration) for water management regime I.
C.2.11) Water movement simulation for water management regime II.
C.2.12) Water movement simulation for water management regime III.

MIKE 21 (Hrusov Reservoir)

C.3.1) Hydrodynamic simulation for water management regime I (pre-dam).
C.3.2) Eutrophication simulation for water management regime I.
C.3.3) Sediment transport simulation for water management regime I.
C.3.4) Hydrodynamic simulation for water management regime II.
C.3.5) Eutrophication simulation for water management regime II.
C.3.6) Sediment transport simulation for water management regime II.
C.3.7) Hydrodynamic simulation for water management regime III.
C.3.8) Eutrophication simulation for water management regime III.
C.3.9) Sediment transport simulation for water management regime III.

6 WORK PLAN FOR PHASE II OF THE PROJECT

This chapter provides a brief summary of the activities that will be carried out during project Phase II which is terminated by December 31, 1995.

Milestones
The following dates constitutes important milestones during Phase II:

March 15	All models will be finally calibrated and validated ready to be used for scenario simulations.
May	An international workshop will be held in May 1995 where the results obtained so far will be presented and discussed. 4-5 international experts will be invited.
June 1	Scenario simulations for water mamagement regimes I-III will be finalized. A steering committee meeting will be held in the beginning of June where water management regime IV will be decided.
August 15	Scenario simulations for water management regime IV will be finalized.
September 15	Draft Final Report.
November 15	Final Report.
December 31	Project Termination.

6.1 Brief Description of Phase II Activities

During project Phase I most of the models have been setup, calibrated and validated and are now ready to be used for the application scenarios. However, some models still needs some calibration. For these models the calibration will be finalized during January, February and March and by March 15, 1995 all models will be calibrated and validated.

At a steering committee meeting on November 29 1994 it was agreed that water management regime IV should be decided based on the model results from scenario simulations for water management regimes I-III. According to the project time schedule these results will be available by June 1. It is therefore suggested that a steering committee meeting shall be held in the beginning of June 1995 aiming at deciding water management regime IV.

MIKE 11

The MIKE 11 hydrodynamic models for the Danube and the river branch system are ready for practical use. Reference- and management scenario simulations for water management regimes I,II and III will be carried out during January and February.

The MIKE 11 water quality and eutrophication models are almost ready. A few adjustments in order to improve the model calibration will be made during January and February. When the MIKE 11 HD simulations have been carried out the water quality modelling of the Danube and eutrophication modelling of the river branch system can be initiated. The water quality and eutrophication scenario simulations will be carried out during March, April and May.

The MIKE 11 sediment transport models still needs som calibration. The final calibration and validation will be carried out during February and March and scenario simulations will be carried out during April and May.

MIKE 21

The MIKE 21 hydrodynamic model for the reservoir is at present being updated with new reservoir bathymetry and some recent velocity measurents in the reservoir have become available for model calibration. The model calibration and validation will be finalized by March 1. Scenario simulations will be carried out in March 1995.

MIKE 21 Eutrophication modelling has just been initiated and will continue during January and February 1995. Scenario simulations depends upon the MIKE 21 HD simulations wich will be available by the end of March. Eutrophication scenarious will be carried out during April and May 1995.

The MIKE 21 sediment transport model for the reservoir is ready but depends upon the results from the MIKE 21 HD simulations. Sediment transport simulations will be carried out during April and May 1995

MIKE SHE

The MIKE SHE regional ground water models for pre- and post-dam conditions still needs to be finally calibrated and validated. This process will go on during January and February. The regional model provides boundary conditions for the local ground water models. Scenario simulations will be carried out during March and April, 1995.

The MIKE SHE/MIKE 11 model for the river branch system has been established but cannot be finally calibrated and validated until the regional ground water model has been finalized. The model for the river branch system will be finalized by April 1 and scenario simulations will be carried during April and May, 1995.

The MIKE SHE/MIKE 11 local ground water model for the reservoir area has been established but as for the model for the river branch system, the reservoir model also awaits the finalization of the regional ground water model. Scenario simulations will be carried out in April 1995.

The geochemical model has been developed but needs some further testing on data from the geochemical field site at Kalinkovo and maybe also some minor adjustments in the source code. Testing and final adjustment of the model will be accomplished by April 1. Scenario simulations will be carried out in May 1995.

DAISY

The scenario simulations with the DAISY model involves some data collection and processing. The preparatory work will be carried out during January and February. As data becomes available reference scenario simulations with DAISY will be carried out. The DAISY management scenario simulations depends on results from the regional ground water model. The DAISY simulations for water management regime I and II will be concluded by June 1, 1995.

6.2 Staff Schedule for Phase II

Table 6.1 shows the staff schedule for project Phase II.

Table 6.1 Staff Schedule for Phase II.

Staff	Man-weeks	Place	Period
J. C. Refsgaard			
Project Management	2	DHI	ad hoc, in between BR-visits
International workshop	1	BR	May 1995
Project Management	3	BR	ad hoc, 3 visits in 1995
Reports	2	DHI	
Total (weeks)	8		

Table 6.1 Staff Schedule (cont'd)

Staff	Man-weeks	Place	Period
H.R. Sørensen			
MIKE SHE regional model Final calibration, Validation	2	BR	Jan 95
MIKE SHE reservoir model Final calibration and scenarios	2	BR	Feb/Mar 95
MIKE SHE scenario simulations reservoir model, floodplain model, International workshop	2	BR	Apr/May 95
MIKE SHE scenario simulations	2	BR	Jun/July 95
MIKE SHE scenario simulations, Draft Final Report	2	BR	Aug 95
Final Report	2	DHI/BR	Sep/Oct 95
Total (weeks)	12		

Staff	Man-weeks	Place	Period
J. Griffioen			
Final Geochem. Interpr.	1	BR	Feb 95
Model scenarios, International Workshop	1	BR	May 95
Model scenarios, Draft Final Report	1	BR	Jul/Aug 95
Draft Final Report	1	BR	Sep/Oct 95
Total (weeks)	4		

Table 6.1 Staff Schedule (cont'd)

Staff	Man-weeks	Place	Period
P. Engesgaard/A. Brun			
Model testing, final development	2	BR/VKI	Feb/Mar 95
Model scenarios, International workshop	2	BR	Apr/May 95
Model scenarios	2	BR	Jun/Jul 95
Model scenarios, Draft Final Report	1	BR	Aug 95
Draft Final Report	1	BR	Sep/Oct 95
Total (weeks)	8		

Staff	Man-weeks	Place	Period
S. Hansen			
DAISY scenarios, International Workshop	1	BR	May 95
Final Report	1	RDAU	Sep/Oct 95
Total (weeks)	2		

Staff	Man-weeks	Place	Period
M. Thorsen			
DAISY data processing, scenarios	2	BR	Feb/Mar 95
DAISY scenario simulations, International workshop	2	BR	May 95
DAISY scenario simulations, Draft Final Report	1	BR	Jul/Aug 95
Final Report	1	BR	Sep/Oct 95
Total (weeks)	6		

Table 6.1 Staff Schedule (cont'd)

Staff	Man-weeks	Place	Period
H.G. Enggrob			
MIKE 21 reservoir model, MIKE 11/21 sediment transport	2	BR	Mar/Apr 95
MIKE 11/21 scenario sim., International Workshop	1	BR	May 95
MIKE 11/21 scenario sim.	1	BR	Jun/Jul 95
MIKE 11/21 scenario sim. Draft Final Report	1	BR	Aug/Sep 95
Final Report	1	BR	Sep/Oct 95
Total (weeks)	6		

Staff	Man-weeks	Place	Period
J.K. Jensen/H. Bach			
MIKE 21 Eutrophication	1	BR	Jan 95
MIKE 11/21 WQ/EU final calibration/validation	1	BR	Feb/Mar 95
MIKE 11/21 WQ/EU scenarios	1	BR	Mar/Apr 95
MIKE 11/21 WQ/EU scenarios, International Workshop	1	BR	May 95
MIKE 11/21 WQ/EU scenarios, Draft Final Report	1	BR	Jul/Aug 95
Final Report	1	BR	Sep/Oct 95
Total (weeks)	6		

Staff	Man-weeks	Place	Period
F. Deckers/F. Wardenburg			
Finalization of DLIS and of Users guide	3	BR	Mar 95
Final Reporting	1	TNO	Sep-Nov 95
Total (weeks)	4		

Staff	Man-weeks	Place	Period
J.L. Fiselier			
Wetland Ecology, data preparation	1	BR	Mar 95
Interpretation of model scenarios, International workshop	1	BR	May 95
Interpretation of model scenarios	1	BR	Jun/jul 95
Interpretation of model scenarios, Draft Final Report	1	BR	Aug 95
Final Report	1	BR	Sep/Oct 95
Total (weeks)	5		

Annex 9

(Extract)

Protocol of the 29th Session of the Mixed Commission, for Application of the Convention concerning fishing in the waters of the Danube, meeting of 3-10 April 1989

Unofficial translation

PROTOCOL

from the XXIXth session of the Mixed Commission for Application of the Convention concerning fishing in the waters of the Danube, concluded among the governments of the Romanian Socialist Republic, Bulgarian People's Republic, Czechoslovak Socialist Republic, Socialist Federative Republic of Yugoslavia, the Hungarian People's Republic and the Union of the Soviet Socialist Republics.

The XXIXth session of the Mixed Commission for Application of the Convention concerning fishing in the waters of the Danube took place in the Romanian Socialist Republic, in Bucharest on 3 - 10 of April 1989. The representatives of all concerned parties took part in this session:

List of participants

(....)

The 29th session of the Mixed Commission for Application of the Convention concerning fishing in the waters of the Danube was opened by Petre Negoescu, the chairman of the Commission.

(....)

The programme of the XXIXth session:

1. Approval of the programme
2. Report of the chairman of the Mixed Commission on works in the period between XXVIIIth and XXIXth session of the Commission.
3. Reports of the parties on results of hunting, situation of supplies, conditions on reproduction and growth of fish between XXVIIIth and XXIXth session and on measures for maintaining of optimum fish supplies in the waters of the Danube.
4. Setting of dates for general stop of fishing in the waters of the Danube in the year 1989 and periodical protection of herring in individual sections of the Danube.
5. Reports and information of situation of fish, other reports and information in the period between XXVIIIth and XXIXth session.

5.1. Situation of supplies of economically important sorts of fishes in the Panonian basin.

5.2. Situation of generation group, age composition and conditions of reproduction of the Danubian herring

5.3. Actual situation, biology and conditions of reproduction, spawning places of fishes fed by plants and other fishes got acclimatized in the Danube
5.4. Information of the Danube water pollution and measures realized for amelioration of the situation
5.5. Situation of generation group of sturgeons, age composition, conditions of reproduction and places of reproduction
5.6. Information on fish stocking with economically important species of fish
5.7. Information of the parties on measures for fish supplies protection in connection with existing water works and water works in construction on the Danube.
5.8. Information of concerned parties on fishing of migration sturgeon species with special nets "ohan"
5.9. Discussion on Yugoslav proposal of changing art.3 and 7 of Fishing rules. Discussion of Romanian proposal of changing art. 2 of the Fishing Rules.
5.10. Other reports
6. Exchange of experience on fishing rules and their changes between XXVIIIth and XXIXth session
7. Publication of materials from the XXIXth session
8. Determination of place and date of XXXth session
9. Election of chairman of the Mixed Commission for the period between XXIXth and XXXth session.
10. Approval of the programme proposal for XXX. session.
(....)

To point 2:
The Mixed Commission listened to the report of the chairman of the Commission of the period between XXVIIIth and XXIXth session. The report states that in 1987, the total catch of fish was 12 849,5 tonnes and in 1988 - 13 406,1 tonnes. In comparison to average catch in the years 1985-86, i.e. 14 219 tonnes, it is 1 370,2 tonnes, respectively 813,6 tonnes less than in 1987 and 1988.

To point 3:
"The hydro-meteorological conditions were generally unfavourable in the mentioned period (1987 and 1988). They were characterized by a strong and long winter 1987, short period of inundation with maximum in the last part of April 1988. These unfavourable conditions together with higher pollution influenced negatively reproduction and growth of fish, especially economically important sorts of fishes.

The Mixed Commission stated that less fish was caught in the Panonian basin, especially in the joint Czechoslovak-Hungarian section of the river due to worsened ecological conditions."
(....)

To point 4:
(....)
The Mixed Commission decided for 1989:
a/ General stop of fish catch (except of the Danube herring and sturgeon species) for 30 days, it means in the period between April 14 and May 13, included.
b/ For the section of the Panonian basin, the dates of fish catch stop were determined according to species and mutual agreements of Panonian basin countries for the period from February 1 to July 15.
c/ Periodical catch stop of the Danube herring:
- in the section I.- from the mouth of the Danube up to Čatal Izmail 5 days, from 20 to 24 April 1989 including,
- in the section II, - from Čatal Izmail up to Vadul Oii 20 days, from 25 April to 14 May 1989 including,
- in the section III. - from Vadul Oii up to the mouth of the river Timok 30 days, from 15 May to 13 June 1989 including.

To point 5:
The Mixed Commission listened to the information and report on results of scientific-research works and it states after having discussed them: according to the information of the Czechoslovak side, the quantity of economically important fish species decreased in the Czechoslovak-Hungarian section of the river due to the worsened ecological conditions.
The Czechoslovak side presented the fact on the basis of research works that measures till the present time, controlling the pike catch (close season 1.1.-31.V., catch length measure 50 cm) make possible to catch also fishes which are not grown up. Therefore the Czechoslovak side considers eventual change of the close season and catch length. (...)

To point 5.2.
The hydroclimatic conditions were in 1988 better during migration than in 1987, thus the fish catch was 1 516,5 tonnes, i.e. 929,2 tonnes more than in 1987. (....)

To point 5.6.

The Mixed Commission listened to the information of participating sides about fish stock of the Danube.

In the years 1987 - 1988, the Romanian side realized fish stock in the Danube and adjacent waters with 8 442 groups of fish-eggs of pike perch, the Bulgarian side realized fish stock of 6 millions of carp spawn and 10 thousand pieces of one-year carp, the Czechoslovak side realized fish stock of 3 millions of pike spawn and carp, 3 millions fish eggs of pike perch, 6 tonnes of one-year carp and 110 thousand pieces of rainbow trout, the Yugoslav side realized fish stock of 413 thousand young carp, 2 millions pieces of carp and fish eggs of pike perch, the Hungarian side realized fish stock of 2 millions pieces of pike spawn, pike perch, sheatfish, sterlet and 100,5 tonnes of carp of different age.

The Mixed Commission recommends that each side continues fish stock according their possibilities. It recommends also to take measures for protection of spawning places, fish growth, as well as terrain adjustment for swimming down of young fish into stagnant waters. (...)

To point 5.7

The Mixed Commission took into account the report of the Czechoslovak side that in accordance with recommendation of the XXVIIIth session, the programme of bilateral cooperation with Hungarian side concerning rational utilization of zones with modified ecological conditions.(....)

This protocol was done in Bucharest, in Romanian Socialist Republic, on April 9th 1989 in six copies, in Russian, Bulgarian, Hungarian, Romanian, Slovak and Serbian-Croatian languages, all having the same validity.

The signatures of the chiefs of delegations:

- Petre Negoescu, Romanian Socialist Republic
- Ivan Stanicov, Bulgarian People's Republic
- Anton Kirka, Czecho-Slovak Federal Republic
- Filip Zarubica, Socialist Federative Republic of Yugoslavia
- Károly Pinter, Hungarian People's Republic
- Vladimír Ismailov, Union of Soviet Socialist Republics

Annex 10

(Extract)

Protocol of the 30th Session of the Mixed Commission, for Application of the Convention concerning fishing in the waters of the Danube, meeting of 2-6 April 1991

Unofficial translation

PROTOCOL

from the XXXth session of the Mixed Commission for Application of the Convention concerning fishing in the waters of the Danube, concluded among the governments of the Czechoslovak Federal Republic, Bulgarian Republic, the Republic of Hungary, Romania, Socialist Federative Republic of Yugoslavia and the Union of the Soviet Socialist Republics.

The XXXth session of the Mixed Commission for Application of the Convention concerning fishing in the waters of the Danube took place in the Union of the Soviet Socialist Republics, in Odessa on 2 - 6 of April 1991. The representatives of all concerned parties took part in this session:

List of participants

(....)

The 30th session of the Mixed Commission for Application of the Convention concerning fishing in the waters of the Danube was opened by Vladimír Izmailov, the chairman of the Commission between the XXIXth and XXXth session. (....)

The programme of the XXXth session:

1. Approval of the programme
2. Report of the chairman of the Mixed Commission on works in the period between XXIXth and XXXth session of the Commission.
3. Reports of the parties on results of hunting, situation of supplies, conditions on reproduction and growth of fish between XXIXth and XXXth session and on measures for maintaining of optimum fish supplies in the waters of the Danube.
4. Setting of dates for general stop of fishing in the waters of the Danube in the year 1991 and periodical protection of herring in individual sections of the Danube.
5. Reports and information of situation of fish, other reports and information in the period between XXIXth and XXXth session.

5.1. Situation of supplies of economically important sorts of fishes in the Panonian basin.

5.2. Situation of generation group, age composition and conditions of reproduction of the Danubian herring
5.3. Actual situation, biology and conditions of reproduction, spawning places of fishes fed by plants and other fishes got acclimatized in the Danube
5.4. Information of the Danube water pollution and measures realized for amelioration of the situation
5.5. Situation of generation group of sturgeons, age composition, conditions of reproduction and places of reproduction
5.6. Information on fish stocking with economically important species of fish
5.7. Information of the parties on measures for fish supplies protection in connection with existing water works and water works in construction on the Danube.
5.8. Information of concerned parties on fishing of migration sturgeon species with special nets "ohan"
5.9. Discussion on Yugoslav proposal of changing art.3 and 7 of Fishing rules. Discussion of Romanian proposal of changing art. 2 and Bulgarian proposal on setting of fish stop of migration sturgeon in the Danube for the period 5 - 10 years.
5.10. Other reports
6. Exchange of experience on fishing rules and their changes between XXIXth and XXXth session
7. Publication of materials from the XXXth session
8. Determination of place and date of XXXIth session
9. Election of chairman of the Mixed Commission for the period between XXXth and XXXIth session.
10. Approval of the programme proposal for XXXI. session.
(....)

To point 2:

The Mixed Commission listened to the report of the chairman of the Commission of the period between XXIX. and XXX. session. The report states that in 1989, the total catch of fish was 9 983,9 tonnes and in 1990 - 8 850,1 tonnes. It is 3 134,6 tonnes, respectively 4 268,4 tonnes less than in 1988. The decrease of fish catch was caused by unfavourable hydrological conditions. (....)

To point 3:
(....) The hydrological conditions were especially unfavourable in the mentioned period (1989 - 1990). They were characterized by low water level and higher pollution, what influenced reproduction and growth of economically important fish species. The Mixed Commission stated that due to ecological situation, the catch substantially decreased in majority of participating parties.
(....)
To point 5.1.
The Mixed Commission listened to the reports of the Hungarian, Romanian, Czecho-Slovak and Yugoslav sides on results of fisheries in the Panonian basin and stated that the catch of majority fishes in 1989 and 1990 decreased due to the low water level in the Danube which caused the isolation of branches which are the main place of spawning and production of fish. The Hungarian side drew attention to the fact that the worsening of conditions for fishes in the Danube was connected not only with worsening of hydrological conditions but also with the construction of water works on the Danube in Germany and Austria which limited migration and development of higher number of economically important fish species. (...)
To point 5.7.
The Mixed Commission was informed that participating parties were realizing measures for fish protection in the waters around existing water works and water works in construction on the Danube and recommends to continue these activities. (....)

This protocol was done in Odesa, the Union of the Soviet Socialist Republics on April 6th 1991 in six copies, in Russian, Bulgarian, Hungarian, Romanian, Slovak and Serbian-Croatian languages, all having the same validity.
<u>The signatures of the chiefs of delegations:</u>
- Anton Kirka, Czecho-Slovak Federal Republic
- Béla Tahy, the Republic of Hungary
- Vladimír Izmailov, Union of Soviet Socialist Republics
- Georgi Pirvanov, Bulgarian Republic
- Dumitru Budescu, Romania
- Radojle Milinkovic, Socialist Federative Republic of Yugoslavia

Annex 11

Comparison of Older and Present Views on the Geological - Tectonic Setting of the Danube Basin in relation to the Seismological Situation of the Water Work Gabčíkovo, Prof. M. Mahel, October 1994 (Annex 26 to Slovakian Counter-Memorial), reference list

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Annex 12

CERTIFICATION

I, the undersigned, Dr. Peter Tomka, Agent of the Slovak Republic, hereby certify that the copy of each document attached in Volume II of the Reply submitted by the Slovak Republic is an accurate copy; and that all translations prepared by Slovakia are acccurate translations.

(Signed)______________________
Dr. Peter Tomka
Agent of the Slovak Republic