Hydrology and Limnology – Another Boundary in the Danube River Basin

A contribution to the IHP Ecohydrology Project

Report on the International Workshop organized by the International Association for Danube Research (IAD) and sponsored by the UNESCO Venice Office

Petronell, Austria, 14-16 October 2004

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Report on the International Workshop
“Hydrology and Limnology – Another Boundary in the Danube River Basin”
held in Petronell, Austria, 14-16 October 2004

A contribution to the UNESCO IHP-VI Ecohydrology Project

Organized by

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1. Preface and Acknowledgements

Based on the experience of two separate conferences of Danubian limnologists and hydrologists held consecutively in 2002 in Romania, the IAD has suggested, on July 10, 2003, through its president (1998-2004) Jürg Bloesch, to launch a joint workshop of limnologists and hydrologists in order to foster cooperation between the two classical disciplines in the Danube River Basin. The UNESCO Regional Bureau for Science in Europe (ROSTE), through Philippe Pypaert, responded positively to provide financial support. Hence, IAD submitted a workshop proposal on October 30, 2003, and the contract no. 875.758.4 was finally signed between IAD and UNESCO on June 10/22, 2004.

The workshop was organized during October 14-16, 2004 by Jürg Bloesch (IAD & EAWAG, Switzerland), Dieter Gutknecht (TU Vienna) and Alexander Zinke (Zinke Environment Consulting). While Jürg Bloesch and Dieter Gutknecht were responsible for the scientific content, programme and invitation of selected participants, Alexander Zinke provided technical support for workshop preparation and took responsibility for the organisational part as sub-contractor. As a result of a long process of keynote invitations, 28 participants from 8 countries finally gathered in Petronell near Vienna (see Annex 10.1). The general results and outcomes of the workshop are summarised in the executive summary (chapter 2).

The structure of the workshop (Annex 10.2) was divided into three parts: (1) In an introduction, keynote presentations on selected topics of hydrology and limnology were presented. (2) Group work, a workshop-related excursion to the nearby Danube National Park and information on the EU-WFD and the EU-FP6 showed common interests and different scientific understanding, and provided the framework for possible joint projects in the Danube River Basin. (3) In a final plenary discussion, the participants identified the topics for a potential joint research project in the Danube River Basin combining hydrology and limnology. The workshop concluded with an agreement on follow-up actions and a short positive evaluation by all participants.

IAD, on behalf of all participants, would like to express its sincere thanks to UNESCO-ROSTE for its generous support. The editors acknowledge the finalizing language check of the document by Chris Robinson (EAWAG) and the professional layout by Rebekka Bachmann (Diener & Bachmann, Zürich).
2. Executive Summary

This workshop aimed at fostering an understanding between two traditional scientific disciplines in view of the catchment approach and sustainable Danube River Basin management and ultimately toward the implementation of the EU-WFD (chapter 3), gathered 28 limnologists and hydrologists from Austria, Bulgaria, Germany, Hungary, Romania, Serbia-Montenegro, Slovakia, and Switzerland.

During the first day, basic scientific state-of-the-art presentations in selected topics of hydrology and limnology were presented and discussed under the general aspects of the cooperation between the two disciplines (chapter 4). It became evident that different ways of thinking and perspectives led to different definitions of scientific issues and problems, and to different approaches how to solve them.

During the second day, some basic prerequisites to form a framework of projects in the Danube River Basin were presented, such as communication in transdisciplinary and transboundary projects, the EU-WFD and the EU-FP6 (chapter 6). Although the social environment within the Danube River Basin is extremely diverse, sufficient institutional and informal structural contacts are available to support joint research efforts. In group work, the following four topics were further developed in the context of cooperation between limnology and hydrology (chapter 7): (1) Water politics: Support of the EU-WFD implementation, mitigation of flooding, stressing the importance of integrative procedures at all levels; (2) Research: Contaminant load budgets/calculation and modelling in the DRB with regard to the Black Sea as a final recipient, emphasizing that quality assurance is necessary to obtain useful data sets for modelling; (3) Universities as foci to applied science: Teaching strategies to improve cooperation between limnology and hydrology, outlining various proposals for joint educational programs such as summer schools and international distance learning; (4) Implementation of science by joint limnology/hydrology consulting: a network between universities, private enterprises and NGOs, stressing the need for developing existing environmental impact assessment (EIA) into ecological impact assessment (EcIA) and strategic environmental assessment (SEA). The afternoon excursion into the nearby Danube National Park elucidated the need for more cooperation by showing the different disciplinary perspectives of restoration sites with strong habitat dynamics (chapter 5).

During the third day, participants discussed in plenary the identification and evaluation of common interests, the elaboration of concepts and tools of cooperation, and the identification of topics for a joint research project (project ideas) with particular emphasis on river morphology and floodplains (chapter 8). It was agreed that the floodplains in the Middle and Lower Danube River and major tributaries ideally combine the research interests of hydrologists and limnologists. Retention of floods, deposition of nutrient and contaminants, biodiversity and sturgeon habitats are major points of scientific and public interest. A follow-up action is proposed to organize a specific workshop on the establishment of a joint project proposal in the Middle Danube River from Gabčíkovo to the Iron Gate Dams (chapter 9). Some workshop participants expressed their willingness to submit a paper to a scientific journal.
3. Introduction

3.1 Hydrology and Limnology – another boundary in the Danube River Basin: What is the view and expectations of limnologists?

By Jürg Bloesch

Ecohydrology as the basis of riverine system function

Boundaries and borders are both natural features and man-made “products” (BLOESCH 2000). In the past decades, science has developed from disciplinary to interdisciplinary and transdisciplinary projects, thereby demonstrating the complexity of nature as well as crossing traditional and artificial borders. When speaking of applied science, transdisciplinarity is even more important and a prerequisite to overcome real borders, either natural (e.g., watersheds, catchments, ecotones) or human (e.g., political state borders, mental boundaries).

Cooperation between limnologists and hydrologists is aimed at overcoming a disciplinary border and needed, for instance, to understand river ecosystem function. Institutional partnership provides an excellent forum for such cooperation. For example in Switzerland, the two formerly independent scientific societies of Limnology and Hydrology have united some years ago into the SGHL, the "Schweizerische Gesellschaft für Hydrologie und Limnologie". However, the "in situ" cooperation remains a difficult task because of different educational backgrounds and, hence, a lack of understanding of the other discipline.

This interdisciplinary cooperation is further hindered in transboundary river basins, where political borders bias ecological boundaries and coordination. The Danube River Basin provides a unique example with 10 riparian countries and 14-18 countries sharing the catchment, the largest number for a river basin worldwide. However, the cooperation between hydrologists and limnologists gains importance in view of flood protection and flood damage mitigation. The hydrological models to predict floods merge with morphological river structures such as floodplains, known to function both as water retention areas and as hot spots of biodiversity. It is obvious that scaling and limnological river concepts are based on the hydrological and morphological features of the catchment, as exemplified by the flood pulse concept and many others (see synopsis in BLOESCH 2002a, 2005). Ecohydrology combines the discharge/flow regime with the ecological function and limnological features of the river system (ZALEWSKI et al. 1997; ZALEWSKI 2004). Presently, the International Commission for the Protection of the Danube River (ICPDR) promotes flood risk assessment within its flood action programme in the frame of the EU Action Programme on Flood Risk Management Planning.

Nutrient and contaminant sources and loads are crucial not only for the Danube River and its tributaries (SCHMID 2004) but also for the recipient of the Danube River, the Black Sea (SCHREIBER et al. 2005; BEHRENDT et al. 2005). Another interesting question is if the Danube Delta acts as sink or source of nutrients, and SUCIU et al. (2002) have shown that discharge is a key parameter: at high flow nutrients are flushed through the delta, at low flow nutrients are retained. Further, and since the Baia Mare gold mine accident in 2000 in particular, loads of contaminants have gained importance with respect to spills and floods, and, hence, flood risk assessment and management. Therefore, the ICPDR has established a map of hot spots of pollution (www.icpdr.com). Plausible loads can only be calculated if hydrological discharge measurements and contaminant sampling and concentration analysis are of the same quality (BLOESCH et al. 2000). Again, the cooperation between hydrologists and chemical limnologists is a prerequisite for the successful implementation of water protection strategies. This is clearly proved by unfavourable results of analytical ring tests and
controversial load figures presented by various national stakeholders in the Danube River Basin.

The need for more transdisciplinary research and transboundary cooperation in the Danube River Basin has been addressed in two separate hydrological and limnological conferences in Romania by BLOESCH (2002, 2003). Modern water management strategies applied and implemented, e.g., in the EU-Water Framework Directive (WFD) need the scientific basis of both disciplines. The WFD states that all surface waters must have “good ecological status”, although yet to be defined in detail. Apart from water quality (e.g., quality class II equivalent to beta-mesosaprobic state) habitat quality need also to be respected. In the Danube River, we find “clear water in destroyed channels” in the upper basin and “polluted water in mostly intact channels” in the lower basin – both unsuitable as a well-functioning aquatic ecosystem.

The ecological quality of running waters ultimately depends on the climate and hydrological regime that transports nutrients and sediments, forms habitats and structures, and periodically inundates floodplains – all prerequisites for a healthy aquatic flora and fauna. In fact, many of the new river concepts are driven by hydrology (BLOESCH 2005). Both flow and habitats are subject to major technical impacts (hydropower, navigation, flood protection, etc.). It is the obligation of water protection to prevent or mitigate these impacts. For instance, residual flow at hydropower plants can be evaluated and economically and ecologically optimized by combining hydraulic models and habitat requirements for fish and benthos (BLOESCH et al. 2005).

While limnological (biological, chemical, physical) investigations of lakes prevail, hydrological aspects are focused mainly on lake water level regulation and reservoir management. The littoral flora and fauna are mostly affected by strong and frequent artificial level fluctuations, but this is mostly neglected by water managers. Last but not least, groundwater research is dominated by hydrology (drinking water supply) and chemistry (contamination), while ecological aspects (hyporheic and phreatic fauna) are mostly neglected (GRIEBLER et al. 2001; DANIELOPOL et al. 2003).

Cooperation between Limnologists and Hydrologists

As mentioned above, cooperation between limnologists and hydrologists is needed and desired, but not trivial. Both hydrological and ecological modelling is a prerequisite to understanding the function of an ecosystem. Model calibration is the technical tool to yield precise predictions, but these are dependent on the many assumptions on which the model is based. Thus, model assumptions and predictions must be checked for biological reality.

However, a general problem is, in my opinion, that non-biologists, such as water managers, chemists, physicists, modellers, engineers and hydrologists, have often lost an understanding of nature. Not knowing the value of biota and ecosystems means that unsound and false decisions are made in respect to the use of waters. Hence, limnologists (biologists) offer good partnership as synergies and to provide a synoptic view of water issues. On the other side, limnologists need the expertise of the other disciplines in order not to emphasize strictly biological details. Only by working together, are we able to get an integrated and holistic picture of ecosystem function and rate human impacts.

In practice, limnologists may expect and need the following input from hydrologists:

1. to calculate nutrient and contaminant loads: proper flow measurements, hydrological models to predict discharge (precipitation-discharge models or discharge-distribution models); flow-concentration models; sediment transport models.
(2) to investigate diffuse nutrient sources: water saturation capacity of soils; percolation; ground water flow models (infiltration, exfiltration); water balance tools (evaporation, transpiration, evapotranspiration).

(3) to study macrophyte, benthic and fish communities: hydraulic flow measurements and models; hydraulic shear stress for sediment/gravel transport and benthos habitat/living conditions; modelling flow patterns in combination with habitat requirements; groundwater flow up-welling and down-welling; categorization of hydrological flow regimes, reservoir regulation schemes; lake level dynamics.

(4) to study floodplain ecology: long-term flow patterns (peak flow, draughts, flooding periods of wetlands); flow simulation models (aquatic connectivity); groundwater table modelling.

(5) to study phreatic fauna: groundwater flow measurements and models.

The IAD-Workshop sponsored by UNESCO aims at the identification and evaluation of common interests, and the elaboration of concepts and tools of future cooperation of these disciplines within the Danube River Basin.

References


3.2 Hydrology and Limnology – another boundary in the Danube River Basin: What is the view and expectations of hydrologists?

By Dieter Gutknecht

When addressing the link between hydrology and limnology, the role of hydrology is commonly seen as a “provider” of hydrologic data considered to serve as “input” to limnological and ecological problem solving studies. Data required in this context are defined mainly by the specific needs of the limnological approaches and concepts. Methods and techniques in hydrology that serve these needs are statistical techniques to describe the time variability of hydrologic variables such as water level and discharge and flow simulation models to describe the spatial variation and areal extent of the flow regions along a river course. The question may arise whether the improved understanding of hydrological processes evidenced by the emergence of new concepts and the development of new measurement and modelling techniques in recent years in the field of hydrology (GUTKNECHT 1993; BÖSCHL & SIVAPALAN 1995; BLÖSCHL 2001; SIVAPALAN et al. 2003; SIVAKUMAR 2004) could lead to new perspectives for joint research activities linking hydrological and limnological aspects more effectively.

In this presentation an attempt is made to draw the attention (i) to some additional facets of variability in hydrological processes that are not taken into account explicitly in conventional hydrological studies and may serve as the starting point to develop new conceptual links between both disciplines, and (ii) to the field of fluvial morphology as a possible new focus point for integrating research in hydrology and limnology into new joint research activities.
Facets of variability in hydrological processes

**Variability** is an inherent feature of hydrological processes. It is commonly described by statistical concepts, models, and techniques such as flow duration curves, frequency curves, etc., thereby attempting to capture the influence of “randomness” on hydrological processes and systems. More regular variations are portrayed in classification schemes such as “regimes” (runoff regime, precipitation regime, etc). More recent studies – based on new field observations and modelling efforts to better understand and conceptualise hydrological processes, particularly the rainfall-runoff process in catchments – have indicated that there might be other phenomena that are influential in determining the characteristics of variability of hydrological processes. In an attempt to categorise these phenomena, they are discussed in the main part of this presentation by introducing the concepts of heterogeneity, disparity, change over/transition, organisation, and composite behaviour.

**Heterogeneity** is used when the diverse and varied character of properties of a system, originally of a material, is emphasized. Heterogeneous systems are often associated with irregular or random behaviour that has lead to concepts such as “effective” parameters and “representative” domains (volumes, areas).

**Disparity** signals the existence of distinct units or elements that display clearly distinguishable properties and response characteristics. Examples are processes that exhibit intermittency or systems that show clearly distinguishable zones. Related to these features is the existence of certain bounds and limits to the extent or the duration of the various elements the system/process is composed of.

**Change over** can be found to occur where thresholds become operative and capacities are exceeded. In such cases, an **abrupt change** of the mode of operation of the process may occur. In other cases the change may take on the form of a **gradual transition** when the process passes into a new dominance domain that is characterised by a different balance of acting forces or parameters.

Systems may also show features of **organisation** such as systematic arrangements and sequences that may cause connectedness between elements. They introduce **structure**, e.g. in the form of spatial dependence and of preferred flow systems. As an example, periodicity refers to a specific form of organisation that is characterised by the regular reappearance of a specific process behaviour.

Complex processes are frequently viewed as **composite processes** being composed of components with different behaviour.

Approaches which build on the awareness of these process features may be seen to introduce process oriented reasoning and modelling. It is felt that many problems arising in hydrologic modelling are strongly related to the complexity that manifests itself in these different aspects of variability and that progress can only be achieved when the behaviour of the processes is analysed and understood in light of these aspects.

Likewise, focusing on process characteristics as described above may assist in the search for a common methodology which links hydrological and limnological viewpoints and methods. Concepts that are essential to understanding hydrological processes may have analogues in the biological sciences. Vice versa, concepts in limnology such as, e.g., zones, corridors, ecotones, habitats, may be seen to have parallels in the hydrological concept of hydrologic response units. Terms such as connectivity, discontinuity, essential in describing the ecological status, are also important in the modelling of flow processes both in surface and in subsurface water bodies. Efforts directed towards an in-depth comparison between these basic concepts may help to overcome “language” or “jargon” difficulties between the disciplines and finally lead to a better mutual understanding.
The Water Framework Directive (WFD) – a vehicle to bring hydrologists and limnologists together

The Water Framework Directive requires one to view rivers as integrated systems. Responding to this requirement means to integrate knowledge about the processes both in the catchment and in the river reach itself into a common framework to assess the ecological status of the surface water body. Catchment geology, geomorphology, soils, and land cover, determine together with precipitation and climatic characteristics the flow and sediment regimes. Via flow pathways as transport routes for all kind of substances, these regimes control nutrient export from land areas into the river system, and determine essential features of the water quality state of the river reach. By interacting with the hydraulic and geomorphological conditions of the fluvial system, the variability introduced by the flow and sediment regimes determines which specific geomorphic structures and which habitat situations can develop. Geomorphic structures, in turn, define the build up and sediment composition of the hyporheic zone where the stream-subsurface interaction and exchange processes take place.

From this perspective geomorphic structures are deemed to build the focus point to concentrate joint hydrological-limnological research activities in the future. Two research areas can be seen in this context that should attract more attention: (i) The river bed as an interface; (ii) River morphology studies to improve understanding of geomorphic structures.

The river bed as an interface

Exchange processes across the interface between flow in the surface channel and in the subsurface flow systems have been of concern to ecologists and hydrologists for many years. Papers reviewing the role of stream-subsurface hydrologic interactions in the context of stream ecology have been presented e.g. by PACKMAN & BENCALA (1999), BATTIN (1999), PACKMAN & BROOKS (2001), among others. Stream-subsurface exchange processes control the removal of nutrients and organic matter from the stream and they act as pathways for the delivery of material to the subsurface zone. Exchange processes result in the retention of stream water in the subsurface and have a dispersive effect on introduced substances. They also influence the downstream transport of the substances along the stream. They are affected by the settling and intrusion of fine sediment transported with river flow which potentially may lead to clogging of the river bed.

Clogging of the river bed was the subject of extensive studies in small streams (LISLE 1989; SCHÄLCHLI 1993; BRUNKE 1999). In these studies two types of stream bed clogging have been identified: Internal clogging, related to an increase of fine material in the upper most centimetres of the stream bed (filter layer); external clogging, related to a build up of an additional fine sediment layer on top of the stream bed. While these types can be considered to capture the situations in free flowing river reaches, different features appear in impounded river sections. A study performed in the impounded Freudenau reservoir reach of the Danube at Vienna revealed the occurrence of additional types of clogging with a type termed “armour layer clogging” characterised by a state where fine sediments fill the voids of the armour layer and by intermediate states (BLASCHKE et al. 2003).

Studying these clogging phenomena means to investigate the interplay of a wide array of processes and factors. Hydraulic (water depth, velocity, turbulence), sedimentologic (sediment input, transport, grain size, suspended sediment concentration), physical (water temperature), chemical, and morphologic factors interact with biological processes (GUTKNECHT et al. 1998). Different situations develop depending on different flow and morphologic conditions at various sites across the river bed. Investigations in this direction can today rely on new innovative methods such as multi-level-piezometer measurement.
installations to measure piezometric head at various levels below the river bed, freeze-panel and freeze-core-techniques to improve river bed sampling and to facilitate macrozoobenthos sampling (HUMPESCH & NIEDERREITER 1993; NIEDERREITER & STEINER 1999); video-recording to document the spatial distribution and the time variation of the river bed state with respect to clogging.

River morphology studies to improve the understanding of geomorphic structures and their role for stream ecology

Fluvial morphologic processes and sediment transport set the scene for the ecological processes in rivers. They determine river bed geometry and the geometric features of river bed structures and influence habitat conditions. Higher or lower river bed elevations determine the flooding of floodplains and the connectivity of main and side channels. By determining the flow rates between channels and between channels and flooded areas they also control the transport and the rate of groundwater infiltration in wetland and floodplain areas.

The past two decades have seen strong improvements in the general understanding of the links between the geomorphic features of the river channel and floodplain areas and the ecological “quality” of a river reach (e.g. ALLEN 1995; WARD et al. 1999). There is also strong progress in understanding specific situations such as, e.g., the role of inshore structures (SCHIEMER et al. 2001). Future cooperation between hydrology and limnology can build on these developments.

Whereas our knowledge to properly assess geomorphic structures with respect to ecological need has greatly improved through continued research efforts, similar strong emphasis has not been given to the study of morphological changes across time and space, despite the fact that drastic changes in the morphological structure have occurred over the past decades, both due to the natural variability and due to human interference into the natural river systems. Morphological dynamics is the result of a complex interplay of sediment input to, and local sediment transport conditions in, a river reach and varies considerably at a variety of temporal and spatial scales. Understanding this interplay and the processes that contribute to it is essential for reaching a state where reliable morphological predictions can be made.

Morphological modelling combined with accompanied field observations should be high on the agenda of modern river management (PETERS 1995; DEVRIEND 2002). Recent research activities on the Danube River could be starting points for integrated research activities. Morphological studies can provide the basis for an assessment of river bed development over time (HOHENSINNER et al. 2003) and for the development of morphological models (FISCHER-ANTZE & GUTKNECHT 2004a,b). The Phare-Project “Morphological changes and the abatement of their negative effects on a selected part of the Danube river” was directed to planning aspects and assessed the morphological state of the Lower Danube. It was recommended to establish an “ecological-hydrological experimental section at the Lower Danube” (BEHR et al. 2000; PHARE 2000; GUTKNECHT et al. 2002) and to prepare a robust basis for future actions in this river reach.

References


4. Scientific Reports

4.1 Hydrological regimes

By Günter Blöschl

What are regimes?
In general, the term regime refers to any system of control. In science, regime refers to a particular state of affairs where a particular physical phenomenon or boundary condition is significant, such as "the superfluid regime" or "the steady state regime". In hydrology, regime refers to the seasonal patterns of runoff which is consistent with the more general notion in science at large, as the regimes reflect classes of processes not known in exact detail that do differ in important aspects. This paper reviews hydrological regimes with a focus on catchments in an Austrian context.

Regime types
In the traditional regime concept, catchments are classified by the seasonal patterns of runoff to reflect climatic controls. Typically, regimes include the rain regime (uniform rainfall throughout the year and maximum runoff in winter due to evaporation lows), snow regime (maximum runoff in spring due to snow melt), glacier/snow regime (maximum runoff in summer due to snow and glacier melt), and autumn rainfall regime (maximum runoff in autumn due to autumn rainfall maxima) (Fig. 1). While these traditional regime types are a useful descriptive approach, hydrological analyses can provide far more detailed information on the relevant catchment scale processes for quantitative hydro-limnological studies.

Regimes and the water balance
The task of hydrology is to solve the water balance equation at various space and time scales. As such, an assessment of hydrological processes in catchments needs to start with an analysis of the water balance components. MERZ & BLÖSCHL (2004) and PARAJKA et al. (2004) estimated the water balance components for a large number of Austrian catchments using climatic inputs, runoff data, and snow depth data, based on a conceptual catchment model. Estimates of the hydrological catchment scale fluxes (precipitation, evapotranspiration, runoff) and storage terms (soil moisture and snow water equivalent) clearly highlight the reasons for the seasonal patterns of runoff. This type of information complements the descriptive regime type approach as it provides quantitative estimates of the relative role of the water balance components, their average seasonal patterns and variability between years as well as their spatial patterns at the regional scale.

Regimes of extremes – low flows and floods
Similar to the water balance, more detailed analyses can provide insight into the main driving processes at the extreme ends of the runoff spectrum, i.e. low flows and floods. In the case of low flows, LAAHA & BLÖSCHL (2004) used seasonality to tag processes, and allowed them to unravel process controls of the Q95 low flow discharges in Austria. The ratio of summer and winter low flows pointed to regions were either summer evaporation or alpine snow packs controlled the presence of low flows. In the case of floods, the analyses of MERZ & BLÖSCHL (2003) were more involved and included process indicators such as the spatial coherence of floods, snow conditions and the moisture state of catchments that were used to classify 12000 annual floods into “flood types” (long rain floods, short rain floods, flash floods, rain on snow floods, snow melt floods). For Austrian conditions, north of the Alps, most floods were long rain floods, while short rain floods dominated south of the Alps. Rain on snow floods were most frequent north of the Danube.
Man made alterations

Two examples are briefly discussed in this paper to illustrate the role of man-made alterations, i.e., anthropogenic effects on hydrologic regimes. The first example relates to the low end of the runoff spectrum where the effect of reservoirs/power plants is apparent in the time patterns of runoff that closely mirror the diurnal and weekly time patterns of power consumption. The second example is set in the Kamp catchment in the north of Austria. Construction of a reservoir in the late 1950s led to a significant reduction of flood peaks downstream of the reservoir (GUTKNECHT et al., 2002). However, the flood of August 2002 produced a flood peak more than twice the largest flood peak on record. The flood was produced by persistent rainfall much larger than any rainfall on record. In the case of this very large flood, the attenuation of the flood wave was small. Man-made alterations may cause significant effects in the case of the low flow end of the runoff spectrum and around the mean, but at the very extreme end, the effects tend to be much smaller.

Links between surface and groundwater

As a final aspect, the discussion of regimes is put in the context of interactions between streams and aquifers. Clearly, stream aquifer interactions are difficult to assess at a regional scale as many of the processes operate at small scales and are highly variable in space and time. For quantifying stream-aquifer interactions, local methods are in use such as hydraulic methods and tracer methods. At the catchment scale, one attractive method is to analyse runoff data in terms of their contributions of runoff components. Runoff components are usually conceptualised as quickflow (fast runoff component on or near the surface), interflow (intermediate runoff component near the surface), or baseflow (slow runoff component deeper in the subsurface, usually associated with groundwater). PARAJKA et al. (2004) estimated the runoff components for a large number of Austrian catchments at a daily time scale. Figure 2 indicates that the slow component (baseflow) dominates in the Alps in winter and the fast component (mix of interflow and quickflow) is most important in spring. These quantitative estimates of the links between surface water and groundwater provide a more complete picture of the runoff regime in catchments than the descriptive regime types alone.

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Figure 1. Regime types. Example catchments in Austria with hydrographs of the year 2000.

Figure 2. Runoff types in Austria (seasonal averages of the period 1976-1997).
4.2 Limnological concepts as the basis for understanding river networks: Perspectives for the Danube

By Thomas Hein¹*, Fritz Schiemer¹ and Klement Tockner²

The role of environmental regulation of ecosystems to understand ecosystem processes is especially important in river networks because they are open systems whose physical structure changes dramatically over many spatial and temporal scales. Within this paper we review some more stimulating concepts, starting with the River Continuum Concept up to recent concepts for river systems. We focus on ecosystem processes and, therefore, span our view hierarchically structured from large-scale concepts to finer scales. Some conceptual papers have addressed aspects of large-scale longitudinal processes (i.e., upstream-downstream changes), such as concepts involving energy sources and allocation (Vannote et al. 1980), nutrient spiraling (Newbold et al. 1982), serial discontinuity and dams (Ward & Stanford 1983) and recently, the integrated view of river networks and landscape interactions (e.g. Montgomery 1999; Gomi et al. 2002; Benda et al. 2004). Others have examined processes operating at mid- to fine scales and involving hierarchical habitat templates (Frisse1 et al. 1986; Poff 1997), flow regime (Lytle & Poff 2004), inshore retention (Schiemer et al. 2001), patch dynamics (e.g. Pringle et al. 1988) and river discontinua (Poole 2002).

Our main focus is on the link between ecology, geomorphology and hydrology with examples of complex river corridors in the Tagliamento and Danube River. Emphasis is given to the importance of eco-hydrological models for the quantification and prediction of key ecosystem processes. The environmental template of complex river corridors is characterized by a shifting habitat mosaic consisting of aquatic, amphibious and terrestrial habitats, ecotones and gradients harboring biotic distribution and biogeochemical cycles. Riverine landscapes are expanding, contracting and fragmenting landscapes controlled by flow and flood pulses. Thermal heterogeneity, the array of surface and subsurface exchange processes and habitat turnover are basic ingredients explaining the high species and functional diversity of these landscape elements. The motivation and need for a profound understanding is due to the fact that rivers and their adjacent aquatic habitats such as floodplains are among the most threatened ecosystems of the world. Numerous anthropogenic disturbances often result in habitat destruction, system fragmentation, and disruption of lotic ecosystem structure and function. The deterioration of riverine landscapes has led to an increasing activity of rehabilitation and restoration works in the last decade. The experience so far points to the importance of a more integrated approach, including landscape dynamics as well as key ecosystem processes. Generally, river restoration and rehabilitation schemes integrating biogeochemical processes obtain a functional ecological integrity of lotic networks and associated coastal areas at large scales.

Example of the Austrian Danube

The Danube Restoration Project located downstream of Vienna in Austria is presented as an example for the successful use in the re-connection of side-arms (Tockner et al. 1998). Its

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value stems mainly from the large size and rich ecological structuring of the affected area, the long-term interdisciplinary planning phase and a comprehensive monitoring programme, that provided fundamental new insights (SCHIEMER & RECKENDORFER 2004). The aim has been to re-initiate key physical processes of pre-regulation conditions to shift the characteristics from a lentic backwater system towards a connected side-arm system by increased upstream surface connectivity (SCHIEMER et al. 1999). To quantify the changes in ecological processes, an ecohydrological approach by means of a detailed hydrological model was developed (RECKENDORFER & STEEL 2004). Model outputs with a high predictive power included the metric connectivity, giving the average duration of upstream surface connection and “water age”; a kind of residence time adapted to the multi-input system. The metric connectivity explained significant nutrient dynamics in the reopened side-arms (HEIN et al. 2004) and biodiversity expressed as species traits as connectivity related to community structure (SCHIEMER & RECKENDORFER 2004). Water age was used to predict nutrient uptake and pelagic processes in the water column of the reopened side-arm (ASPETSBERGER et al. 2002, BARANYI et al. 2002, HEIN et al. 2003, KECKEIS et al. 2003). Further, more recent results point to the importance of water age in explaining the interaction between different compartments of primary production in a side-arm system.

Research perspectives

The conceptual knowledge presented in the paper and the need for application in terms of river basin management clearly point to the importance of increasing basic ecologic understanding at multiple scales, using modern technologies, and to introduce this fundamental information in river management. Furthermore, the link between function and structure of lotic networks must be expanded to all aspects of biodiversity for a sustainable use of this highly endangered ecosystem. An important basic feature of all research initiatives is the linkage between scales and hierarchical structure. Ecosystem modeling and an ecohydrologic approach can be the tool to solve these challenges and identify nodes between different spatio-temporal scales. Resulting research ideas can be the following:

- The role of slackwater areas in different functional process zones, their hydrological and geomorphic interaction and the effect on chemical and biological processes.
- Understanding the complexity, especially of braided river corridors, needs to link the temporal dynamics and spatial heterogeneity of geomorphic processes, lateral as well as vertical flow paths, to habitat related ecosystem processes.
- A basic issue in various concepts and models is the question what source of carbon fuels the food webs – are there differences between the metazoan food web and the microbial loop in lotic systems?

The proposed research ideas (see also chapter 8) present some fields for experimental and empirical work in fluvial ecology under the pre-requisites of integrating different disciplines using a landscape approach. All presented questions have their foundation in basic research and have a high potential for application, especially in river restoration and river basin management (Water Framework Directive, EU 2000).

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4.3 Limnological (chemical and biological) methods: Sampling, analysis and data processing; species identification and concepts of river characterisation (bio-indices); river typology

By Norbert Matsché & Norbert Kreuzinger

Introduction

Based on the hydrological cycle, freshwater bodies are connected to each others. Parts of the hydrological cycle are the inland freshwaters that appear in the form of rivers, lakes or groundwaters. These are interconnected and may influence each other directly or through intermediate stages. Each of the three principal types of water body has distinctly different hydrodynamic as well as hydrochemical and hydrobiological properties.

Individual patterns of physical and chemical characteristics are determined by the climatic, geomorphological and geochemical conditions in the drainage basin and the connected aquifer. Parameters such as total dissolved solids, conductivity and redox potential, provide a general classification of water bodies with a similar nature. Mineral content - the total dissolved matter present - is an essential feature of the quality of any water body. Redox conditions are another vital feature of any water body because it greatly influences the solubility of metals and is essential for all forms of biological life. Particulate matter is another key factor in water quality, regulating adsorption-desorption processes.

The development of aquatic life (flora and fauna) in surface waters is influenced by a variety of environmental conditions that determine the species as well as the physiological performance of individual organisms. The degradation of organic substances and the associated bacterial production may be a long-term process that can be important in groundwaters and deep lake waters importing energy into other systems. In contrast to the chemical quality of water bodies, which can be measured by analytical methods, the description of the biological quality of a water body is a combination of qualitative and quantitative characterisation. Biological quality has a much longer time dimension than the chemical quality of the water since biota can be affected by chemical and hydrological events that may have lasted only a few days, some months or even years before the monitoring was carried out. The analysis of water from a grab sample represents a short time period in the history of the aquatic environment. Diurnal fluctuations in lakes and rivers are responsible for marked variations in concentrations of nutrients, dissolved oxygen, pH, conductivity, calcium and bicarbonates. Careful interpretation of grab sample analysis is therefore necessary even for bioassays performed with grab sample material.

The representative time span of many types of biological methods is often unclear to non-biologists. Biotic indices based on benthic communities usually integrate conditions for a few weeks to several months (i.e., the time required for the organisms' life cycle or development). One method providing a very long-term integration of environmental conditions, particularly the presence of toxic residues, is the analysis of biological tissues that can concentrate such residues over life spans of many years. Table 1 compiles the general features and prerequisites of limnological methods.

Sampling

Spatial variation in water quality is one of the main features of different types of water bodies, and is largely determined by the hydrodynamic characteristics of the water body. Water quality varies in all three dimensions that are further modified by flow direction, discharge and time. Consequently, water quality cannot usually be measured in only one location within a water body but may require a grid or network of sampling sites investigated over time.
### Table 1. General features and prerequisites of limnological methods.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Water</th>
<th>Particulate matter</th>
<th>Living organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Suspended</td>
<td>Deposited</td>
<td>Tissue analyses</td>
</tr>
<tr>
<td>Intercomparability</td>
<td>global</td>
<td>depends on species occurrence</td>
<td>global</td>
</tr>
<tr>
<td>Specificity to given pollutant</td>
<td>&lt;-specific-→</td>
<td>&lt;-integrative-→</td>
<td>&lt;-relative-→</td>
</tr>
<tr>
<td>Quantification</td>
<td>&lt;-complete-→</td>
<td>concentrations only</td>
<td>quantitative</td>
</tr>
<tr>
<td>Sensitivity to low levels of pollution</td>
<td>low</td>
<td>&lt;-high-→</td>
<td>variable</td>
</tr>
<tr>
<td>Temporal span of information obtained</td>
<td>instant</td>
<td>short</td>
<td>long to very long (continuous record)</td>
</tr>
<tr>
<td>Levels of field operators</td>
<td>untrained to highly trained</td>
<td>trained</td>
<td>untrained to trained</td>
</tr>
<tr>
<td>Permissible sample storage duration</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Minimum duration of determination</td>
<td>instant (in situ determ.) to days</td>
<td>days</td>
<td>days to weeks</td>
</tr>
</tbody>
</table>

### Location

Processes affecting water quality and their influence should be taken into account when sampling sites are selected. A sampling site is the general area of a water body from which samples are to be taken. The exact place at which the sample is taken is commonly referred to as a sampling station. Selection of sampling sites requires consideration of the monitoring objectives and some knowledge of the geography of the water-course system, as well as of the uses of the water and of any discharges of wastes.

Sampling stations on rivers should, as a general rule, be established at places where the water is sufficiently well mixed for only a single sample to be required (Fig. 1). The lateral and vertical mixing of a wastewater effluent or a tributary stream with the main river can be rather slow, particularly if the flow in the river is laminar and the waters are at different temperatures and salt content. Complete mixing of tributary and main stream waters may not take place for a considerable distance, sometimes many kilometres, downstream of the confluence. Bends in the river, riffles or a waterfall induce mixing.

![Figure 1. Scheme of the merging of a discharge into a river and the main channel and corresponding concentrations](image-url)
**Time**

The time variability of pollutant release into the aquatic environment falls into four main categories. Sources can be permanent or continuous (e.g. effluents of waste water treatment plants), periodic (e.g. seasonal variation associated with tourist seasons), occasional (e.g. certain industrial waste releases), or accidental (e.g. truck or train accidents, fires, etc.). The effects of these various types of pollutants on receiving water bodies are rather different. The temporal variation of the chemical quality of water bodies can be described by studying concentrations (and loads in the case of rivers) or by determining rates such as settling rates, biodegradation rates or transport rates. It is important to define temporal variability. Five major types can be considered:

- Minute-to-minute to day-to-day variability resulting from water mixing, fluctuations in inputs, etc., mostly linked to meteorological conditions and water body size (e.g. variations during river floods).
- Diurnal variability (24 hour variations) limited to biological cycles, light/dark cycles etc. (e.g. O₂, nutrients, pH), and to cycles in pollution inputs (e.g. domestic wastes).
- Day-to-month variability mostly in connection with climatic factors (river regime, lake overturn, etc.) and to pollution sources (e.g. industrial wastewaters, run-off from agricultural land).
- Seasonal hydrological and biological cycles (mostly in connection with climatic factors).
- Year-to-year trends, mostly due to human influences.

**Chemical methods**

All water quality variables should be grouped according to the specific operations preceding analysis (filtration, preservation, types of bottles for storage and transportation of the sample, conditions and permissible time of storage). Monitoring may require a lot of storage vessels, depending on the parameters to analyze. For each analytical category, accurate observance of the predetermined requirements of the sample handling is necessary.

Collected samples can be contaminated by inadequately or inappropriately cleaned glassware, filters, filter apparatus, chemicals used for preservation, etc. For example, conductivity must not be determined after measurements of pH in the same water sample because concentrated electrolytes from storage of the electrode used in the pH determination may enter the sample and affect the conductivity measurement.

**Chemical Parameters**

The selection of variables for water quality assessment programmes depends on the objectives of the programme. Appropriate selection of variables will help the objectives to be met efficiently and in the most cost effective way.

**Temperature** - Temperature affects physical, chemical and biological processes in water bodies and, therefore, the concentration of many variables. As water temperature increases, the rate of chemical reactions generally increases together with the evaporation and volatilisation of substances from the water. Increased temperature also decreases the solubility of gases in water, such as O₂, CO₂, N₂, CH₄ and others. The metabolic rate of aquatic organisms is related to temperature. Growth rates also increase.

**Conductivity** - Conductivity is a measure of the ability of water to conduct an electric current. It is sensitive to variations in dissolved solids, mostly mineral salts. Typically, crystalline
waters feature a conductivity <100 µS/cm, and carbonate waters show conductivity >200 up to 1’000 µS/cm.

\textbf{pH} - The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment. In unpolluted waters, pH is principally controlled by the balance between carbon dioxide, carbonate and bicarbonate ions as well as other natural compounds such as humic acids.

\textbf{Dissolved oxygen} - Oxygen is essential to all forms of aquatic life, including those organisms responsible for the self-purification processes in natural waters. The oxygen content of natural waters varies with temperature, salinity, turbulence, the photosynthetic activity of algae and plants, and atmospheric pressure.

\textbf{Nitrogen compounds} - Nitrogen is essential for living organisms as an important constituent of proteins, including genetic material. In the environment, inorganic nitrogen occurs in a range of oxidation states as nitrate (NO$_3^-$) and nitrite (NO$_2^-$), the ammonium ion (NH$_4^+$) and molecular nitrogen (N$_2$). It undergoes biological and nonbiological transformations in the environment as part of the nitrogen cycle.

For a better understanding of the nitrogen cycle, it is strongly recommended that all nitrogen species are reported in moles per litre or as mg l$^{-1}$ of nitrogen (e.g. NO$_3$-N, NH$_4$-N), rather than as mg l$^{-1}$ of NO$_3^-$ or NH$_4^+$.

\textbf{Phosphorus compounds} - Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. It is generally the limiting nutrient for algal growth and, therefore, controls the primary productivity of a water body. Artificial increases in concentrations due to human activities are the principal cause of eutrophication.

In natural waters and in wastewaters, phosphorus occurs mostly as dissolved orthophosphates and polyphosphates, and organically bound phosphates.

\textbf{Organic matter} - Most freshwaters contain organic matter and can be measured as total organic carbon (TOC). For comparative purposes, an indication of the amount of organic matter present can be obtained by measuring related properties, principally the biochemical oxygen demand (BOD) or the chemical oxygen demand (COD). The COD usually includes all, or most, of BOD as well as some other chemical demands. In most samples: COD > BOD > TOC.

\textbf{Major ions} - Major ions (Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$, Cl$^-$, SO$_4^{2-}$, HCO$_3^-$) are naturally variable in surface and groundwaters due to local geological, climatic and geographical conditions.

The presence of carbonates (CO$_3^{2-}$) and bicarbonates (HCO$_3^-$) influences the hardness and alkalinity of water. The inorganic carbon component (CO$_2$) arises from the atmosphere and biological respiration. The weathering of rocks contributes carbonate and bicarbonate salts. In areas of non-carbonate rocks, the HCO$_3^-$ and CO$_3^{2-}$ originate entirely from the atmosphere and soil CO$_2$, whereas in areas of carbonate rocks, the rock itself contributes to the carbonate and bicarbonate present.

\textbf{Silica} - Silica is widespread and always present in surface and groundwaters. It exists in water in dissolved, suspended and colloidal states. Dissolved forms are represented mostly by silicic acid, products of its dissociation and association, and organosilicon compounds. Reactive silicic acid mainly arises from chemical weathering of siliceous minerals. Silica is the structural material of diatoms.
**Organic contaminants** - Many thousands of organic compounds enter water bodies as a result of human activities. These compounds have significantly different physical, chemical and toxicological properties. Monitoring every individual compound is not feasible. However, it is possible to select priority organic pollutants based on their prevalence, toxicity and other properties. Mineral oil, petroleum products, phenols, pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and surfactants are examples of such classes of compounds. However, their determination requires sophisticated instrumentation and highly trained personnel.

**Particulate matter** - It is commonly accepted, as an operational definition, that particulate matter (PM) refers to particles greater than 0.45 µm. By this definition, dissolved matter includes particles finer than 0.45 µm, including colloids.

**Biological methods**
The flora and fauna present in specific aquatic systems are a function of the combined effects of various hydrological, physical and chemical factors. Biological assessment of water, water bodies and effluents is based on five main approaches.

1. **Ecological methods:**
   - analysis of the biological communities (biocenoses) of the water body
   - analysis of the biocenoses on artificial substrates placed in a water body
   - presence or absence of specific species

2. **Physiological and biochemical methods:**
   - oxygen production and consumption, stimulation or inhibition
   - respiration and growth of organisms suspended in the water
   - studies of the effects on enzymes

3. **The use of organisms in controlled environments:**
   - assessment of the toxic (or even beneficial) effects of samples on organisms under defined laboratory conditions (toxicity tests or bioassays)
   - assessing the effects on defined organisms (e.g. behavioural effects) of waters and effluents in situ, or on-site, under controlled situations (continuous, field or “dynamic” tests)

4. **Biological accumulation:**
   - studies of the bioaccumulation of substances by organisms living in the environment (passive monitoring)
   - studies of the bioaccumulation of substances by organisms deliberately exposed in the environment (active monitoring)

5. **Histological and morphological methods:**
   - observation of histological and morphological changes
   - embryological development or early life-stage tests

**Disciplines**

**Microbiology**
The natural bacterial communities of freshwaters are largely responsible for the self-purification processes that biodegrade organic matter. They are particularly important with respect to the decomposition of sewage effluents and can be indicative of the presence of very high levels of organic matter. However, domestic sewage effluents also add to water bodies large numbers of certain bacterial species which arise from the human intestine. These
bacteria (*Escherichia coli* in particular) can be used as indicators of the presence of human faecal matter and other pathogens possibly associated with it. Since the presence of human faecal matter in water bodies presents significant health risks when the water is used for drinking, personal hygiene, contact recreation or food processing, it is often the most basic and important reason for water quality assessment, especially in countries where sewage treatment is inadequate. Therefore, simple and cheap methods have been developed for detecting the presence of faecal bacteria, some of which (through the use of kits) can be carried out in the field.

**Toxicity**

It is important to know what kind of impact an effluent may have on a receiving ecosystem and the associated organisms. To avoid extensive laboratory simulations, some standardised laboratory procedures have been designed to test the toxic effects of chemical compounds or effluents on selected aquatic organisms. Such tests can also be helpful in determining the toxicity of water from a water body, for example, following an accidental pollution discharge.

Toxicity occurs in two forms: acute or chronic. Acute toxicity is usually caused by exposure to a large dose of a toxic compound for a short period of time. A rapid effect is produced on the organisms, usually death, and this may be used to determine the lethal concentration of a compound or effluent over a given period of time. For example, the concentration that kills 50 per cent of all the organisms in a test within 48 hours is described as the “48 hour LC$_{50}$”. When an effect other than death is used for a similar test it is described in terms of the effective concentration (e.g. 48 hour EC$_{50}$). Chronic toxicity is caused by very low doses of a toxic compound or effluent over a long period of time and may be either lethal or sub-lethal (not sufficient to cause death). Sub-lethal effects can occur at the biochemical, physiological or behavioural level, including mutagenicity and genotoxicity and interference with the normal life cycle of an organism. There is currently great interest in developing methods for detecting sub-lethal toxicity as a means of early warning for environmental damage.

**Macroinvertebrates**

The most studied and monitored degradation of water quality is due to organic pollution arising from sewage discharges. Standardised collection methods are used for benthic macroinvertebrates and indices are derived from scores allocated according to the presence or absence of indicator groups or indicator species. It is important that biotic indices are used together with all other available information to ensure correct interpretation of the biological information.

Aquatic organisms have preferred habitats that are defined by physical, chemical and other biological features. Variation in one or more of these can lead to stress on individuals and possibly a reduction in the total numbers of species or organisms that are present. In extreme situations of environmental change, perhaps due to contamination, certain species will be unable to tolerate the changes in their environment and will disappear completely from the area concerned, either as a result of death or migration. Thus the presence or absence of certain species or family groups, or the total species number and abundance have been exploited as a means of measuring environmental degradation. Two main approaches have been used: methods based on community structure and methods based on “indicator” organisms. An indicator organism is a species selected for its sensitivity or tolerance (more frequently sensitivity) to various kinds of pollution or its effects, e.g. metal pollution or oxygen depletion. Some groups of organisms, such as benthic invertebrates, have been exploited more than others in the development of ecological methods and this is due to a combination of the specific role of the organisms within the aquatic environment, their lifestyle and the degree of information available to hydrobiologists.
**Sampling** - Sampling for biological assessments of water quality frequently require special methods, apparatus and precautions. There are many sampling devices for collecting benthic or planktonic organisms, many of which are available commercially, and some of which can be manufactured fairly simply. Guidance on the use of different samplers for macroinvertebrates has been provided by ISO (1991).

Water samples taken for testing toxicity or for use in physiological tests should be taken with as much care as for chemical analysis, i.e. without any contamination, and preserved cool (and possibly in the dark). Samples that are used for any form of microbiological analysis must be collected with sterlised glass bottles and kept cool and dark. When sampling biota for chemical analysis (bioaccumulation studies), particular species or even particular parts of an organism must be collected. For aquatic plants, the growing tips are usually suitable. Biological samples for chemical analysis should be handled with extreme care to avoid contamination, particularly from contact with sampling apparatus, storage vessels, dissecting instruments and the chemicals used in the preparation for analysis.

**Groups of Macrozoobenthos** - In order to detect environmental disturbance using biota it is important that the organisms reflect the situation at the site from which they are collected, i.e. they must not migrate. As a result, the most widely used group of aquatic organisms are benthic macroinvertebrates. These organisms are usually relatively immobile, thereby indicating local conditions and, since many have life spans covering a year or more, they are also good integrators of environmental conditions. They are ubiquitous and abundant in aquatic ecosystems. No expensive equipment is necessary for their collection. It is sometimes possible to get a qualitative impression of water quality in the field because the presence or absence of certain groups is related to their tolerance to specific environmental conditions (such as organic pollution) and may be well documented.

Mayor groups of macroinvertebrates are easy to determine, but characterisation down to species level is very complex as differences between species most often are only visible under the binocular for experts. Recognizing differences in the position of body hairs, layout and forms of mandibles or extremities require intensive knowledge and often experts are focused only on one particular group of macroinvertebrates.

**Biotic indices** - At the beginning of the twentieth century, the effect of point source pollution from sewage discharges on aquatic fauna and flora downstream of urbanised areas became evident. KOLKWITZ & MARSSON (1902, 1908, 1909) were the first to exploit these effects and present a practical system for water quality assessment using biota. Their system, known as the Saprobic system, has been used mainly in Central Europe. It is based on the observation that downstream of a major source of organic matter pollution a change in biota occurs. As self-purification takes place, further ecosystem changes can be observed, principally in the components of the biotic communities. Odour and other chemical variants in the water also change. Kolkwitz and Marsson were principally concerned with an ecological approach, dealing with biological communities and not purely with indicator species. Since the taxonomy of aquatic organisms in Central Europe is well developed, it is possible to use the species level (which is the most precise) in the Saprobic system developed in that region.

The Saprobic system is based on four zones of gradual self-purification: the polysaprobic zone, the α-mesosaprobic zone, the β-mesosaprobic zone, and the oligosaprobic zone. These zones are characterised by indicator species, certain chemical conditions and the general nature of the bottom of the water body and of the water itself.

Each of the four zones can be characterised by indicator species that live almost exclusively in those particular zones. Therefore, comparison of the species list from a specific sampling point with the list of indicator species for the four zones enables surface waters to be
classified into quality categories, particularly when combined with other important and often characteristic details (e.g. generation of gas in sediments, development of froth, iron sulphide on the undersides of stones, etc.).

The classification system has been used to design Saprobic Indices particularly for data treatment, assessment and interpretation in relation to decision making and management. The first Saprobic Index designed by Pantle & Buck (1955) was modified by Liebmann (1962). The frequency of occurrence of each species at the sampling point, as well as the saprobic value of that indicator species are expressed numerically. The system was further developed by Zelinka & Marvan (1961) and Sládeček (1973).

The community structure approach examines the numerical abundance of each species in a community. The methods most widely used to assess aquatic pollution are based on either a diversity index or a similarity index. A diversity index attempts to combine the data on species abundance in a community into a single number. The most common diversity indices in use are those based on information theory, such as the Shannon-Wiener Index ($H'$). Although they are applicable to a wide variety of aquatic situations they have not been thoroughly tested for biological relevance. Nevertheless, such indices can be used until other systems have been adequately field tested or developed.

Similarity indices are based on the comparison of the community structure in two samples, one of which is often a control. Different indices compare abundance in particular species, or abundance in any species, found at the sampling area. Their use is limited by the necessity for a clean water sampling station of similar nature for comparison purposes. Therefore, they are most suitable for point sources of pollution in a river where samples can be taken upstream and downstream of an input. A typical, simple index is that of Jaccard (1908).

Diversity indices are best applied to situations of toxic or physical pollution that impose general stress on the organisms. Stable ecosystems are generally characterised by a high species diversity, with each species represented by relatively few individuals. A widely used diversity index is the Shannon Index which combines data on species or taxa richness with data on individual abundance. The species number indicates the diversity of the system and the distribution of numbers of individuals between species indicates the evenness.

**Chemistry versus Biology**

Chemical approaches should not automatically be preferred to biological approaches because both have advantages and shortcomings (Table 2). Instead, the two approaches should be regarded as complementary. Each category of water quality assessment operations has its own requirements in relation to its characteristics. Some relevant examples are:

- All monitoring activities should take into account such characteristics as continuity of the monitoring chain and the required levels of field operators.
- International monitoring programmes should consider, among others, the inter-comparability, the quantification, and the sample storage requirements.
- Trend monitoring should consider the signal amplification, the duration of information obtained, the sample storage capacity, etc.
- Basic surveys within a given region should consider biological monitoring (chemical analyses of tissues, biotic indices, physiological determinations) and/or particulate matter monitoring.
- Operational surveillance for a specific use is usually focused on water analysis and the duration of the determinations should be short.
- Impact surveys may consider field biotic indices.
- Emergency surveys imply the sampling of each medium for rapid or delayed chemical analysis and physiological effects.
Early warning surveillance mostly relies on the continuous exposure of sensitive organisms to water and/or on the continuous measurement of some chemicals (e.g. ammonia).

Background monitoring and surveys undertaken for modelling purposes may involve all three monitoring media.

Table 2. Advantages and shortcomings of biological and chemical water quality monitoring

<table>
<thead>
<tr>
<th>Biological monitoring</th>
<th>Chemical monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td></td>
</tr>
<tr>
<td>Good spatial and temporal integration</td>
<td>Possibility of very fine temporal variations</td>
</tr>
<tr>
<td>Good response to chronic, minor pollution events</td>
<td>Possibility of precise pollutant determination</td>
</tr>
<tr>
<td>Signal amplification (bioaccumulation, biomagnification)</td>
<td>Determination of pollutant fluxes</td>
</tr>
<tr>
<td>Real time studies (in-line bioassays)</td>
<td>Valid for all water bodies, including groundwaters</td>
</tr>
<tr>
<td>Measures the physical degradation of the aquatic habitat</td>
<td>Standardisation possible</td>
</tr>
<tr>
<td><strong>Shortcomings</strong></td>
<td></td>
</tr>
<tr>
<td>General lack of temporal sensitivity</td>
<td>High detection limits for many routine analyses (micropollutants)</td>
</tr>
<tr>
<td>Many semi-quantitative or quantitative responses possible</td>
<td>No time-integration for water grab samples</td>
</tr>
<tr>
<td>Standardisation difficult</td>
<td>Possible sample contamination for some micropollutants (e.g. metals)</td>
</tr>
<tr>
<td>Not valid for pollutant flux studies</td>
<td>High costs involved in surveys</td>
</tr>
<tr>
<td>Not yet adapted to groundwaters</td>
<td>Limited use for continuous surveillance</td>
</tr>
</tbody>
</table>

Links hydrology – limnology

No meaningful interpretation of analytical results for the assessment of water quality is possible without the corresponding hydrometric data base. Consequently, all aquatic environment monitoring should take into account the hydrological characteristics of the water bodies, which should be determined by preliminary inventories and surveys. All field observations and samples should be associated with the relevant hydrological measurements for different types of water bodies.

The combined evaluation of water quantity and quality data sets should also take into account spatial and temporal variabilities. The hydrological features of water bodies follow their own variability patterns that may be quite separate from natural and/or man-made water quality fluctuations. In practical terms, however, they tend to be rather closely inter-linked.

Determining the hydrological regime of a water body is an important aspect of a water quality assessment. Discharge measurements, for example, are necessary for mass flow or mass balance calculations and as inputs for water quality models.

References

*The content of this paper mainly is compiled from:


Further literature quoted:


4.4 Modelling flow and discharge distributions in the Danube River Basin
By János Józsa, Tamás Krámer & Sándor Baranya

Abstract written by J. Bloesch on the basis of the slide show on CD-ROM

A representative study reach for flow modelling was chosen in the Danube River between river km 1792-1802. The models used were derived from general 2D flow equations and based on accurate topographic information (scanned, high resolution digital bed model). The digital bed model was extended to the floodplains, providing flow resistance and smoothness. Bottom smoothness (grain size) was measured by freezer-plate sampling of river bed surface.

The 2D model was applied to various prevailing discharge conditions (shown in coloured maps) and the smoothness coefficients for low and high flow conditions were calibrated. Velocity measurements were performed to collect flow model calibration data, and typical ADCP results in cross-sections at different discharge were presented. ADCP also provided layer-averaged velocity profiles and logarithmic profiles fitting with no slip and slip bottom conditions.

The turbulent flow was modelled with a 3D model. Turbulence, especially in rivers, plays an important role, e.g., in respect to mixing, suspended sediment transport and scouring, and the drag force on swimming bodies (fish). Various movies showed the 3D turbulent flow modelling using SSIIM. Model testing showed typical 3D pathways of water particles with and without groynes. A comparison of measured and modelled velocity distributions yielded satisfying agreement. The interpretation of flow patterns provided estimates of residence time in a fictitious dish-shaped river reservoir. This provides the basis for model application in riverine reservoirs such as the Iron Gate reservoir.

The 2D models were applied during the Tisza flood event in 2001. This flood showed the 3D nature and complexity of the flow near the dike and the shallow 2D (depth-integrated) nature farther away. Remote sensing was used for model calibration (smoothness coefficient). Aerial observation and numerical modelling of the inundation areas yielded a good fit. Hence, the models can be used for flood-prediction and flood risk-assessment.
4.5 Water quantity and flow as key parameters for benthos and fish – an investigation using ecohydraulic approaches

By Matthias Schneider

Assessing and affecting ecological status

Running waters throughout the world are increasingly affected by human activities such as dams, dikes, water pollution, navigation, and water extraction. All these constraints strongly affect the ecosystem goods that originally were provided by rivers and streams. The related problems are widely recognized not only in the scientific community but also in society and administration. This awareness finds its expression, e.g., in the EU Water Framework Directive (WFD) in which the “ecological status” of river systems is the focus of consideration. But how to assess the ecological status of rivers and make it understandable for non-experts?

Possible ways to tackle this task are found in the field of ecohydraulics. Being a rather young discipline, it is one key to support the enhancement of affected flowing waters providing the scientific background about the linkages between physical processes and biota. The present state of rivers and connected ecosystems can be described by biological indicators as suggested in the WFD. However, it is much more difficult to predict the future development of river ecosystems. But at the same time, this is a major goal of the Directive: to maintain and recover good ecological status. Thus, for the effective implementation and achievement of this goal, predictive simulation tools are needed.

The basic assumption of ecohydraulic approaches is that ecological status of rivers can be defined not only by biological indicators such as, e.g., abundance of indicator species or diversity of fish community, but also by living conditions for aquatic organisms. These living conditions are described by physical parameters because most organisms are adapted to specific physical conditions (hydraulics, morphology, water quality). One example is given in Figure 1 showing fish species with different hydraulic preferences that are expressed by their body shape (morphology).

Figure 1. Species with different preferences related to flow velocity. Carp with high flow resistance adapted to stillwater, bullhead as bottom fish with compact body shape and brown trout with aerodynamic body capable to withstand fast currents.

Ecohydraulic investigations are highly practice-oriented because they are based on physical conditions like water quality, channel morphology, or spatial and temporal distribution of flow (flow regime), and because the effect of measures in the first instance is restricted to these physical conditions. Because modifications of these factors were the main reason for the deterioration of rivers, it is more or less evident that the focus must be on these factors to improve river ecology.
Although the assessment of current ecological status following the WFD is mainly based on biology, there is a strong need for predictive tools based on physical conditions to assess future ecological status. Habitat models based on ecohydraulic approaches allow one to predict the impact of changes in river morphology and flow on habitats of riverine species. By these means the effectiveness of measures (as required in the management plans of the WFD) can be investigated comparing different scenarios that can be defined in models.

**Actual modelling approaches**

While early efforts in ecohydraulic investigations were mainly based on mechanistic principles and univariate preference functions, in newly developed models a number of stochastic and statistic approaches have been considered, including multivariate statistics, logistic regression, fuzzy-logic and neural networks. **Multivariate approaches** were introduced in order to consider the linkages between different physical factors right from the “start” of modelling. Examples are multivariate preference functions (STALNAKER et al. 1995), logistic regression (SCHMUTZ et al. 1997), and artificial neural networks (BROSSE & LEK 2000).

In contrast to these approaches, the **fuzzy rule-based approach** introduced in 2001 as part of the modelling system CASiMiR (JORDE 1997; SCHNEIDER 2001) is based on knowledge about fish habitat demands as available: imprecise (fuzzy), multivariate and defined by linguistic expressions.

For example (Fig. 2), an expert could tell IF water depth is „High“ AND substratum size is „Medium“ AND flow velocity is „Medium“ THEN Habitat suitability is „High“. Up to now, the following parameters have been considered using the fuzzy-rule based fish habitat model: flow velocity and hydraulic forces; water depth; size of dominating substrate; cover types; pool types, portion of gravel classes (fine, mid-sized, coarse), and embeddedness.

**Figure 2.** Fuzzy rule-based approach for fish habitat modelling as implemented in the model system CASiMiR. Linkage to biology is performed by expert knowledge about habitat demands. Expert rules integrate the combination of input parameters as well as the impreciseness of knowledge by using linguistic expressions that are defined by fuzzy sets.
The outputs of the mentioned models are usually predictions of habitat quality based on physical properties or bioenergetic aspects. Recently the focus is not only on water body and riparian zones but also on connected floodplains and morphodynamics.

**New developments in ecohydraulics**

Research and development in the future must address more complex linkages between physical processes and biota over larger spatial and temporal scales. For instance, long-term investigations and morphodynamics are needed to respect the smooth changes of biotic communities. A first study aimed in this direction was performed on the River Rhine (KERLE et al. 2002, Fig. 3). It dealt with the long-term development of reconnected floodplain areas and changes in fish habitats within these areas. By linkage of morphodynamic and habitat models, predictions of the ecological development in terms of fish habitat suitability over a period of 30 years could be made. In the future, this kind of long-term investigation will not only be crucial for the selection of sustainable measures but also for the efficient use of available finances and security issues.

![Figure 3. Example of an ecohydraulic long-term investigation on the lower Rhine River. Predicted changes in fish habitats for a life stage of pike in a reconnected floodplain within a time frame of 30 years are given. Predictions were made using the fish habitat module of CASiMiR that was linked with morphodynamic calculations performed by Delft Hydraulics (KERLE et al. 2002).](image)

An integrative river management must concentrate on the catchment or “water body” scale rather than on the site specific scale. Currently, the assessment of larger river reaches is mainly based on extrapolation using modelling results gained by site-focused investigations.
In order to consider the networking and connectivity of habitats that are crucial for the function of river systems, regional approaches (with lower model resolution) are being developed (Fig. 4). These approaches are designed with respect to the fact that physical habitat quality is only one attribute needed to support aquatic species and communities.

**Figure 4.** Site-focused approach (a) and regional approach (b) for habitat modelling in a river catchment. While approach (a) is based on results gained by habitat modelling on the micro-scale (resolution is several centimeters up to meters) in representative reaches and a following extrapolation, approach (b) covers the whole system using a lower resolution definition of mesohabitats (several meters to hundreds of meters).

Another recent development in ecohydraulics is the concept of succession modelling for vegetation dynamics in the riparian and floodplain zone (Fig. 5). Temporal aspects as well as the interactions between system components are considered. These components can be either physical (as soil moisture of trophic level) or biological as, e.g., competition for light between different species of different age classes of the same species. It is assumed that using this kind of model, a range of possible developments in floodplains with different degrees of connectivity can be predicted. This will be of major importance, e.g., within the context of ecologically oriented, flood defense measures.

**Figure 5.** Elements of a succession model for vegetation dynamics in the riparian zone and floodplain. Temporal aspects (e.g. time slots for settling), physical conditions (e.g. soil moisture), competition (e.g. for light) and disturbance (e.g. hydraulic stress) affect the life cycle of plants and build a complex network of interactions.
Certainly, more research is needed to understand what are the main factors for species to let them be successful or survive under harsh transient conditions. In order to be a crucial support in the assessment and enhancement of ecological status, this kind of knowledge must be integrated in future ecohydraulic modelling.

However, ecohydraulics are a young and fast developing discipline. In order to consider the mentioned complex questions connected to, e.g., flow regime, upscaling, morphodynamics and succession, highly transdisciplinary views and work are needed. In this sense ecohydraulics need, but also support, real cooperation between ecologists and hydrologists.

References

4.6 The Catchment Approach in Danube River Basin Management and its Implementation - Emphasis on Flood Control and Protection
By Felix Seebacher

Four topics were raised and possible approaches shortly discussed. The themes were:
a) Water Framework Directive (WFD) and River Basin Management Plan (RBMP)
b) WFD and flood protection – new position paper
c) Example of urban development into the flood plains
d) Permit trading approach for retention volume

a) The Water Framework Directive introduced in 2000 became part of the individual water legislation in all member states in 2003. The general rule is protection of all water bodies (except the sea) and ensuring that the aquatic ecosystem improves – ‘achieve a good ecological and chemical status’. The emphasis in the WFD is clearly a qualitative one and to a lesser extent a quantitative – hydrologic one.
One of the major topics or even the core of the WFD is the River Basin Management Plan (RBMP). Already in the Preamble of the WFD, in paragraph 30 (implementation of the WFD) and 46 (public participation) the RBMP appears. Article 2 defines a river basin as the surface area which drains to the sea; and river basin districts as the main units for river basin management. Article 3 sets the administrative rules for the river basin districts. The identified river basin districts had to be reported to the Commission by 2003. Article 4 sets the operational framework for implementing a RBMP and sets the goals that drafts of RBMPs have to be submitted by 2008 and the final version including the programme of measures by 2009. Article 9 demands that within the RBMP tools have to be developed to ensure proper cost recovery for water use. These tools are outlined in Annex III. The real core for developing a RBMP is laid out in Article 13 and Annex VII with the description on how a RBMP is established and what it has to contain. Finally, in Article 14 procedures for Public Information on RBMP (participation and not only information) are set.

The River Basin Management Plan, hence, enforces an integrative catchment approach. Until 2009 within the Danube Basin, a unique organized form of data set, geographically referenced and structured, will be available on the basis of the WFD’s RBMPs. We are now sure that the evaluation and presentation of the collected data follow the same basin-wide rules.

b) “Flood protection” appears only twice in the WFD; in Article 4 in a rather negative context (water bodies which may remain artificial or heavily modified bodies have to serve e.g. … flood protection, etc. ..) and in Annex II in connection with groundwater. Therefore, engineers claim that their work and goals are not properly represented in the WFD. Thus, a Flood Risk Management Plan was proposed by the Commission under Dutch leadership on July 12, 2004, called “Flood risk management – Flood prevention, protection and mitigation”. It suggests to establish an own directive with its own Action Plan / Programme. It claims to be more cost-effective due to co-ordination and cooperation on this single topic.

However, the author suggests that flood risk management should be integrated into the WFD to avoid two parallel management plans. It must be clear that new flood protection schemes are only feasible if ecological improvement in the water body can be achieved. Furthermore, the establishment of harmonized flood-risk maps within the river basin would become an additional advantage over today’s heterogeneous situation.

c) Over the time span of 130 years (1870 – 2000) the development of a city (St. Pölten – Lower Austria) in relationship to the river (Traisen) was evaluated. Historical maps of the city’s development as well as the development of the river drainage were evaluated for five time steps. As we have observed in other places, at St. Pölten the old centre also is situated on a slightly elevated plot which cannot be seen or observed by walking within the city. It could be shown, however, that the city developed equally fast towards the river, i.e., flood prone areas as in any other less dangerous direction. The early developments occurred generally on a lower scale, such as gardens with small sheds, which slowly transformed into areas with houses and villas. Technical flood protection facilities were usually built after former flood-prone areas had been densely populated or used by industry. The flood protection schemes protect the areas from a flood with a return period of approximately 100 years. With bigger, e.g., 300-years floods, the flood protection scheme will fail and some of the flood water will flow through the city. It has been shown for St. Pölten, that even such an extraordinary event will not cause more damage, than a flood of a 100 year return period would have caused if no flood protection would have been implemented.

d) A new concept of permit trading with retention volume, as it becomes already common with emission permits, should be discussed. Retention volume is limited and should only be
increased but not destroyed, as it is often the case with the implementation of flood protection projects. A paradigm change is needed, considering retention volume as a necessity that must not be lost. New retention volume has to be re-created with a distinct price (€/m³, yr) which can be calculated over a time span (e.g. 100 years). Only newly created retention volume (retention basin, etc.) can become a tradeable commodity and can be sold or auctioned off. To be effective in exchange for lost volume, the newly created retention volume should only be located further upstream or ‘close by’ to be similarly effective. Retention volume trading would ensure an economically viable means to control further developments and encroachment into the flood pains.

4.7 River Monitoring – where Limnology meets Hydrology and Chemistry. Nutrients and Contaminants in the Danube River and its Tributaries and their Affect on Black Sea Coastal Area

By Helmut Kroiss, Matthias Zessner & Christoph Lampert

Introduction

The EU Water Framework Directive (EU WFD) based on advanced research investigation requires water management on the basis of river basins, starting at the coastal area influenced by the river and comprising the whole area from the mouth to the boundaries of the hydrological catchment. The main goal of this directive is to achieve or maintain a good status of all waters and to avoid any deterioration of the actual status.

In order to achieve these goals and to develop the required management plans, monitoring is one of the basic decision support tools. Monitoring results can only be correctly interpreted if all the processes having influence on the measured data are well understood and quantitatively related to natural and anthropogenic influences. At the same time, a correct interpretation of the data in regard to the processes involved is only possible if the data are correct and consistent, i.e. that all relevant information needed for their interpretation (temperature, pH, weather conditions, time and location of sampling, etc.) is available. In many cases this cannot be achieved with the existing monitoring schemes that result in inaccuracies and uncertainties, even when correct and comprehensive mathematical models are applied. The main problems are closely linked to the high variability of nearly all physical and chemical parameters in time and space.

The biological or limnological data have a great advantage as they reflect the mid-term integrated reaction of the natural living communities to anthropogenic and natural changes. The biological monitoring represents the backbone of water quality assessment for all surface waters. Normally, a monitoring frequency of twice a year is sufficient. Biological monitoring cannot be used for groundwater quality assessment.

Monitoring has at least 3 different goals:

- Assess compliance with legal requirements, detection of hazardous spills.
- Basis for materials management and land use planning.
- Understanding the processes involved (research and modelling).

Depending on the specific questions to be answered, monitoring procedures need to be adapted (time and point of sampling or measuring, sample treatment, analytical procedure, data management, etc.). This represents one of the most difficult problems for the development of long-term monitoring schemes that are always limited by financial resources.
It is therefore of great importance to further develop “indicators” able to detect specific even complex changes in a water body and that can be related to anthropogenic activity.

In order to understand the processes involved, different information is necessary:

- Concentrations of chemical species allow the detection of limiting factors (e.g. phosphorus limiting algae growth) and can be related to Monod or Michaelis Menten relationships, i.e. rate of processes.
- Loads of elements represent a potential for growth or other processes, depending on the availability (dissolved versus suspended form, etc.) and limiting concentrations.
- Climatic conditions (influencing precipitation, solar radiation, evaporation, evapotranspiration, wind, marine flow pattern, etc.) strongly influence temperature and currents. Temperature influences all biological and chemical processes (Arrhenius).
- Flow in rivers and other hydrological data are not only relevant for the load calculation but also for storage and mobilisation of particulate matter and is directly related to water level. Water levels are interlinked with flow velocities and directions in groundwater, inundation areas, etc.

Chemical and physical parameters are needed for:

- Assessing short-term compliance (from monthly sampling to continuous monitoring). For instance, it is possible to continuously monitor the ammonia effluent variation of the main waste water treatment plant of Vienna some km downstream of the discharge.
- Assessing the actual situation of water quality and limiting factors (together with quantitative input – output models including storage, removal and mobilisation processes).
- Assessing future development of water quality (influence of management decisions, new discharges, discharge of hazardous substances).
- Alarm systems operation.

Biological monitoring by limnologists (marine ecologists) is needed for:

- Assessing the quality of the water as ecological environment for a living community adapting to the specific natural and anthropogenic loading situation (mid-term control parameter).
- Detecting specific deficiencies which can be related to specific anthropogenic inputs.

Hydrological data:

- Evaluation of flow conditions for load and dilution capacity calculations, water levels in rivers, sediment transport, statistical interpretation of the data.
- Relation of hydrological to climate data.
- Residence time of water in lakes and reservoirs.
- Groundwater data for flow, dilution, and residence time modelling.

**Nutrient management in the Danube Basin and its consequences for eutrophication in the Black Sea coastal area**

The daNUbs Research Project within the 5th European Research Frame Work Program deals with this problem in regard to the Danube River Basin and the Black Sea coastal area influenced by the discharge of River Danube (Table 1). It is performed by an international and multidisciplinary research team with 17 partners in 7 European countries and over a period of 4 years (2001 to 2005).

Most of the research is based on existing monitoring results from different sources. For detailed analysis of specific processes especially in small sub-catchments extensive additional hydrological and chemical monitoring was performed. A relationship between physical-
chemical data and limnological results was only performed for the assessment of eutrophication in Western Black Sea Coastal Area (WBSC).

<table>
<thead>
<tr>
<th>DANUBE RIVER</th>
</tr>
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<tbody>
<tr>
<td>Length: 2,857 km</td>
</tr>
<tr>
<td>Catchment 817,000 km², includes larger parts of 13 countries</td>
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<tr>
<td>Population within the catchment: 85 million people</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>BLACK SEA</th>
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<tbody>
<tr>
<td>Total catchment: 2,3 million km², population 190 million people</td>
</tr>
<tr>
<td>Surface Area: 461,000 km², average depth 1,240 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WESTERN BLACK SEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influenced by Danube plume; surface area about 30,000 km²</td>
</tr>
<tr>
<td>Depth along the coastline: ~70 m, shelf ~140 m</td>
</tr>
</tbody>
</table>

Table 1. Characteristics of the study region (Danube and Black Sea)

**DANUBS—Project characterisation (Figure 1)**

The motivation for the daNUbs project can be characterised by the following aims:

- Understanding the fate of nutrients (N, P, Si) from their sources (especially the diffuse sources) to the sea in order to derive adequate mathematical models (MONERIS, Danube River Quality Model, Danube Delta Model).
- Understanding the role of river pollution for eutrophication of the Black Sea to derive information about the nutrient load that leads to sustainable Black Sea quality along the Western coast region.
- Development of technical and operational measures to reduce excessive discharge of nutrients to improve the marine quality, with special emphasis on waste water treatment requirements, agriculture and land use.
- Development of different scenarios linked to political and socio-economic tools that can be applied to achieve a good status of all waters in Danube Basin as required by EU WFD.
- Development of monitoring procedures to check the effect of the measures implemented.

![Figure 1. Concept of the daNUbs research project](image)
The daNUbs project was developed in close cooperation with the International Commission for the Protection of the Danube River (ICPDR), established to implement a common water protection policy in the whole catchment. The project results already had a strong impact on the development of the so-called roof report fulfilling the status report requirements of the WFD in regard to the whole catchment.

**Actual state of the project**

The MONERIS model, describing the transport and transformation of nutrients from their source to the river system, and the DWQ-model, describing the same processes in the rivers, are suitable to describe the consequences of the dramatic changes in the catchment due to the economic crisis in CEE countries for N and P discharge to the Black Sea with adequate accuracy for strategic decisions. Application of the models to small-scale sub-catchments and an increase in data availability helped improve the model application to large scale catchments.

The main anthropogenic driving forces for N and P discharge to the Black Sea are (Fig. 2):

- Agriculture.
- Wastewater management (Sewerage, wastewater treatment).
- Air pollution by the traffic with NOX.

![Figure 2. sources of nutrient emissions 1998-2000 into the Danube](image)

**Agricultural activity influencing nutrient emissions to water systems:**

- Fertilizer management in plant production.
- Production of animal protein and fat (milk, meat, eggs).
- Soil quality management, erosion abatement, etc.
- Agricultural Policy (financial support) on national, EU and WTO levels.

**Important natural influences on nutrient emissions to water systems are:**

- Soil geology.
- Climatic conditions (precipitation, etc.).
- Slope.
- Residence time in groundwater.

**Driving forces for transport and losses:**

- Denitrification potential mainly from the source to medium-size rivers with strong emphasis on processes in soil and groundwater (residence time) and the interaction between ground and river water (riparian zones).
- Large rivers (including wetlands along these rivers and the delta) have little influence on N transport and loss.
Erosion, together with over-fertilisation, strongly contributes to transport of particulate nutrient loads; their role for eutrophication is still not well understood.

The large dam at Iron Gate represents an important sink for phosphorus even in the next decades.

Actual status of Western Black Sea Coastal Area (WBSC)
There was strong improvement of water quality during the last few years. But, it must be stated that climatic conditions have been favourable for this development and that the fish populations have still not recovered. Indicators for this improvement are:
- Anaerobic conditions in the sediments (anoxia) have nearly disappeared.
- Number of macrobenthos species in the WBSC has markedly increased.
- Algae growth is phosphorus limited (in summer, in winter probably light limited).
- Rare algae blooms (similar to the 1960s).

This positive development can mainly be related to:
- Economic crisis in CEE countries since 1989.
- Change of agriculture from economically driven production to nutritional survival of the population, closure of the large animal production plants and of the fertilizer industry (market fertilizer application close to zero) in CEE countries.
- Use of P-free detergents in D, A, and increasingly in EDC.
- N and P removal at municipal treatment plants in D, A, CZ.
- Improved agricultural practices.

Conclusions
- The Danube River is the main contributor to eutrophication phenomena in WBSC.
- Nutrient concentrations in the Danube River will probably meet good status requirements.
- The actual status of WBSC is close to “good” (except for fish populations).
- The climatic conditions during the last few years were favourable for WBSC.
- Eutrophication in the Romanian part of WBSC is actually phosphorus limited and the N/P ratio is “good”. In the Bulgarian part of the WBSC, the frequency of N-limited situations is increasing.
- Economic crisis and decrease of soluble P by P-free detergents and P removal at treatment plants (A, D, CZ) were the main drivers for the improvements in WBSC.
- Agriculture is a main driver for nutrient emission to water systems. The nitrogen loads influenced by agricultural practices are actually in the same order of magnitude as point sources (municipal waste water).
- For dissolved phosphorus, point sources are of primary importance, particulate phosphorus mainly stems from agricultural soil erosion.
- The establishment of a clear correlation between measures taken in the Danube catchment and the response in the status of the Danube River and WBSC needs long-term reliable monitoring adapted to the questions to be answered.

Anticipated pressures for nutrient management in the Danube Basin
The actual situation is characterised by a non-sustainable economic situation in CEE countries. Economic development can result in important increases in nutrient discharges from diffuse
(agricultural development) and point sources (sewerage development without adequate waste water treatment with nutrient removal). It will therefore be important to quickly develop a common nutrient management policy that enables economic growth without compromising water quality in Danube Basin and WBSC. Changes in climate can increase these pressures. Nutrient management needs a long lasting strategy for sustainable development, and a prospective of a minimum of about 30 years for stable success. This must be considered for the monitoring program. Data quality assessment finally decides whether the financial resources for monitoring pay result in improved management or are wasted.

4.8 The Rhine-Danube-Waterway as a passage for alien species

By Franz Schöll

The biodiversity of large European rivers is mainly affected by (1) pollution and (2) hydromorphological degradation. While the negative effects of pollution are decreasing because of improved wastewater treatment, hydromorphological degradation is still affecting the biota in rivers. In the last decades, a third major factor has been threatening biodiversity in large European rivers: The increasing number and density of invasive species. In some river sections, invasive species have become the most abundant inhabitants. Today, invasive species have become the most prominent threat to native biodiversity in large European rivers.

The term "neozoao" designates animals that have invaded a previously inaccessible faunal region since the beginning of modern times in 1492 with direct or indirect anthropogenic involvement and which succeeded to establish new populations. For aquatic animals it was the interlinkage of European river basins that especially promoted faunal exchanges between completely independent faunal provinces. Through navigation, neozoao dispersal advanced even against the flow of rivers.

Some examples illustrate the invasion of neozoao into German Federal waterways. One of the first animals to immigrate into Central European waters was the zebra mussel *Dreissena polymorpha*, which was introduced with navigation from Eastern-European waters as early as the 18th century. The Black Sea region is also the origin of the mud crab *Corophium curvispinum* that spread in the 1930s via European canals into the Rhine River Basin. Its dwelling tubes cover stones as well as sessile animals, and lead to severe reductions of the stocks of zebra mussels. The basket clam *Corbicula fluminea* stems from Australasian and African faunal provinces. This species can establish itself successfully only where water temperature in winter does not drop below 2°C over longer periods.

The water flea *Dikerogammarus villosus* (Fig. 1) entered the River Rhine through the Main-Danube Canal that was completed in 1992 and spread in a veritable outbreak. *D. villosus* is under suspicion to have contributed through its predatory mode of life to the decimation of other crustaceans such as *Gammarus tigrinus*. In this regard, the Main-Danube Canal plays a major role by enabling an exchange of fauna between the rivers Rhine and Danube. Thus, a total of eleven macrozoobenthic species that are characteristic for the Danube have entered the Rhine and then the rivers Weser, Elbe, and Oder, while two species went the opposite direction. In the River Rhine, the invasion of these species caused a restructuring of the zoocoenosis, because the new species proliferated in an outbreak at the expense of indigenous fauna (Fig. 2).

Neozoao are successful because of (1) great tolerance against many environmental factors, (2) r-strategy (high fecundity, short generations), (3) high mobility, (4) special breeding strategies, (5) anthropogenic modification of the environment (aquaculture, fishing, impact of
wastewater and salt, global warming, river training, navigation, etc.). The highest percentages of alien species among all taxonomic groups are found in crustaceans.

**Figure 1.** Spread of *Dikerogammarus villosus* Germany (TITTIZER et al. 2000, modified).

**Figure 2.** Dominance structure of macrozoobenthos of the Upper Rhine 1990, 1995 and 2000. Since 1990 immigrated species are black signed.
Nature conservation

The phenomenon of neozoa invasions is discussed controversially: Enrichment of the natural inventory versus its distortion. However, it should be kept in mind that neozoa can never be removed from waters without detrimental environmental effects.

The evaluation (“good or bad”) of alien species depends on the point of view of the observer. Arguments for “good“ are: (1) expansions of new species have happened many times during the biological history of earth, (2) enrichment of the spectrum of species, (3) food source for indigenous species, and (4) preservation of the ecological function after changed environmental factors. Arguments for “bad“ are: (1) loss of biodiversity in a very short time, (2) elimination of indigenous species, (3) loss of genetic diversity because of hybridisation, and (4) economic damage and health risks.

Research on alien species

(1) Identifying the migratory routes of alien species in Europe, (2) Autecological studies on neozoa (life cycle, nutrient, breeding strategy, habitat demand, tolerance against environmental abiotic factors like pollution, temperature, salt, etc.), (3) Effects of alien species on the native fauna (dominance and constancy structure, individual density, biodiversity), (4) Differences in the behaviour of alien species in their native and their new ranges, (5) The role of alien species with regard to the assessment of the ecological status of rivers according to the WFD.

References


4.9 Technical, hydrological and environmental aspects of the Iron Gate I and II Dams

By Slobodan Petkovic, Marina Babic-Mladenovic, & Milena Damnjanovic

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Technical aspects of Iron Gate I and Iron Gate II

The Iron Gate I Water Power and Navigation System was completed in 1972, by joint efforts of Yugoslavia and Romania. Its main purpose is to use the considerable hydropower potential of the Danube, and to improve the navigation on a previously difficult reach of the river, in the Djerdap gorge. The dam is located 943 km upstream from the Black Sea (Fig. 1). In 1985, a second dam, the Iron Gate II, was built 80 km downstream from the first one for additional power production and more flexibility of the joint operation of the two power plants. The average annual power production of the two systems is estimated at 14,500 Gwh, and is a considerable contribution to the energy balance of the two countries.
Impacts of Iron Gate I and II on flow regime and sediment transport in the Danube River

The backwater zone of Iron Gate I is large and extends 250 - 300 km upstream in the Danube River, reaching the cities of Belgrade and Novi Sad. The problem of sedimentation in Iron Gate I reservoir is complex and serious. Although the suspended sediment concentrations in the Danube River are rather low (10^{-3} to 10^{-1} kg/m^3), considerable volumes of sediment enter the reservoir (7 - 30 million tons per year). The sediment deposition in the period 1976 – 1997 about 50 km upstream of the dam is shown in Figure 2.

Environmental aspects of Iron Gate I and II

The hot spot of Iron Gate sedimentation is pollution of the sediment, which was not adequately anticipated in the design of the dam. The pollution should, however, be considerable, as over 80 million inhabitants live in the basin upstream from the dam, with
large cities, developed industry and intensive agriculture. Hence, during the 30 years of reservoir operation, various types of sediment-bound pollutants were deposited within the reservoir. Especially severe incidents happened during 1999 (as a result of the NATO bombing campaign), and 2000 (two accidental pollutions in the Tisza River Basin).

An investigation of the chemical composition of deposited sediment was only recently included within the regular water quality monitoring programme. Acquisition of sediment quality data is needed to determine origin and long-term trends, estimate mass transport of selected constituents into the reservoir, render environmental aspects of reservoir sediment pollution, and initiate further investigations concerning the reservoir pollution and possible protective or remedial measures.

With regard to environmental impacts of Iron Gate I, the nutrient load and its variation along the reservoir are also interesting. The results of investigation are presented as the phosphorus load profile along the Danube River (Fig. 3). The local pollution sink in Iron Gate I and II is potentially negative for the aquatic ecosystem in this zone. However, this effect is very positive from the point of view of the protection of the Black Sea against nutrient inputs. Consequently, Iron Gate I and II could be considered as protective structures for the Black Sea.

Figure 3. River load profile of phosphorus subdivided over countries of origin.

It should be noted that the distribution of fish species after the construction of Iron Gate I and II is not yet clearly identified and understood. For example, according to some observations, the migration path of sturgeon is restricted to the Lower Danube stretch and these fishes cannot reach Iron Gate II anymore. Thus, two dams are not the primary cause of the disruption of the fish migration towards the upstream reaches of the Danube River. According to the ICPDR Roof Report 2004, "sturgeons are endangered due to habitat loss, habitation degradation and over exploitation".
4.10 The Hydropower Station Gabčíkovo: Deficits in hydrology (sediment transport, groundwater) and biology

By Alexander Zinke

On 24 October 2004, the Gabčíkovo hydrodam system has been in operation for 12 years. For years, this project was one of the hottest water disputes in Europe, but even today ecological deficits are not resolved.

Background

At Bratislava, the Danube enters the Hungarian plain where it formerly deposited a large fan of sediments. The Danube flows over this gravel and sand body, which is filled with one of the largest groundwater reservoirs in Europe. This so-called “inland delta” is a dynamic network of forked and meandering arms that regularly change structure. This wild system was “tamed” since 1880 by various river engineering steps to improve navigability and local flood protection.

Modern river engineering was initiated in September 1977 by a joint treaty between Czechoslovakia and Hungary to construct the Gabčíkovo-Nagymaros riverdam complex. Objectives were to improve navigation and flood protection, and also to produce hydropower at the two dams (peak operation of the Gabčíkovo dam and Hrusov reservoir near Bratislava, and flood waves being caught up in the 130 km long reservoir of the Nagymaros dam upstream of Budapest).

While Czechoslovakia completed most of the scheme in the 1980s, Hungary started later, halted the works in 1989 as a result of public protests and changed political powers, and abandoned the bilateral treaty in May 1992. Czechoslovakia, having already advanced the construction of the dam and canal, decided in November 1991 to quickly build a unilateral solution in the form of a new Danube diversion dam at Cunovo, only a few hundred meters upstream of the Hungarian border. While new bilateral negotiations were supervised by the European Commission, Slovak engineers dammed the river bed in late October 1992 and started operating the power plant (the diversion weir was under construction until 1997). Over 80% of the river flow and all commercial navigation are directed through the 25 km long, sealed Gabčíkovo side-canal which was built through the surrounding landscape. The entire scheme (reservoir, diversion weir, canal, power plant with locks and tailrace canal) extends over 50 km (direct impact area: 5,400 ha of floodplain forests and 3,900 ha of fields) and has a vertical drop of 24 m. It forms the second-largest dam along the entire Danube after the Iron Gate dams and one of the most disputed in the world.

As a result of operations, parts of the Danube bed and the extended side-arm system fell dry. In spring 1993, artificial irrigation provided water for these floodplain biotopes on both sides of the river (altogether 8,000 hectares). However, numerous dikes and cross-barriers dissected the former open and interconnected ecosystem into separated parts. The Danube lost its function as a “life pump” that regularly moistened and drained the riparian landscape. The stabilisation of formerly dynamic hydrological and morphological processes led to a continuous degradation, with many forest areas drying, fisheries decreasing, and rare pioneer habitats and species largely disappearing. Most former purification effects of Danube waters through the filtering process by rich vegetation and soils are largely lost today, as only a very small amount of water from the reservoir runs through the side-arms (ca. 30-100 m³/s on each side of the river, compared to 0-2,000 m³/s before: WWF 1997, ZINKE 2000).
Environmental monitoring since 1992 is rather limited, has weaknesses on both sides of the river, and is not well coordinated. Main action is a bilateral hydrological monitoring of the Danube flow and the relation between the discharge diverted into the canal and the volume left for the “old” Danube bed. In addition, a number of research studies and a few major scientific reports on the Slovak side have been published, although “supervised” by the dam supporters. On the Hungarian side, scientific research is even more limited to a few studies (e.g. NOSEK 2004), mainly due to the lack of government support.

Upon pressure from the European Commission, both countries asked the International Court of Justice in The Hague (NL) in 1993 to assess the conflict (i.e. the breaking of the joint treaty - not the environmental impact). From 1993 to 1997, intense impact monitoring of the affected Danube region served both states in their Court proceedings. On 25 September 1997, the ICJ ruled that both parties must negotiate a new solution, jointly using the present technical support (i.e. without Nagymaros) in such a way as to accommodate both the economic operation (electricity generation) and the satisfaction of essential environmental concerns (WWF 1997).

Since autumn 1997, both parties conducted a number of related negotiations without finding a joint solution. In addition, it was found that Gabčíkovo is a major economic burden for Slovakia, as the costs for large credits for its construction and dam maintenance cannot be covered by the income made by hydropower (ZINKE ENVIRONMENT CONSULTING 2003). This reality is largely hidden from the public and the dam is still presented as a national pride.

On 15 April 2004, the Hungarian and Slovak environment ministers signed a new cooperative agreement to reinforce bilateral negotiations and find a satisfying solution. This happened in the framework of the EU accession where both states have to cooperate under EU law (e.g. Fauna-Flora-Habitats Directive, FFH, and Water Framework Directive, WFD) and to implement new commitments for sustainable flood protection (EC 2003, ICPDR 2004). The urgent development and implementation of related measures requires close cooperation of hydrologists, ecologists and river engineers and can start from various proposals to restore the river-floodplain system (e.g. WWF 1994 & 1997; LISICKY 1999; KERN & ZINKE 2000).

The deficits in hydrology and biology

Environmental conditions along the Danube and in the 8,000 ha of still valuable floodplains have basically prevailed over the last 12 years, thus leading to continued ecosystem degradation (see WWF 1994, WWF 1997, ZINKE & EICHELMANN 1996, KERN & ZINKE 2000). They can be summarised as follows:

**Fragmented Ecosystem**

The wetland is subdivided into three separated and largely isolated parts (the “old” river bed and the two side-arm systems), the formerly existing, ecologically decisive open connections for water exchange and species migration (e.g. fish rejuvenation) do not exist anymore (see Fig. 1).

**Untypical Hydrological Conditions**

Both wetlands are artificially irrigated with a largely continuous and limited discharge (some 30-100 m³/s) and related water table fluctuations (few decimetres), i.e. the former dynamic differences (0 m³/s up to over 2,000 m³/s with an amplitude of over 6 m) between dry periods and large inundations can never be restored. In addition, the prescribed inundations depend on an agreement of various local interest groups over the “best” timing.
The “old” Danube bed has a largely stable discharge of 400 m³/s that can suddenly change in case of floods exceeding some 4,000 m³/s (3,500 m³/s is the capacity of the Gabčíkovo turbines; the average Danube discharge is 2,000 m³/s and a centennial flood event is 11,000 m³/s).

**Degradation of Morphodynamics**
During a Danube flood released into the “old” bed, large quantities of fine sediments from the Cunovo reservoir were caught and deposited along the overgrown former river banks (see below). While in natural floodplains such sediments are being (laterally) eroded over time, these sediments are accumulating in the “old” river bed. This could be best observed during and after the last floods in April and August 2002.

In the floodplain and side-arm system, former erosion and sedimentation processes as key factors for habitat change are much suppressed. The typical flushing effect of Danube flood waters, taking away fine sediments and creating pioneer habitats, has been eliminated. Today, almost all gravel and sand bars are overgrown, and siltation prevails.

**Degradation of Biocenoses**
The atypical, non-varying hydrological and morphological conditions lead to a degradation of forests and wetland biocenoses, i.e.:

- A disappearance of most open biotopes (e.g. gravel and sand bars, mud flats). The dominance of the forested surface was further extended since 1992.
- Change of forestry practices, like clear cuts before the prime (many stands remain dry after artificial irrigation) and re-planting with more drought-tolerant species; logging activities were observed even during the breeding season.
- Species depending on open connections between the river and the side-arms are at risk. This is particularly valid for many fish species that need to move between both water bodies during their life cycles (feeding, spawning, sheltering).
- Continued spread of invasive species (alien and ubiquitous species) due to the absence of long inundation and erosive forces in the understory.

This alteration and levelling of formerly diverse local habitat features has lead to a certain uniformity of the spatial composition and distribution pattern of the floodplain, as was shown for the macroinvertebrate fauna of the side-arm system in the Szigetköz (NOSEK 2004).

**Overgrowth of the “old” river bed**
With only 10-20% of water left in the river bed, large new river banks became subject to natural succession processes. This is supported by lateral groynes, formerly built to constrain the navigation route, which catch fine sediments. After 12 years, significant parts of the bed especially along the former regulated banks, are overgrown by young willow forests (see Fig. 2). As a result, a new riverine habitat has developed within the regulated river bed. However, this “old Danube” section is subject to unnatural hydro-morphological conditions in the form of rare and strong flood events (very quickly starting and ending, high load of fine sediments). This results from opening the flood gates in Cunovo during a Danube flood. For a short time, surplus reservoir water and sediments are released, until the Danube waters recede into the Gabčíkovo power canal.

**Increased recreational disturbances of the protected area**
The Danube floodplains always served local recreation uses but this severely changed after 1992. “Wild” recreation areas developed in the Slovak floodplain around two gravel lakes, creating growing problems in the late 1990s. In the sensitive floodplain area (a protected landscape with, e.g., nests of white-tailed eagle) next to Gabčíkovo, some 1,300 non-
permitted weekend houses were built since 1992: They range from primitive wagons to fenced-in summer cottages and weekend family houses. Built in the former active floodplain along the side-arms, many of them were damaged by the August 2002 flood.

**Natural and artificial flood events**

2002 was the first year since 1991 with inundations of the floodplain. The 30-year flood event at the end of March and the centennial flood in August were large enough for a complete flooding of the forests on both sides of the river – different to the failed artificial inundation efforts after the start of Gabčíkovo. Here, increased irrigation discharges up to 130 m³/s were too small to spread water into the forested areas. In 2002, some sediment deposition and erosion effects were observed, allowing re-appearance of pioneer species. However, it took 10 years and over 10,000 m³/s of flood volume to briefly restore some of the former typical conditions.

This continued degradation was also the reason for the Slovak National Ramsar Committee to prepare in 2002 a document for putting this wetland area on the Ramsar list of threatened wetlands (“Montreux List”).

**Proposals for solutions**

The effected wetland is one of the largest and most important floodplain landscapes in the Danube Basin. Despite the widespread damage to date, the *restoration potential* is considered as very high:

- Firstly, the morphological floodplain relief - in contrast to many other heavily exploited riparian landscapes (e.g. gravel excavation along the Upper Rhine) - is still largely intact.
- Secondly, there is reason to hope that the 12 years of alteration in connection with the construction and operation of Gabčíkovo has not yet resulted in mostly irreversible losses of the typical bio-cenoses.
- Thirdly, economic considerations showed that Gabčíkovo is not profitable even after 15 years (ZINKE ENVIRONMENT CONSULTING 2003). So, there is reason to compare the economic benefits from allowing more water to flow through the Danube bed (i.e. to feed the groundwater, forests, wells, agricultural land and to restore natural self-purification, nutrient sink etc.) than through the power plant.

In recent years, a number of different mitigation proposals have been put forward for the reduction of ecological damage and rehabilitation of the river-floodplain ecosystem. Whilst accepting a reduced availability of water (i.e. assuming a continued operation of Gabčíkovo), all proposals involved raising the Danube water level in the “old” bed - and thus also the groundwater level near the river banks - and a restoration of open links with the river side-arms.

A *technical proposal* suggested in the early 1990s by river engineers aimed at the

- Construction of 3-12 supporting weirs in the Danube riverbed with the object of raising the water level of the Danube to the original mean water level and reconnecting a few side-arms. This proposal also wanted to shift navigation in the old riverbed.

This, however, would constitute a cataract of stabilised, i.e., atypical water bodies in the Danube bed, similar to those built in the Slovak side-arm system; they would block the river continuum that is essential, e.g., for fish migration.

On the other hand, there exist today three *alternative proposals*:
The WWF proposal (WWF 1994, WWF 1997) aims at restoring the big river and its dynamics, and open the system by a constricted and raised river bed without impoundment (see figure 3). Specifically, it suggests:
- a river discharge below Cunovo starting with minimum 600 m³/s and connected with
- a dynamic flow of at least 65% of Danube waters (measured at the Devin gauge) into the “old” river bed, and of no more than 35% into the Gabčíkovo canal. This would be fulfilling the Slovak legal standards (“19 Conditions” from 1991), and the EC proposal of February 1993 (political conflict negotiations). In addition,
- compensation for the discharge deficit of 35% by raising and constricting the present river bed through new gravel bars and islands – at best of local material – on a stretch of approx. 20-30 km downstream of Cunovo.

The Meander proposal (KERN & ZINKE 2000) suggests linking again the former large arms (meanders) across the Danube (i.e. create a continuum across the river bed). While detailed calculation is still missing (it requires probably some 40-60% of water), this variant suggests
- the installation of a new river channel that will meander across the entire floodplain landscape using the existing side-arm systems (with diversion fords in the river bed in order to cross it at a higher elevation, see figure 4).

The ‘meander proposal’ is based on the conception adopted for the reconstruction of the Upper Danube in Baden-Württemberg (see KERN 1995). It aims at linking the existing side-arm system on both sides of the river in order to form a continuous flow at a higher level. At the crossing points with the Danube, as it is at present, it would be necessary to construct weirs in the form of ramps in order to elevate the water level in the old riverbed sufficient to allow flow into the other floodplain side. This way, the “old” Danube riverbed would be dammed, but at the same time a free-flowing body of water with greater length would flow (meander) through the riparian landscape. The new water course would be free to develop morphologically within the restrictions imposed by the deficit in bed load and the presence of the fixed crossing points with the old river bed. The ecological efficiency with this proposal will depend on a minimum flow rate of similar magnitude as in the case of the ‘WWF solution’. The old, dammed riverbed could still be used to channel off major flood flows.

The LISICKY proposal (1999) aims at restoring this Danube section in the ancient pattern of a braided and meandering river ecosystem while maintaining its natural dynamics. This would also mean refraining from the substitute navigation possibility in the old riverbed and restructuring the existing system of groynes (wing-dams), so that the sedimentation be enhanced where appropriate and discharge gradually shifted into the former anabranch system.
- Two parallel cross-dikes would guide the water from one side-arm across the old river bed into the neighboring side-arm, without losing velocity and volume. Thus, the water levels are raised by these cross-dikes up to the level of the side-arms. Up- and downstream of the new cross-dike channel, water bodies would fill in the Danube bed and slowly silt up.

This proposal also still needs physical and mathematical modelling. LISICKY suggests discharging only small water volumes through the side-arms without initially excavating them and to observe what are the natural volumes for these arms. This variant should allow one to three inundations per year, according to the natural river discharges (gauge Devin). In case of a centennial flood, the cross-dikes may be swept away but be rebuilt later. Within the side-
arm system, the river can change its flow direction and develop either a new meandering or braided system; only the flood protection dikes would be reinforced.

**Discussion**

At present, the floodplain is missing open connections as well as minor and major flood events governing local biotope characteristics. Accordingly, any future solution must provide for floodwater volumes securing a sustained development of the floodplain ecosystem. This would possibly mean a reduced power production at Gabčíkovo, particularly during rising flood flows, in order to channel the full volume of water into the Danube riverbed and from there into the side-arms.

All three alternative proposals suggest restoration of the lateral connection between the river and floodplain waters. This would help to conserve the rare rheophilic species and to restore typical hydro-morphological dynamics, but with the limitation that – due to Cunovo - there is no coarse sediment supply from upstream. An artificial supply of sediments - as being practised on the Upper Rhine - should be investigated but may not be needed with the reduced sediment transport capacity after the division of the flows between side-arms (new meandering river), old Danube and canal.

It is clear that the “WWF proposal” comes closest to restoring the original dynamics and character of the Danube. Its feasibility with regard to the amounts of gravel necessary in order to narrow and raise the river channel, and also with regard to the morpho-dynamic processes, requires close investigation. The two “meander proposals”, where a part of the side-arm system will again become a flowing river, seem to be easier to implement but need building another technical structure in the Danube bed and limit the ecological restoration potential.

Each variant involves major interventions in the existing riverine landscape, and are needed in order to mitigate former interventions. In a pending technical feasibility study and environment impact assessment, it will therefore be necessary to appraise, in particular, the medium and long-term achievement of the objectives. Such a study, that could involve IAD experts, should not only review the effects on the river and floodplain ecosystems but also assess the changes in the groundwater regime and technical requirements (flood control, discharge of ice, and recreation). The resulting investment and maintenance needs, and the desired model character for other rivers will also influence the political decisions.

Whatever future mitigation variant will be discussed for the ecological problems triggered by the Gabčíkovo system, it will have to respect the existing EU legislation, in particular the Fauna-Flora-Habitats Directive (FFH 92/43/EEC) and the Wild Bird Directive (WB 79/409/EEC) as well as the Water Framework Directive (WFD 2000/60/EC). The floodplains are candidate Natura 2000 sites because they still host various listed habitats and species of European importance.

The Water Framework Directive aims at stopping further deterioration of all EU waters (surface and groundwaters, including wetlands) and demands their protection and improvement by achieving a “good status” (ecologically and chemically) by 2015. Any non-compliance can lead to sanctions. These obligations also refer to the future management of the wetlands impacted by Gabčíkovo, i.e., they have to become subject of a restoration programme.

For all water-dependent habitats and water-related species found along the Danube and the connected wetlands, a programme of measures securing the achievement of the “good quality” status must be presented by 2009. The “good quality” is presently being assessed for habitats and species in the Danube Basin via the respective expert groups of the EC and of the
ICPDR (RBM, MLIM, ECO, FP, etc.) and is addressed in the EU Guidance documents of the CIS (Common Implementation Strategy for the WFD: a EU Wetlands Guidance was published only in November 2003). So, any new intervention must aim at achieving the “good quality” of these water bodies. The restoration of the Danube river bed and side-arm system will have to be realised jointly with the neighbouring country.

Even though the Danube section around Gabčíkovo is provisionally designated in the new WFD Roof Report (ICPDR 2004) as an important “Heavily Modified Water Body”, Kern (2004) assumes that the “old” Danube will not be accepted as a HMWB by the EC but that “good ecological status” has to be achieved, i.e., restoration of former water levels and morpho-dynamics, of seasonal fluctuations and free-flowing conditions. It seems that this new situation is already recognised by the environmental ministers of both states in their new cooperation agreement from 15 April 2004.

A complementing policy obligation has recently been developed for flood protection. Since the 1990s, more and more states are recognising mistakes in their river and flood management and have started to define and execute new river policies. This process was further accelerated by the year 2002 floods on the Elbe and Danube Rivers, with Germany, the European Commission and Hungary taking lead roles: Germany is presently finalising the adoption of a new model Law on Preventive Flood Protection (expected to enter into force in early 2005), the EC has established in 2002 a special aid fund for floods and published in June 2003 a Best Practice Document on Flood Prevention, Protection and Mitigation, and Hungary has started the Budapest Initiative in December 2002 on Strengthening International Cooperation on Sustainable Flood Management. Finally, ICPDR via its Flood Protection Expert Group has adopted in December 2004 at the Ministerial Conference an Action Programme on Sustainable Flood Protection in the Danube Basin.

These important political commitments demand that all surface waters must be managed by retaining floods as much as possible and by preventing flood damages downstream. All areas available along rivers, i.e. without settlements or other intensive land use, have to serve ecologically benign flood retention. All available natural retention areas have to be used to maintain, restore or extend their flood retention function. All states have to cooperate within a joint river basin. This new policy will have to be implemented in the entire Danube Basin, i.e. the floodplains near Gabčíkovo can be considered a priority area. Theoretically possible economic uses such as emergency and recreational navigation have no priority (anymore) in this section. This gives the chance that this area could become the only stretch of the navigable Danube where ships bypass the main river bed and floodplain, and would allow unhindered self-restoration processes (Zinke Environment Consulting 2002).

Conclusions

The revealed economic data have shown that Gabčíkovo is another example of big dams that are not profitable. Along the Danube, the past 12 years of river diversion and Gabčíkovo operation have resulted in severe environmental degradation. Although the monitoring of the ecological impacts of the dam system has been inadequate (at least since 1998), all indications confirm lasting degradation, in particular in floodplain forests, habitats (loss of dynamic and pioneer sites) and typical floodplain biodiversity (especially fish and species needing dynamic habitats). The lack of governmental nature conservation triggered, especially on the Slovak side, an uncontrolled development of recreation and related disturbances in this sensitive wetland.

While artificial irrigation could not improve the wetland ecology, the annually needed inundations of the floodplain depend on changing the present situation in the “old” river bed.
A further decay of this internationally important wetland can only be prevented if the area experiences more large-scale hydro- and morpho-dynamics, through open connections with the Danube, as prescribed by Slovak legal standards ("19 Conditions") and by the new EU legislation.

The alternative restoration variants of local and international experts differ in detail but start from the same diagnosis (lack of dynamic discharges and open connections) and come up with similar recommendations (restore the longitudinal and lateral continuum).

Whatever mitigation variant is chosen, it can only be implemented with the consent of, and the co-operation between, the two countries. Every delay will further reduce the ecological and economic value of the riverine landscape. Since October 1997, experts from both countries did not succeed in jointly working out an environment-compatible solution, as recommended in the 1997 judgement of the International Court of Justice in The Hague.

With the EU accession, a new opportunity for making progress arises from the needs to implement the EU law (FFH/WB and WFD directives) and the government commitments for sustainable flood protection. International donors (UNDP, EC) can support Hungary and Slovakia with the needed funds for investigating and calculating the needed details for the suggested restoration variants. Such a Concept for Regional Development of the Danube and its floodplains near Gabčíkovo should urgently be commissioned to an independent international river research institute or group (like IAD), involving local experts and data.

References


Figure 1. Schematic situation of the Gabcikovo hydro-engineering complex and the floodplains north and south of the "old" Danube (from WWF 1997)

Figure 2. The “old” Danube bed (at left with the navigation route sign) fills up with sediments and pioneer vegetation (Photos: Zinke, April 2002)
Figure 3. Restoration Proposals for Gabcikovo (WWF 1994/1997): Lifting and constricting the river bed with islands
4.11 Sturgeon and ecological status of the river system

By Mirjana Lenhardt

Increased human impact during centuries, comprising overexploitation, water and sediment pollution and river regulation, led to the extinction of sturgeons in some parts of their former area and critical endangerment in others (for details see Reinartz 2002). This fact points out that sturgeon should be considered as a good indicator of ecological status of rivers. The main goal to be achieved is to establish connection between different levels of aquatic habitat degradation on one side and the status of the sturgeon population on the other.

The present state of rivers can be described by biological indicators as suggested in the EU Water Framework Directive. The field of ecohydraulics, which links in a complex way physical processes and biota over large spatial and temporal scales, can be useful in determining the habitat quality that is needed to support sturgeon survival. The main task is to define sturgeon requirements in a quantitative way and to establish habitat requirements for sturgeon in different life phases. Reinartz et al. (2003) have outlined the needed measures for sturgeon restoration and conservation, and Suciuc (2002) has developed the idea of “Sturgeon 2020”, a revitalisation programme similar to the “Salmon 2000” in the River Rhine.

The sterlet (Acipenser ruthenus L.) is still an important commercial fish in some parts of the Danube River, so it can be a good model system for sturgeon. The catch of sterlet occurs in specific periods of the year and on specific places in the Danube River. Complex investigations of these places and their definition in a quantitative way can give better insight in sterlet habitat requirements.
The development of a proper model can provide the basis for the evolution of practical methods for routine environmental assessment and could be a useful tool in environmental management.

References


4.12 The side-effect of river regulation – Loss of biodiversity (literature review)

By Cristina Sandu

Human population growth and increased water usage are placing greater demands on the world’s freshwater supplies (POSTEL 2000). Consequently, alterations in the hydrologic regime due to structural and operational measures – dam construction and associated water diversion, exploitation of groundwater aquifers, stream channelization and inter-catchment water transfer – are producing global-scale effects on the environment (ROSENBERG et al. 2000).

Dams represent a major cause of disruption in natural river flows - they are built to store water, to compensate the water level fluctuation, or to raise the level of water upstream, either to increase hydraulic head or to divert water into a channel. The storage capacity allows dams to generate electricity, to supply water for agriculture, industries and municipalities, to mitigate flooding and to assist river navigation (ROSENBERG et al. 2000).

Large dams and river diversions have proven to be primary destroyers of aquatic habitat, contributing substantially to fisheries destruction, the extinction of species and the overall loss of ecosystem services on which human economy depends (POSTEL 1998).

According to the International Commission on Large Dams (ICOLD), in 1996 there were approximately 42,000 large dams in the world (large dams being > 15m height from foundation to crest, see ICOLD definition), while McCully estimated the number of small dams to be approx. 800,000 in 1996 (MARCH et al. 2003).

It is easy to understand the environmental impact of this huge number of hydrological interventions: habitat fragmentation, loss of floodplains, riparian zones and adjacent wetlands, and deterioration of river deltas and ocean estuaries (ROSENBERG et al. 1997); deterioration of irrigated terrestrial environments and associated surface waters (McCULLY 1996); and diminishment of river flow leading to impaired water quality because point or diffuse pollution cannot be adequately diluted (GILLILAN & BROWN 1997).

The river channel and riparian zone are affected immediately because riparian areas are particularly sensitive to variations in the hydrological cycle (NILSSON & BERGGREN 2000). Riparian ecosystems offer habitat for many species, function as filters between land and water, and serve as pathways for dispersing and migrating organisms (NAIMAN & DECAMPS 1997), therefore being extremely important in conservation of biological diversity.
Some effects are immediate and obvious: dams obstruct migration pathways for fish, and reservoirs act as a sediment trap. Other effects are gradual and subtle, making them difficult to predict (NILSSON & BERGGREN 2000).

The biodiversity of aquatic fauna is also affected because the natural seasonal flow patterns to which it is adapted are altered, normal seasonal migration paths are blocked and populations are therefore fragmented (DUDGEON 2000). Although dams with spillways allow the passage of migratory biota, macrofauna abundance upstream of these dams is lower than in river reaches downstream of dams or in comparable reaches without dams (CONCEPTION & NELSON 1999). Sometimes, low-head dams may act as a bottleneck, increasing the density of upstream migrating animals below the dam, attracting a large number of predators and, therefore, resulting in increased mortality among the migratory species (BENSTEAD et al. 1999).

In their natural state, healthy rivers perform myriad ecosystem services such as purifying water, moderating floods and droughts, maintaining habitat for fisheries, birds and wildlife. They connect the continental interiors with the coasts, bringing sediment to deltas and coastal beaches, delivering nutrients to fish habitat and maintaining salinity balances that sustain productive estuaries. The diversity and abundance of life in running waters reflect millions of years of evolution and adaptation to these natural rhythms (RICHTER & POSTEL 2004).

The construction of Egypt’s Dam at Aswan during the 1960s, altered the habitat and diversity of life in the northern part of the Nile River: of the 47 commercial fish species in the Nile before the dam construction, only 17 were still harvested a decade after the dam’s completion. Similarly, fisheries decline dramatically after completion in 1994 of the Pak Mun Dam, on Thailand’s Mun River (a large tributary of Mekong). According to the World Conservation Union, 20% of the world’s 10,000 freshwater fish species are at risk of extinction or are already extinct (RICHTER & POSTEL 2004).

Sturgeons (Acipenseriformes), as a group of 25 species distributed in temperate waters of the Northern hemisphere of Eurasia and North America, have experienced a dramatic worldwide decline (BIRSTEIN 1993). All sturgeon species have been added to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which has been effective since 1998. Dam construction and channel modifications are considered the major causes of decline: the loss of spawning grounds and suitable sites for incubation and rearing of early life stages by creation of reservoirs seem to be the most critical (COUTANT 2004). Individual rivers were transformed into a series of broad, deep runs ending in artificial impoundments, permanently flooding both feeding shoals and spawning habitat rapids. Thus, the original habitat of most sturgeon species has been permanently transformed. Even in protected recovering species, populations are highly altered in size, length frequency composition and year-class mix, as well as continuously impacted by human activities that limit annual spawning and recruitment success (SULAK & RANDALL 2002).

All freshwater bodies are more or less connected to groundwater through the hyporheic zone (the saturated sediments under and laterally adjacent to freshwater bodies where there is active exchange between groundwater and surface water). While many aquatic organisms spend their entire lives in the sediment or in the water, many others live at the interface or spend part of their time in the water column and part in the saturated sediments. Further, some aquatic fauna (especially insects) spend part of their life cycle on land or in the air (PALMER et al. 2000). Sediment biota not only mediate biogeochemical transformations of global significance but are essential to the maintenance of clean water, the decomposition of organic material, the uptake and transfer of materials (including sediment-bound contaminants) and primary production (FRECKMAN et al. 1997).

Floodplain river ecosystems are dynamic spatial mosaics in which water plays an important role in connecting various landscape patches (THOMS 2003). Lateral connections between the
main river channel and floodplains are considered to be essential for the functioning and integrity of floodplain river ecosystems (Amoros & Bornette 2002). Baldwin & Mitchell (2000) have reported that inundation of floodplains facilitates the release of dissolved organic carbon and nutrients from surface sediments, making them potentially available, along with plant matter, to be transported back into the river channel during flood recession. Carbon, in particular, is an important energy source for aquatic organisms, forming the base of food webs, and therefore influencing the productivity of the entire river system (Thoms 2003).

Human activities change the lateral connectivity of floodplain river systems in two ways: by altering the natural hydrological pattern of floodplain inundation and through land use changes brought about by the construction of levees, dykes and other engineering structures on the floodplain itself which reduce reactive floodplain surface areas. Conceptual river system models, such as the "flood pulse concept" (Junk et al. 1989) recognize the importance of lateral connections for biogeochemical cycles, the structure of biotic communities and the overall ecological integrity of floodplain river ecosystems.

As riverine landscapes depend to a high extent on natural disturbances, the seasonal hydrological dynamics are crucial for maintaining ecological integrity (Junkwirth et al. 2002). Flood control by levees, land drainage, river bed dredging, river regulation by dams and various alterations of the natural hydrological regimes (e.g. water diversion, hydropeaking, truncation of bed-load transport followed by river bed degradation) isolate rivers from their floodplains and have been the major factors in physical habitat degradation (Petts 1996).

The most general upstream effect of a dam is that the water volume increases and inundates terrestrial and riparian areas. When flooded soils and vegetation decompose, they release greenhouse gases, which contribute to global warming (St. Louis et al. 2000). Decomposition of flooded soils also releases nutrients, such as nitrogen and phosphorus that may temporarily increases aquatic productivity (Nilsson & Berggren 2000). An increased amount of organic matter will accumulate, which will require a higher amount of oxygen for decomposition - consequently, the oxygen content within the water column will fluctuate, affecting the biota.

Many regulated rivers have storage reservoirs in the headwater regions, and downstream there is a channel with regulated flow - this will modify the riparian zone and its communities, and may also lead to salinization and invasion of exotic species (Nilsson & Berggren 2000). Increased water use and evaporation losses often reduce downstream discharge, affecting consequently groundwater recharge and reduce the active floodplain extent. Another downstream effect is the change of geomorphological processes, such as sediment cycling: reservoirs may trap large amounts of sediment, previously transported farther downstream (Nilsson & Berggren 2000), changing the morphology of deltas or coastlines (Mee 1992). Some regulated rivers may suffer from siltation - this leads to an elevation of the riverbed and increased overbank flooding (Dudgeon 1995).

Elimination of perturbing effects of floods and lowered groundwater levels (consequences of river regulation) determine changes in species composition of riparian forests to that of more characteristic for unflooded upland area (Decamps et al. 1988). But changes in the hydrological regime can start a new succession of riparian plants, well adapted to such conditions: easily dispersed seeds, rapid germination, rapid root and height growth (Johnson 1994).

Even changes in the flood timing can cause environmental changes: delayed flooding may negatively affect reproduction and feeding of amphibians and birds (Dudgeon 2000). The loss of freshwater prey may lead also to a decline in their predators. For example, loss of fish in Mediterranean streams can be linked with the decline in otter populations (Olmo et al. 2001).
Much of the biodiversity associated with riverine landscapes is attributable to heterogeneity at the habitat scale. From a holistic landscape perspective, riverine habitats comprise running and standing waters (abandoned channels), permanent and temporary waters, wetlands and groundwaters (WARD 1998).

The relationship between species richness and connectivity is determined by complex relationships among several interacting variables (WARD et al. 2002). Species richness maxima for different faunal and floral elements occur at different positions along the connectivity gradient (TOCKNER et al. 1998). Fish diversity, for example, may peak in highly connected habitats, whereas amphibian diversity tends to be highest in habitats with low connectivity (WARD et al. 2002).

Environmental gradients lead to high levels of spatio-temporal heterogeneity; movements and migration also contribute to high biodiversity levels over an annual cycle (WARD 1998). Flood-dependent fishes migrate regularly between the river channel and the inundated floodplain for spawning and feeding (WELCOMME 1979); some invertebrates also exhibit movements between the channel and floodplain waterbodies as part of their life cycles (SODERSTROM 1987).

Anthropogenic impacts on riverine landscapes, such as damming, dredging, channelization, disrupt natural disturbances regimes and truncate environmental gradients (WARD & STANFORD 1989). Ecosystem management, therefore, becomes a problem of re-establishing the environmental gradients, re-establishing the ecological connectivity between landscape elements and reconstitute some semblance of natural dynamics (WARD 1998).

A sustainable conservation of the diversity of floodplain river ecosystems implies an interdisciplinary approach, involving knowledge of geomorphology, hydrology, chemistry and ecology. Although different disciplines are often brought together to solve environmental problems in river systems, their integration is very difficult. PICKETT et al. (1994) identify three main problems in combining disciplines:

- gaps in understanding appear at the interface between disciplines;
- disciplines focus on specific scales or levels of organization;
- as subdisciplines become rich in detail, they develop their own view points, assumptions, definitions, lexicons and methods.

Unfortunately, many morphological and hydrological alterations resulted in irreversible damage of riverine ecosystems (BLOESCH & SIEBER 2002). Therefore, when evaluating the effects of dams or other anthropogenic disturbances, it is important for managers to have a good understanding of the ecology of the specific rivers they are managing. Collaboration with biologists, which can provide information about river flora and fauna (e.g. life-cycle, reproduction, feeding patterns, migration, habitat requirements), can offer useful tools for mitigation of negative effects of dams or reservoirs construction.

References


4.13 Bottlenecks in the Lower Danube River

By Stefan Modev²

The Lower Danube River is an important section of the navigation channel Rhine-Main-Danube. In this section are more than twenty bottleneck/ford stretches and six of them are extremely critical for navigation. Since 1989 the navigation is partially or completely stopped during the low-flow period.

The main characteristics of the bottleneck stretches are evaluated for the period 1947-1998 by engineering analysis of bathymetric information, and hydrological and hydraulic data. The bottlenecks have the tendency to develop into a more critical obstacle for big ships.

Because of the high intensity of the accumulation process at the bottleneck stretches (up to 150,000 m³/per day), technical decisions that are based only on flow-directed dredging will have low efficiency.

Introduction

The natural river bottlenecks represent a combination of morphological forms typical of rivers with a movable bed. The river bottlenecks are classified into two main groups:

- under the conditions of an expanded river bed
- under the conditions of a straight-line river bed

In its lower course, the Danube is a typical low-land river. The thickness of the alluvial deposition on which the river bed is formed, varies from 5-6 m to 25-30 m. The river bed often expands, the cross-section area changes and when it gets larger, the flow velocity

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decreases and there are favourable conditions for sediment deposition. Consequently, bars appear which cross the river along its whole width and form bottlenecks. The formation or disappearance of a river bottleneck is a sequence of processes, different in origin and character, influenced by the geological structure of the river bed and the river terrace, and the hydrological and hydraulic regime.

The river bottlenecks are specific morphological forms. They are composed of the following elements:

- upstream shallow site;
- upstream bar;
- downstream shallow site;
- downstream bar;
- crest of the bottleneck - connects the two shallow sites;
- bottleneck bed - the surface that connects the two shallow sites.

A bottleneck which changes its location, or several bottlenecks that are situated one beside the other, form a bottleneck stretch.

The two shallow sites and the bottleneck bed form a surface along which the river can be crossed. Therefore, in hydrological terms the bottleneck is called “cross-over” or “ford”. From the point of view of navigation, the river bottlenecks are sites of limited traffic capacity, restricted navigation and hence, they are called “bottlenecks”.

Commonly, the expansion of the river bed results in the formation of islands. In the lower and upper parts of the islands, there is deposition of sand. This deposition and the deposition in the close proximity of the opposite bank form two shallow sites - upstream and downstream.

With relatively long straight-line river stretches, the bottom sediment is non-homogeneous, there is turbulence and the flow conditions in the close proximity of the banks are unsteady; shallow sites of sand are formed. When closely situated between opposite banks, the shallow sites form a bottleneck.

When studying river bottlenecks we must define two typical profiles: cross-section profile - it shows the river bed along a line which connects the upstream and downstream shallow sites and runs along the bottleneck bed, and longitudinal profile - it shows the river bed along a line which connects the upstream and downstream bars and crosses the bottleneck bed over the crest.

Depending on their location and formation, river bottlenecks can be classified into 5 groups:

- bottleneck formed of sand deposition towards the two banks of the river (Type 1) - the bottleneck bed is situated slantwise to river flow. The crest is in close proximity of the downstream shallow place. The location of the bottleneck is steady. When the water stages rise the crest elevation likewise increases and when they go down, the bottleneck erodes and is washed away;
- bottleneck formed of a multitude of sand depositions scattered about the river bed (Type 2) - usually it is formed when the river bed has expanded considerably. Its location is steady. Permanent regularities between the elements of the bottleneck and the characteristics of the hydraulic regime are not observed;
- bottleneck formed in the upstream part of an island (Type 3) - commonly, it is formed when the island is in a bent river stretch and the water flow along the island is not even. Consequently, a shallow site of sand is formed in the upstream part of the island in the direction of river flow which is re-directed towards the opposite bank. Transverse circulation develops. Sand depositions towards the opposite bank are formed. The
location of the bottleneck is steady and the changes in the hydrological regime do not have a strong impact;

- bottleneck formed in the downstream part of the island (Type 4) - it is formed when one of the two river bends has small flow capacity and runs dry during the low-flow period. The eroded depositions in the upstream part of the island deposit in its downstream part and often extend to the opposite bank. The location of the bottleneck is steady. The bottleneck erodes when the water level is high but after a long low-flow period, the process of “washing” away is slow;

- bottleneck formed in the middle of the river bed (Type 5) - it is formed during a low-flow period in river stretches where the flow tends to branch out into numerous bends. When the low-flow period lasts for a long time, the bottleneck gets stable.

**Historical overview of Bulgarian research activities**

The beginning of the study of bottlenecks in the Bulgarian-Romanian section (river-km 854-375) of the Lower Danube River may be dated to 1885 when the Russian military topography corps made the first river-bed survey. However, the photo was not preserved. From 1904 to 1911 the whole section was surveyed and a map was made of the river bed at the scale of 1:10,000, known as *Minchev map*. Therefore, the first survey activities must be dated to 1904.

Elements of the river bottlenecks were measured regularly after 1938 when the third complete map of the river bed was made. The Danube River Navigation Book published in 1948 contains a relatively comprehensive review and analysis of the bottleneck stretches by Peter Kostov.

In 1965 Petar Nikolov carried out the first methodical survey of bottlenecks along the Danube River in connection with a project for the construction of the Somovit-Islas hydro-power system.

During the period 1976-1983 D. Pechinov and St. Modev conducted the first echo sounding surveys of bottlenecks in the stretch from r-km 559 to 600. Some of the results of these surveys were included in the study “River-bed morphological processes at the Svishtov-Nikolov Danube River section” made in 1978 by Stefan Modev.

The study “Fords of the Danube River - 1993” was carried out under the IHP-UNESCO program in 1993. The report of the Bulgarian stretch of the Danube River was made by G. Gergov.

All initial information and data for the present study are provided by Eng. K. Yalamov.

**Monitoring, available information and object of the study**

The monitoring of bottleneck stretches of the Danube River is conducted by the *Institute for Maintenance and Management of the Navigation Passes of the Danube River (IMMNPDNR) - Russe*. In conformity with the requirements of the Danube Commission - Budapest and, under the terms of the 1957 Danube Convention, the Republic of Bulgaria performs measurements and maintains the navigation route in the stretch from r-km 610 at Somovit to r-km 375 at Silistra. After 1956, IMMNPDNR started monitoring the bottleneck in this stretch.

The available information from the surveys made on the bottleneck stretches is classified into the following groups:

- *topographic information*. IMMNPDNR makes a geodetic survey of the bottleneck stretches depending on the necessity of maintaining the navigation way. The topographic surveys are bathymetric. The transfer to absolute elevations is done by means of the average water
surface slope. Initial benchmarks connected with a certain height system (Baltic or Black sea – Varna systems), are used relatively seldom. The surveys are limited in scope - commonly, they encompass the bed and crest of the bottleneck;

- hydrological information. The depth above the crest of the bottleneck during the low-flow period is measured by IMMNPDR every day when the bottlenecks jeopardize navigation. The composition of the sediments is studied by the National Institute of Meteorology and Hydrology (NIMH) at the Bulgarian Academy of Sciences (BAS) and by a team of the University of Architecture, Civil Engineering and Geodesy - Sofia (UACEG). The measurements were made during expeditions and are not systematic. The distribution of the suspended and bed sediments as well as their grain size are not monitored systematically;

- hydraulic information. Special surveys of the hydraulic regime of the bottlenecks have not been made. Occasional measurements of flow velocity on the crest of some bottlenecks are available at IMMNPDR-Russe. Hydraulic model surveys have been made at UACEG of some bottleneck stretches of the Danube River (at the Belene island group). The data of these surveys are usable within certain limits.

**A systematic monitoring on bottlenecks of the Danube River has been neither organized nor conducted in the Republic of Bulgaria. Neither is there a programme for detailed measurements and monitoring of the regime of bottlenecks.**

**In the Republic of Bulgaria, specialized surveys of bottleneck stretches of the Danube River that render a full account of their topographic, geological, hydrological and hydraulic characteristics, have not been made.**

Basically, the present report seeks **to reveal the common regularities in the formation and development of bottlenecks in the Danube River section object of the report (from r-km 610 to 375).**

Six of the most important bottleneck-sections limiting navigation have been surveyed:

- **Somovit** Section: km 610 - km 608;
- **Malka Barzina** Section: km 575 - km 574;
- **Milka** Section: km 566 - km 564;
- **Batin** Section: km 529 - km 521;
- **Mishka** Section: km 463 - km 461;
- **Popina** Section: km 404 - km 401.

The following relationships have been established and analyzed in the process of surveying:

- water stage and minimum depth over the bottleneck crest;
- water stages between neighbor hydrological stations;
- water stage and crest elevation of the bottleneck.

Calculations have been made and there have been drafted:

- low-flow hydrographs of the daily volumes of deposition or erosion of the bottleneck;
- integral curves of the daily volumes of bottleneck deformations during the low-flow period.

All calculations and surveys relate to the period from 1988 to 1997. Data of some bottleneck characteristics in 1947 are included for comparison.

**Main results of the study**

**Water level variability.** The variation in water level has been studied for low-flow periods at the stations in Svishtov (km 554.3), Russe (km 495.6) and Silistra (km 375.5). The surveys
encompass a 10-year period from 1988 to 1997 and the results of the survey of 1947 are given as reference.

The main results of water level variability (Table 1) are as follows:

- During the period 1947-1997, water stages at Russe decreased by 40-60 cm as compared to the water stages at Svishtov. At the same time the flow capacity of the river bed at Svishtov increased by 189-552 m³/s and at Russe by 80-363 m³/s.
- During the period 1988-1997 the flow capacity of the river bed at Svishtov went up by 174-263 m³/s and at Russe by 44-189 m³/s.

<table>
<thead>
<tr>
<th>Year</th>
<th>Svishtov (km.554.3)</th>
<th>Russe (km.495.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H [cm]</td>
<td>Q [m³/s]</td>
</tr>
<tr>
<td>0</td>
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<td>3143</td>
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<tr>
<td>150</td>
<td>3286</td>
<td>3838</td>
</tr>
</tbody>
</table>

- From 1947 to 1988 the corresponding daily water stages at Silistra decreased by 34-51 cm. At the same time the flow capacity of the river bed decreased by 11-116 m³/s. Over the period 1988-1997 the water stages at Silistra increased by 39-44 cm and the flow capacity of the river bed increased by 320-634 m³/s (Table 2).
- Evidently, intensive morphological processes develop in the Danube River stretch downstream Silistra which are determined for water levels and flow capacity of the river bed at this cross-section. Generally, from 1947 to 1997 the change in the water levels at Silistra was from -9 to +5 cm and the flow capacity of the river bed increased by 309-518 m³/s.

<table>
<thead>
<tr>
<th>Year</th>
<th>Svishtov (km.554.3)</th>
<th>Silistra (km.375.5)</th>
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<tr>
<td>150</td>
<td>3286</td>
<td>3838</td>
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</table>

It is evident from figure 1 and Table 1 that alteration of the correspondence of water levels is most strongly manifested at low water levels. Besides, there is a tendency towards the restoration of water levels at Silistra, however, with an increased flow capacity of the river.

The survey of corresponding daily water levels at Svishtov, Russe and Silistra shows that the morphological changes of the river bed in the Russe-Silistra section are in a process of development. In the Svishtov-Russe section, changes of the river bed are not significant but the increase in flow capacity is considerable.
Bottleneck characteristic changes. The survey of the six bottlenecks limiting navigation, given above, encompasses the period from 1947 to 1997. The main results for the bottlenecks situated on the Danube River section from km 610 to 375.5 are given in Table 3. The table contains generalized characteristics of the bottlenecks when they form at a depth of 25 dm, which is critical for navigation.
Table 3. Annual characteristics of the main bottlenecks in the section from km 610 to km 375.5. Critical depth of the bottleneck crest 25 dm.

<table>
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<td>-</td>
</tr>
<tr>
<td>Q sv</td>
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<td>-</td>
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<td>-</td>
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<td>H rs</td>
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<tr>
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<td>-</td>
<td>4.73</td>
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<td>-</td>
<td>-</td>
<td>68</td>
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<td>Q rs</td>
<td></td>
<td>-</td>
<td>-</td>
<td>3050</td>
<td>3992</td>
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<td>-</td>
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<td>Q ss</td>
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<td>S</td>
<td></td>
<td>-</td>
<td>-</td>
<td>4.48</td>
<td>4.26</td>
</tr>
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</table>

- "Somovit" bottleneck section (km 610-608). It is situated on the main bed of the Danube River between the island of Kalnovats and the Bulgarian bank. The bottleneck was formed of sand deposition by the waterside of the island and by sand deposition downstream of the Bulgarian bank (type 1). The bottleneck appeared after 1975. Its location is stable. After 1990 it exhibited a tendency to erode and the flow capacity of the river-bed in the bottleneck zone increased.
“Malka Barzina” bottleneck section (km 575-574). It is situated just next to the waterside of the Belene island and upstream on the main river-bed of the Danube. It was formed of sand deposition that went with the stream along the foremost part of the Belene island and of deposition towards the Romanian bank in the upstream part of the island of Malka Barzina (type 4). The bottleneck was formed after 1965. Characteristically, the bottleneck crest elevation changed from 15.05 to 15.61 m. In 1988, the critical depth for navigation of 25 dm was reached when the water discharge was 3,425 m$^3$/s and in 1997 – 4,059 m$^3$/s. The 24-hour deformations of the bottleneck in the zone of the navigation route change from 56,700 m$^3$/day of accumulation to 63,990 m$^3$/day of erosion. There is a tendency towards stabilization of the bottleneck.

“Milka” bottleneck section (km 566-564). It was formed of sand deposition downstream of the island of Milka and upstream of the island of Lyuta (type 3). Its location is stable. The bottleneck crest elevation varies from 13.28 to 15.92 m (Baltic height system). The amplitude of change is the highest as compared to the other bottlenecks in the Lower Danube (2.56 m). In 1988, the critical for navigation depth of 25 dm was reached when the water discharge was 3,250 m$^3$/s and in 1997 – 4,231 m$^3$/s. The 24-hour deformations of the bottleneck in the zone of the navigation route changed from 50,760 m$^3$/day of accumulation to 54,600 m$^3$/day of erosion. During low-flow periods, erosion is prevalent but during the flood period the bottleneck is restored. It is one of the most critical bottlenecks for navigation.

“Batin” bottleneck section (km 529-521). This section is one of the most critical for navigation in the Lower Danube. It is formed of sand deposition that goes with the stream in its main bed along the island of Batin and by sand deposition past the left bank (type 1). The bottleneck crest reaches a critical height at r-km 525. The limiting depth of 25 dm is formed with a bottleneck crest elevation varying from 11.37 to 12.12 m. The bottleneck crest elevation ranges from 11.16 to 12.56 m. The amplitude of change of 1.40 m is the lowest as compared to the other bottlenecks. The daily deformations vary from 74,376 m$^3$/day of accumulation to 77,648 m$^3$/day of erosion. The bottleneck is comparatively stable. Throughout the period 1947-1988, the flow capacity of the river bed increased by over 1,000 m$^3$/s. In 1947 the bottleneck was critical when the water discharge exceeded 2,203 m$^3$/s or was a bit below that value. In 1990 it was critical with a water discharge equal to or less than 2,970 m$^3$/s and in 1997 - with a water discharge of 3,524 m$^3$/s. The bottleneck is stable and significant erosion should not be expected (Fig. 2).

“Mishka” bottleneck section (km 464-461). It was formed of sand deposition in the downstream part of the island of Lungu and of sand deposition in the upstream part of the island of Mishka (type 3). The location of the bottleneck crest varies but the most critical depth has been measured at r-km 463. In 1947 the critical depth of 25 dm was registered with a bottleneck crest elevation of 8.64 m and a water discharge of 2,425 m$^3$/s. In 1997 the limiting depth of 25 dm was measured with a bottleneck crest elevation of 9.34 m and a water discharge of 3,813 m$^3$/s. During the low-flow periods in 1998-1997 the bottleneck crest elevation...
varied from 7.79 m to 10.21 m. The amplitude of the elevation change was 2.42 m. Within 24 hours the volume of deposited or eroded sediments ranged from 151,340 m³/day of accumulation to 250,336 m³/day of erosion. The bottleneck is stable and significant erosion is not to be expected.

- **“Popina” bottleneck section (km 404-401).** The section formed as a bottleneck after 1988. The upstream shallow place was formed of sand deposition in the middle of the river bed downstream at the island of Garvan and by sand deposition at the uppermost part of the island of Popina. During the period 1990 - 1997 the bottleneck crest elevation at r-km 403 at a depth of 25 dm increased from 4.73 to 5.91 m. The water discharge that formed the depth was 2,918 m³/s and 4,220 m³/s, respectively. The bottleneck is in process of development but will not erode. During the period 1990-1997 the bottleneck crest elevation varied from 5.17 m to 7.53 m. The amplitude of the change is 2.36 m. The 24-hour volumes of the bottleneck deformations changed from 56,543 m³/day of deposition to 116,167 m³/day of erosion. The outline of the bottleneck bed may change provided the flow capacity of the branch between the island of Popina and the Bulgarian bank increases.

The surveys testify to a tendency toward the formation of bottlenecks downstream in the Danube River (in the close proximity of Silistra - km 384-385; km 375-377). Table 4 contains some results that characterize the dynamics of the process of bottleneck formation in the Bulgarian-Romanian section of the Danube River.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Maximum of the crest elevation Zd max [m]</td>
<td>17.10</td>
<td>15.61</td>
<td>15.92</td>
<td>12.56</td>
<td>10.21</td>
<td>7.53</td>
</tr>
<tr>
<td>Minimum of the crest elevation Zd min [m]</td>
<td>16.23</td>
<td>14.05</td>
<td>13.36</td>
<td>11.16</td>
<td>7.79</td>
<td>5.17</td>
</tr>
<tr>
<td>Average elevation of the crest Zd aver [m]</td>
<td>16.64</td>
<td>14.92</td>
<td>14.28</td>
<td>11.82</td>
<td>8.59</td>
<td>5.85</td>
</tr>
<tr>
<td>Amplitude dZd = Zd max - Zd min [m]</td>
<td>0.87</td>
<td>1.56</td>
<td>2.56</td>
<td>1.40</td>
<td>2.42</td>
<td>2.36</td>
</tr>
<tr>
<td>Standard deviation of the crest elevation STDZd [m]</td>
<td>0.20</td>
<td>0.29</td>
<td>0.48</td>
<td>0.32</td>
<td>0.59</td>
<td>0.50</td>
</tr>
<tr>
<td>Maximum of the daily deformation dV max [m³]</td>
<td>12150</td>
<td>56700</td>
<td>50760</td>
<td>74376</td>
<td>151340</td>
<td>56543</td>
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<tr>
<td>Minimum of the daily deformation dV min [m³]</td>
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<td>-63990</td>
<td>-54600</td>
<td>-77648</td>
<td>-250336</td>
<td>-116167</td>
</tr>
<tr>
<td>Average crest elevation by 25 dm depth at Year 1997 Zd aver [m]</td>
<td>16.52</td>
<td>14.94</td>
<td>14.30</td>
<td>11.96</td>
<td>9.16</td>
<td>5.32</td>
</tr>
<tr>
<td>Average crest elevation by 25 dm depth at Year 1947 Zd aver [m]</td>
<td>-</td>
<td>-</td>
<td>14.04</td>
<td>11.37</td>
<td>8.64</td>
<td>-</td>
</tr>
</tbody>
</table>

The accuracy of the above estimates is of vital significance. The data about the observed water stages refer to 07:00 h MET and are registered with an accuracy of ± 2 cm. Therefore, the mean error in determining the average upstream slope of the water surface varies from 1.1 to 1.3 % (the ratio of rise between the water elevations for the adjacent hydrological stations ranges from 3.22 m to 3.40 m). Water discharge has been assessed by using discharge rating curves for the relevant hydrological stations. The mean error of the rating curve varies from 1.7 to 3.2 % and the mean error of the measured water discharge is between 2.8 and 3.6 %. Consequently, the standard error in the measured average twenty-four-hour water discharge is between 3.3 and 4.8 % or about 60 ÷ 150 m³/s. Hence, the increase in flow capacity of the river in the Svishtov-Silistra section, as presented in the study, exceeds considerably the triple amount of the error rate (3σ - rule) and should be accepted as reliable enough.
The accuracy of the depth measurement on the bottleneck crest with a mechanical lot is ± 10 cm or 4 %. Bearing in mind that the deviations of the water surface elevation from the estimates for an average slope elevation are within ± 30 cm, the standard error in determining the bottleneck crest elevation does not exceed ± 0.32 m. Noting that the variations of the bottleneck crest elevations exceed to a large degree the triple value of the standard error, it follows that the present study is reliable enough and can be used for engineering and scientific purposes.

Conclusions
The following main conclusions can be drawn from the calculations and surveys made:

1. The accuracy of the calculations and surveys is good and the results can be used for engineering and scientific purposes;

2. Over the period 1947-1997, the slope of the water surface of the Danube River in the Svishtov-Russe and Russe-Silistra sections increased by 1.0 – 1.2 cm/km. The increase is from 18 to 24 %;

3. During the same period the flow capacity of the river bed increased by 12 - 18 %;

4. The bottleneck crest elevations increased on average by 0.3 – 0.9 m;

5. The amplitude of the change of the bottleneck crest elevations during the low-flow period is within 1.40 – 2.56 m and tends to increase downstream (from Svishtov to Silistra);

6. The bottleneck at km 608 probably tends to erode;

7. New bottlenecks are formed in the close proximity of Silistra (km 375-404);

8. The water level regime over the bottlenecks becomes aggravated. With all bottlenecks that have been surveyed (except the bottleneck at km 608), the water discharge that forms the critical limit of 25 dm increase.

9. The volumes of the 24-hour deformations of the bottlenecks change within broad limits: from 35,000 to 150,000 m³/per day of accumulation and from 37,000 to 230,000 m³/per day of erosion. There is a tendency toward higher intensity of change of bottlenecks downstream;

10. The improvement of the conditions for navigation along the Danube River by the help of systems of river training structures requires the application of complex structures and activities;

11. When the bed elevations of the flow-directed dredging are designed, the use of the minimum elevations of the bottleneck bed given in table 4 (the minimum crest elevation), is recommended;

12. Because of the high intensity of the processes of accumulation at bottleneck stretches (up to 150,000 m³/per day), technical decisions that are based only on flow-directed dredging, will have low efficiency.
5. Excursion: The Danube Floodplain Natural Park near Hainburg

By Christian Baumgartner

Abstract written by J. Bloesch on the basis of the slide show on CD-ROM

The excursion into the River Restoration Project “Haslau – Regelsbrunn” showed one of various restoration projects in the Danube Floodplain Natural Park (Fig. 1). The introductory slide-show demonstrated the history of the Danube River downstream of Vienna, the “natural” reference and the drastic morphological destruction through channelisation, and the partially restored hydrological dynamics of the river (Fig. 2). The workshop participants could see in situ the side-arm reconnection featuring different technical solutions of culverts such as simple concrete openings or near-natural bed-ramps (Figs. 3a and 3b). It became obvious that issues of flood protection have priority over requirements of dynamic flood plain ecology. However, at the present low water level one could see the result of re-introduced flow dynamics in the side arms in form of bank erosion and formation, pools (some filled with groundwater and a refuge for fish), and accumulated woody debris (Fig. 4). Besides these morphological-hydrological features, biological characteristics of the flood plain were visible such as the succession of riparian forests, tracks of beavers, large raptor’ nests, and invading alien plant species (e.g., the Indian or Himalayan Balsam, Impatiens glandulifera).

**Figure 1.** Restoration scheme of the Danube River downstream of Vienna (Haslau-Regelsbrunn).
Figure 2. Areal view of the side-arm reconnection Haslau-Regelsbrunn in the Danube River downstream of Vienna. In the back is the main Danube channel.

Figure 3. Two types of culverts in Haslau: (a) concrete bridge used by pedestrians, left; (b) lowering of the towing path, right.

Figure 4. Orther side-channel at low flow showing bank erosion, isolated pools and woody debris.
6. The Framework of Projects in the DRB

6.1 Communication in transdisciplinary and transboundary projects

By Virgil Iordache

Introduction

In this article I adopt a cultural perspective in order to analyse both the transdisciplinary and transboundary communication aspects of a project dealing with problems of the Danube Basin and involving scientists from different fields, in particular from the fields of hydrology and limnology. A project is considered to be a short-lived organisation. Hydrological and limnological knowledge are kinds of institutionalized knowledge, as opposed to common knowledge, i.e. are produced in specialized organizations.

In this context, the first objective of the paper is to establish how different are limnology and hydrology, and to point out how communication between them could be made easier. The second objective is to identify ways in which effective communication could be obtained in transdisciplinary and transboundary projects.

Methods

In order to reach the first objective, I made a screening of the main concepts of semiotic, in particular of communication theory, and of cross-cultural studies. I have also looked at the types of academic organisations developing knowledge in the area of hydrology and limnology. Then, I proposed to interpret limnology and hydrology as semantical field within different cultures and, based on this, identified ways for improving the communication between the people involved in the use and development of the two semantical fields. As for the second objective, I used a model of socio-economic systems in which organisation are grouped into functional modules, two functional modules develop a market in between (GEORGESCU et al. 2001), and each functional module is characterized by a different culture. I considered that communication in an organisation, and, in particular, in a project, can be of three types: internal communication (necessary dimension), communication systems as the product of the project (contingent dimension), and external communication between the project organisation and its environment (necessary dimension). Then for each type of communication I identified tips for enhancing its efficiency.

Results

Objective 1 Hydrology vs. Limnology

A code is a system of signs governed by explicit or implicit rules shared by the members of a culture (LASSWELL 1948). The denotative and the conotative meaning of an element (sign) derives from the agreement of the users and from their shared cultural experience. A culture is a meanings system that is shared by a majority of individuals in a particular community, a patterned way of living by a group. Within a culture one can find different subsystems, fields and axes of significance (ECO 1982). It is more difficult to change drastically the code (i.e., a semantical field into an another, more appropriate from the value or knowledge point of view), and it is easier to let the different fields to coexist, even if they are contradictory to some extent. The semantic fields are of social or individual nature (cultures or personalities).

A scientific discipline can be seen as semantical field. Hydrologists usually belong both to the scientific culture and to the engineer’s culture, and hydrology is a ‘pretty hard’ science, but a
‘somehow soft’ engineering. Limnologists belong to the scientific culture, and limnology is a ‘soft’ science. Table 1 compares the characteristics of the engineer’s culture with those of the scientific culture.

**Table 1** Engineer’s culture vs. Scientific culture.

<table>
<thead>
<tr>
<th>Engineer’s culture</th>
<th>Scientific culture</th>
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<tbody>
<tr>
<td>Deals with constructing artificial entities (physical product oriented)</td>
<td>Deals with knowing natural entities</td>
</tr>
<tr>
<td>Failure of the end product is obvious and not acceptable</td>
<td>Failure of the end product is not obvious, and, moreover, is within the condition of the scientific progress</td>
</tr>
<tr>
<td>Good organizational, managerial skills, to prevent failure</td>
<td>Not necessarily good managerial skills, ‘the scientist in the ivory tower’</td>
</tr>
<tr>
<td>‘Hard’ engineering: high tech</td>
<td>‘Hard’ science: physics (more math)</td>
</tr>
</tbody>
</table>

Techniques to minimize the communication difficulties between limnology and hydrology are:
- On the side of limnologists: to extend the managerial and math capabilities (building ‘l’esprit geometrique’), but without reducing their knowledge to math modeling as an ‘ideal’ methodology.
- On the side of hydrologists: to accept that not only hard concepts and methodology deserve to exist, and that math thinking is not applicable everywhere (building ‘l’esprit de finesse’).
- On both sides: to attract people with multiple background formation (e.g. licence in hydrology, PhD in limnology/ecology), and develop human resource formation programs in this direction.

Beside communication problems related to the belongness to different semantical fields, there are also problems due to the intrinsic ambiguity of signs. Many of the concepts of the natural languages are fuzzy concepts, i.e., not perfectly defined and separated from one another. So, a natural semantic system is never clear and geometric. Other problems may be related to the ambiguity of translations, and to the accidental ambiguity of signs. Communication can be defined by five structural components: who tells what by which channel, to whom and with what effect. There is a sequence of events, from source to transmitter (codification) – signal – channel (noise) – receptor – message – destinator (decodification). The underlined aspects can generate accidental communication problems. However, it takes resources to control them, so one cannot fully eliminate these problems, only optimise them. A particular problem especially when dealing with environmental and societal problems is to use the ambiguity in the form of ideology in order to direct the behaviour of the people towards a desired way. Awareness about all these aspects can lead to the improvement of the communication between people belonging to different cultures, and even to the same culture.

**Objective 2 Efficient communication in transboundary projects**

With regard to internal communication, I followed BRILLHART & GALANES (1995). The internal organisation is driven by the organisational culture, and the ways for its optimisation follows general rules for effective group discussions. Leaders should have self-monitoring ability and rhetorical sensitivity, and should be open-minded critical thinkers. The last requirement applies also to group members: passive yessers do not express genuine agreement. Ideally the designated leader encourages members to enact a variety of leadership functions while serving as a completor for functions not being supplied by other members. The distributed leadership works well in small groups. Figure 1 presents the characteristics of the
productive groups and of the leadership distribution.

From an external communication perspective, the organizational approach leads us to the conclusion that one should concentrate on persuading the consequences of the scientific product (the output of the project organization) relevant for the intermediary consumer (usually the government) and especially for the final consumer (private organizations), and should not focus only on the scientific argument (the processing compartment in the organization). For instance, one should offer natural resources and services estimations (space-time distribution), not simply the mechanisms supporting them.

![Figure 1](image)

**Figure 1** Characteristics of the productive groups and of the leadership distribution (after BRILHART & GALANES 1995).

What blocks external communication? There are several theories (TING-TOOMEY et al. 1996):
- Anxiety-uncertainty theory (effective communication is a function of uncertainty, i.e. perceived unpredictability, and anxiety, i.e. feelings associated to uncertainty);
- Expectancy violations theory (communication effectiveness controlled by actions discrepant from initial anticipation);
- Face negotiation theory and interpersonal face theory (communication effectiveness controlled by losing/not losing face, i.e. shame, pride, feeling awkward, embarrassed);
- Communication accommodation theory (effectiveness controlled by speech convergence/divergence to increase/decrease communicative distance among members of different groups.

It is expected that the difficulty of external communication increases as follows:
- Between organization of the same functional module and socio-economic system (SES)
- Between organization of the same type of functional module, but different SES
- Between organizations from different functional modules of the same SES
- Between organizations from different functional modules of different SES

A key difference between cultures is related to their individualistic or collective character. Individualism is a broad value tendency of people in a culture to emphasize individual identity vs. group identity (the „I” concept of the self). It is characterised by direct verbal assertions. Collectivism is a broad value tendency of people in a culture to emphasize
collective identity vs. group identity (the „we” concept of the self). It is characterised by indirect verbal expressions. It is not known what types of cultures from this perspective are in the Danube Basin.

Agreement between people belonging to different cultures can be reached based on revealing some common cultural background (to eat pork or not to eat pork vs. to eat healthy) and based on common goals (e.g. accepted natural public goods). The argument chain underpinning such a shared public goal may be different from one group to another. The external discourse can adopt either a deictic perspective (the speakers refer to the consequences of their speech) or an anaphoric perspective (the speakers refer to the profound feelings motivating them to give the speech).

In a given culture, semantical fields with different refinement and analytical levels coexist. The fields of a not institutionalized culture suffer aculturation phenomena, critical revision of knowledge, or value crisis. This means that monitoring cultural change is needed in order to optimise the external communication. It also means that any communication system as a product of a project should be conceived as adaptive, sensitive to the changes in the cultures of the end-users.

Conclusions

So how to cross the border between hydrology and limnology?
• By government care in the financing program design to not induce competition between the disciplines, but rather cooperation.
• By building confidence through personal relationships between the scientists in the two fields.
• By transforming external communication in internal communication by way of internalizing the disciplines in the same temporary organization (project).

How to convince hydrologists and limnologists to work together?
• Show them that basic and applied questions can be easier solved together, i.e., that there are common clients for a common research product.
• Give them the perspective of an economic benefit higher than in case of no cooperation, i.e., that these clients are able to pay for the common research product.
• Give them a common theoretical attractor. Systems ecology can play an heuristic role in this respect. A scientific journal open to the publication of common results is desirable.
• Show them how their own cultural identity (disciplinary tradition) will not dissolve.

References

6.2 The ICPDR and the implementation of the EU-WFD in the Danube River Basin

By Philip Weller

(Executive Secretary of the ICPDR)

Abstract written by J. Bloesch on the basis of the slide show on CD-ROM

This workshop report cannot provide the full contents and detailed description of the WFD and the organisation of the ICPDR; thus, we refer to the websites http://www.europa.eu.int and http://www.icpdr.org.

With regard to the protection of aquatic ecosystems and water in Europe, it is clear that the EU-WFD sets the standards and pace for all Union countries as well as accessory countries. The Danube River Protection Convention (DRPC) provides the legal framework for cooperation to assure the protection of water and ecological resources and their sustainable use in the Danube River Basin (DRB). In particular, the International Commission for the Protection of the Danube River (ICPDR) is the governmental body to implement the objectives and provisions and to achieve the goals of the DRPC. In a Joint Action Programme (JAP) most of the Danube countries (by definition a maximum of 18 countries sharing various sizes of territories of the DRB) are dedicated to river basin management encompassing:

- an emission inventory and pollution reduction;
- the restoration of wetlands and flood plains;
- a transnational monitoring network (TNMN) and extended water quality standards;
- a list of priority substances / recommendations on BAT and BEP;
- an accident warning system (AEWS) and prevention;
- a flood control and sustainable flood prevention;
- a domestic and basin wide water balance.

The objectives and goals of the EU-WFD can be summarised as follows: The EU-WFD

- sets uniform standards in water policy throughout the European Union and integrates different policy areas involving water issues;
- introduces the river basin approach for the development of integrated and coordinated river basin management plans for all European river systems;
- stipulates a defined time-frame for the achievement of the good status of surface water and groundwater;
- introduces the economic analysis of water use in order to estimate the most cost-effective combination of measures in respect to water uses;
- includes public participation in the development of river basin management plans encouraging active involvement of interested parties including stakeholders, non-governmental organisations and citizens.

Several phases have been established in the time frame of WFD-implementation until 2015:

- Phase 1 (2003): Framework for cooperation, i.e., to adapt legal framework to provisions of WFD, to define institutional frame such as competent authorities, to define mechanisms for coordination;
- Phase 2 (2004): GIS and mapping, i.e., to define river basin district and sub-units, to develop maps and GIS; river basin characteristics, i.e., to define typology and reference conditions for surface waters, to identify pressures and impacts on surface...
and groundwaters, to identify artificial and heavily modified water bodies, to carry out economic analysis of water uses, to identify and describe groundwater bodies, to establish a register of protected areas; the results of phase 2 are to be officially released to public as the “Roof Report” during the 7th Plenary ICPDR Ministerial Meeting in Vienna on December 13, 2004;

- Phase 3 (2006-2007): Monitoring and adaption of the TNMN, i.e., to establish intercalibration network, to establish monitoring programmes; definition of environmental objectives according to the Joint Action Programme (JAP) for surface waters, groundwaters, protected areas, and artificial and heavily modified water bodies;
- Phase 4 (2008-2015): RBM Plan and programme of measures, i.e., to develop River Basin Management Plan, to develop programme of measures, to implement programme of measures, to update management plan, and to update programmes of measures; by 2015, all surface waters in the DRB and throughout Europe should achieve “good ecological status”.

The ICPDR, mainly through its expert group “River Basin Management” (RBM-EG), provides the platform for coordination and information exchange, develops the strategy for producing the RBM Plan, and leads the harmonization of methods and mechanisms. All ICPDR actions are supported by public information and consultation, i.e., the publication of a timetable and work programme of the RBM Plan, the publication of most important water management issues, the publication of drafts of the RBM Plan, the consultation of the public and the revision of the RBM Plan, and the final publication of the RBM Plan.

Future tasks of the RBM-EG of ICPDR are: the preparation of the Danube RBMP, the review of monitoring networks, the harmonization of environmental objectives, the preparation of a programme of measures (dam construction impacts vs. floodplains), the organization of public participation, the development and harmonization of GIS in the DRB, the review of analysis, and the modification of water pricing policies. Non-governmental organisations (NGOs) such as IAD play an important role in public participation, as they can focus public interests to the issues of water protection.

The following activities are needed to make the TNMN operational:

- selection of monitoring sites (61 locations with 93 sampling points);
- selection of water quality determinants;
- harmonization of methods for sampling and analysis;
- introduction of external control of laboratories (“ring-tests”);
- introduction of joint format for data exchange;
- administration of a central database of TNMN data;
- publishing of Danube Yearbook;
- preparation of water quality classification;
- agreement to use the Saprobic System for biological water quality assessment.

The ICPDR gives financial support through the UNDP-GEF Danube Regional Project to fill gaps on the national and the basin-wide level. Twenty projects are organized under the four objectives (1) Support for policy development, (2) Capacity building and transboundary cooperation, (3) Public participation, and (4) Monitoring and evaluation of projects. Research projects are Aqua Terra, Rebecca, and daNUBs. The latter is presented at an International Conference on “Nutrient management in the Danube River Basin and its impact on the Black Sea” on December 16, 2004, in Vienna (http://www.danubs.tuwien.ac.at).
6.3 The framework of the EU-FP6

By Bettina Asamer
(Nationale Kontaktstelle für Nachhaltige Entwicklung, Globale Veränderungen und Ökosysteme des 6. EU-RP)

Abstract written by V. Iordache based on the slide show on CD-ROM and on other public web documents.

The purpose of this presentation was to inform the participants about the current stage of implementation of the FP6, and to indicate the opportunities for applications in the near future. Some tips to increase the application chances were also provided.

After presenting the general framework of the FP6, the discussion focused on the priority of main interests for the workshop, namely 6.3 Global Change and Ecosystems. Details concerning the structure of FP6 can be found elsewhere (e.g. EC 2002, downloadable from the FP6 web site www.cordis.lu/fp6/find-doc.htm).

Useful information for those intending to develop a project is the average budget of the projects applied by now under the 6.3 priority and the number of participants in a project. These were 12-13 MEUR and 33-34 participants for Integrated Projects, 11-18 MEUR and 33-49 participants for Networks of Excellence, 2 MEUR and 11 participants for Specific Targeted Research Projects, 1 MEUR and 16-20 participants for Concerted Actions, and 0.4-0.6 MEUR and 12 participants for Specific Support Actions. Some of the topics of the calls within the area 6.3 Global Change and Ecosystems were not covered by accepted projects and might be of interest for IAD when they will appear in future calls. These topics are:

- Improved modelling of climate-water interactions at catchment-regional scales
- Development of a European virtual center for flood and drought studies
- Waste water treatment for re-use
- Water scenarios for Europe and for neighbouring countries.

In this context it seems relatively difficult to define research projects applicable to FP6 which fit well to the profile of IAD and without involving other European partners. Tips for increasing the chances of an application are: to carefully follow and answer ALL the evaluation criteria, to select the appropriate consortium and clearly define the roles of the partners, to connect to other projects and initiatives of European interest. Information concerning the existing projects can be found on the www.cordis.lu and www.europa.eu.int web sites.

The next call on Global Change and Ecosystem will be published in spring / early summer 2005. But there is also a certain possibility that some specific calls might be launched earlier, e.g., a dedicated call on the GEO (Group on Earth Observation)-Initiative.

Relevant topics for IAD and funding areas of the FP6 other than area 6.3 may be the area “Scientific support to policies” (Publication in October, 2004, Deadline in February 2005) and the CRAFT-Cooperative Research-Scheme. Other, smaller scale, opportunities for basic research in the IAD area of interest come from the INTAS program (www.intas.be). This funding scheme is directed toward the states of the former Soviet Union, but the consortium should include at least two members from Europe or candidate countries (INTAS states) and 2 members from the former Soviet Union. The project duration must be 24, 30 or 36 months, and the maximum budget is 20,000 Euro/year/partner. Details are provided by INTAS 2003, 2004a-b.

\(^{1}\) Millions of Euro
Another important aspect is the emphasis put at the European level on the export of knowledge in European areas with low research capabilities, together with enhancing their research infrastructure. The way forward towards FP7 (TILCHE 2004) explicitly suggests the need for raising research excellence in all European regions. Until we know better how FP7 looks like (first form to be circulated at the beginning of 2005), we notice that within FP6 there are still some opportunities for developing some international cooperation. Romania can play an important role in the development of knowledge transfer towards NIS countries and Russia (former USSR countries), and towards Western Balkan countries. IAD could function as a platform between EC countries and these countries.

In this respect there are two open calls, which will close in March 2005:

- FP6 2002-INCO-Russia + NIS/SSA-4
- FP6-2002-INCO-WBC/SSA-5

The involvement of non-member and member countries in the design of such Specific Support Actions (SSA) would be probably welcomed by DG XII Research, because by now the candidate countries have a very low rate of participation in projects funded by FP6. See annex A for a description of what SSA should do (EC 2002). After reviewing this document it seems clear that several SSA projects may be very opportune for enhancing the cooperation between IAD members.

Another way to enhance the cooperation between IAD countries could be to develop some Marie Curie Instruments (Annex B, from EC 2004) in an area connected to “Technologies and risk assessment in pollution disaster areas”. There are several new mobility calls in October relevant from this point of view. As for the instruments, the universities from all geographic regions can work in a mutually beneficial, complementary manner and might develop a Marie Curie Research Training Network, or a Marie-Curie Host fellowship for Early Stage Research Training. Additionally, Eastern Universities might develop Marie-Curie Host fellowship projects for transfer or knowledge involving professors and scientists from Western universities. Furthermore, young researchers from Eastern universities might be involved in research at Western universities by developing a Marie-Curie Intra-European fellowships project.

**Conclusion**

Based on the above information it seems that a good strategy for IAD is to catalyze the development of four types of project schemes:

- A larger scale research project for the FP6 or even FP7 (Integrated Project, specific targeted research projects, eventually participating in a Network of Excellence)
- Several research projects for INTAS
- Several prospective projects for the SSA calls of FP6
- Several human resource projects for several types of Marie Curie Instruments of FP6

IAD, by statutes of 1.1.2004, can be a professional NGO member in all these projects.

**References**

TILCHE, A. (2004): The 3rd FP6 Call of “Global Change and Ecosystems” and the way forward towards FP7, Presentation at Wiena, Information Day.
Annex A Specific Support Action (cited from EC 2002)

These projects aim to contribute actively to the implementation of activities of the work programme, the analysis and dissemination of results or the preparation of future activities, with a view to enabling the Community to achieve or define its RTD strategic objectives. Therefore, a significant emphasis has been placed on Support Actions:

- to promote and facilitate the dissemination, transfer, exploitation, assessment and/or broad take-up of past and present programme results (over and above the standard diffusion and exploitation activities of individual projects);
- to contribute to strategic objectives, notably regarding the European research area (e.g. pilot initiatives on benchmarking, mapping, networking, etc.);
- to prepare future community RTD activities, (e.g. via prospective studies, exploratory measures. pilot actions etc.);

as opposed to awareness and information exchange activities, e.g. annual Workshops and Conferences, that would take place anyway without Commission support. The latter activities will not be welcome if they do not serve the programme’s strategic objectives, (in the sense of the European Research Area, improved co-ordination, public awareness, preparation of future Community initiatives, etc.). SSAs can be proposed by a single participant or by a consortium of several participants. The activities of a specific support action will be supported through a grant to the budget of up to 100% of the budget or, if necessary, as a lump sum.

Further information: http://www.cordis.lu/fp6/instrument-ssa/

Annex B Marie Curie Instruments (cited from EC 2002)

Marie Curie Research Training Networks

These Networks provide the means for research teams of recognised international stature to link up, in the context of a well-defined collaborative research project, in order to formulate and implement a structured training programme for researchers in a particular field of research. Networks will provide a cohesive, but flexible framework for the training and professional development of researchers, especially in the early stages of their research career. Networks also aim to achieve a critical mass of qualified researchers, especially in areas that are highly-specialised and/or fragmented; and to contribute to overcoming institutional and disciplinary boundaries, notably through the promotion of multidisciplinary research. They will also provide a straightforward and effective means to involve the less-favoured regions of the EU and Associated Candidate Countries in internationally recognised European research co-operation.

Marie Curie Host Fellowships for Early Stage Research Training

These Fellowships will be targeted at higher education and research institutions, training centres and enterprises, with a view to reinforcing their training capability. The scheme will be directed at researchers in the early stages of their professional career. It will focus on the acquisition of specific scientific and technological competencies in research, as well as of complementary skills.

Marie Curie Host Fellowships for the Transfer of Knowledge

These Fellowships will be directed at European organisations (universities, research centres, enterprises, etc.) in need of developing new areas of competence, as well as at furthering the development of research capabilities in the less-favoured regions of the EU and in the Associated Candidate Countries. Knowledge transfer fellowships will allow experienced researchers to be hosted at such organisations for the transfer of knowledge, research competencies and technology.

Implementation

This action will be implemented through:
- the reinforcement of the research potential of host entities, with priority to entities situated in Less Favoured Regions of the Member States and in the Associated Candidate Countries, in need of new areas of competence (Marie Curie Development Scheme);
- the creation and development of real strategic and durable partnerships between the academic world and the world of enterprises, in particular SMEs, aiming at the establishment of lasting collaborations of mutual interest (Marie Curie Industry-Academia Strategic Partnership Scheme).

Marie Curie Intra-European Fellowships

These Fellowships will allow the most promising researchers from EU and Associated countries to undertake training through research in the European organisations most appropriate to their individual needs. The topic will be freely chosen by the researcher in collaboration with the host, with a view to completing or diversifying his/her expertise.
7. Outcome of Group Work

On purpose, the themes of the group work were chosen as general problems of linking hydrology and limnology, and not aimed at focusing on possible joint projects.

7.1 Water politics: Flood risk management – role of floodplains and a political framework (EU-WFD)

Reported by Günter Blöschl

Preparing the grounds for a joint hydrology-limnology project can only be done by respecting the scientific, social and political environment. Applied science aiming, for instance, at influencing environmental policy needs to take care of problems politicians have to solve. Such societal questions envisage flood risk management, apart from the many uses of waters such as shipping, hydropower, drinking water, irrigation, and recreation. A healthy environment for the whole population can only be maintained by finding compromises between use and protection.

With reference to the role of floodplains in flood risk management different views on policy goals exist: Connecting floodplains or cut off floodplains (which is not a disaster if nature can adapt); is the least influence of humans on the environment the best situation? All variants of ecological management are acceptable provided they do not increase the flood risk. There is a need to give alternatives to the decision makers.

An integrative procedure at various levels is needed. A major question is what is the right level of integration (for physical/chemical/biological; economic; societal processes)? A conceptual problem is: should we integrate at the lowest possible level, or should we aggregate at the highest possible level because of non-linearities inherent in the system that may lead to missing important feedbacks? An integration at technical levels is also needed.

The integration of processes encompasses the integration of hydrologic risk (both floods and droughts, i.e. the extremes) with environmental assessment and economic analysis. For instance, can biocoenoses adapt, can biodiversity be maintained, and at what cost? The integration at the technological level addresses, e.g., flood protection through ecological restoration. The flood damage and losses due to drought should be included in economic analysis.

Integration in space needs to consider the whole complex system integrity and catchment approach such as upstream / downstream neighbourhood issues in flood management and trading permits. Floodplains of both small and large streams must be considered (small streams being very important in terms of nutrient removal and restoration for the overall system) as well as the role of tributaries for flood risk. Large deviations in small parts of the systems from the average should be accepted, as for instance both poorer and better quality.

Finally, the integration at the procedural level is of great importance for flood risk mitigation and prevention, and the implementation of recommended measures. Pilot studies at Sava and Tisza Rivers with a RBM Plan including floods demonstrate successful integration of hydrological risk (floods and droughts) with the EU-WFD. Science is interested in the response of the ecosystem to management (success control, monitoring), and hence in the overall policy goals and integration at various levels.

The group developed some SPECIFIC RESEARCH QUESTIONS:

Q: Can we reduce pollution load by managing floodplains differently? Are the floodplains sinks or sources? This may depend on hydrological conditions.
Q: What happens with pollutants at the beginning of large floods?
Q: How much space does a river need, i.e., what are the minimum requirements of river space for the biocenosis to develop? Can a lack of that space be compensated for by something else, and perhaps traded?
Q: Artificial flooding - what are the management options for combined flood retention and ecological flooding?
Q: Stream aquifer interactions, specifically for small streams. What are the processes?
Q: Monitoring aspects: find improved indicators that contain maximum information at the lowest cost.
Q: How do we deal with steep gradients in space and time (modelling, monitoring) - identify important changes? (Small fraction of data may be relevant; optimisation of monitoring network in terms of scales, variables, instruments).

7.2 Research: Contaminant load budgets/calculation and modelling in the DRB with regard to the Black Sea as the final recipient

Reported by Norbert Matsché

The needs for the budget and balance of loads and sediments are

- Monitoring at critical points (dams, existing and future sources of pollution)
- Data of water flow and quality, and sediments sources
- Emphasize the sedimentation and erosion areas (morphological changes)
- Measurements during flood events
- Regular chemical monitoring of water and sediment quality

A serious and persistent problem in the DRB is the availability and quality of field data. A quality assurance of field and laboratory data is of utmost importance, as well as the intercalibration and harmonization of methods.

With respect to pollution sources we need

- Inventory of point sources (existing and future), see, e.g., daNUbs, ICPDR
- Estimation of diffuse sources, see, e.g., daNUbs, ICPDR
- Estimation of potential internal sources (remobilization)

From the practical point of view, micropollutants (quite often at sub-lethal concentrations) are getting more important with respect to human health.

Understanding of processes is the eternal big task of science. In general, we still need

- Better understanding of processes taking place at the sediment-water interface
- Special investigation of basic processes (transport, accumulation, transformation of most significant anthropogenic pollutants)
- Combined effects

In this respect, upscaling (local to regional to basin) is of crucial difficulty.

Calculation and modelling involves

- Typology (hydrological, quality and ecological)
- Applicability (general, local, punctual) – River Basin Management Plan
- Approach (dynamic and non-dynamic)

The quality of the model depends on knowledge, while results depend on quality of data (calibration).
7.3 Teaching: Strategies to improve cooperation between limnology and hydrology (universities as foci to applied science)

Reported by Ivana Teodorović

Definitions are considered crucial for the understanding between disciplines and between science and society. In most cases, definitions are not precise and depend on the educational background of a person and his understanding of the system and/or function in question. For instance, the term “limnology” is hardly ever known by “ordinary” non scientific people. In limnology itself, the definition has passed several phases of development, from “science of lakes” to “science of freshwater”. However, today the “best” definition would be the “science of inland waters” as the opposite of marine systems, i.e., oceanography (estuaries being the transition zone between them), and as such including freshwater rivers, lakes, ponds and reservoirs, groundwater, and salt lakes. The group brought up a funny definition made by hydrologists, namely „limnology is a branch of hydrology dealing with living organisms“. In the context of the above definition limnology rather is the discipline of ecology dealing with inland aquatic ecological systems (i.e., aquatic ecology as compared to terrestrial ecology).

Background at the university level:

• Diversity of education approaches
• Limnological education includes some basic information on hydrology
• Basic education for engineers hardly gives any ecological education
• Motivation for a more interdisciplinary approach: requirements of WFD

Possibilities to improve interdisciplinary research and cooperation:

• A frequent and regular exchange of guest lecturers
• Some interdisciplinary modules for the post graduate education
• International distance learning: hydrology for limnologists and vice versa
• Summer schools (by institutions like IAD, SIL, EGU, IWA) according to IPGL courses, in best case with govermental support

Products to be developed for a better interdisciplinary cooperation:

• Cross reference glossary as a first step for a booklet
• Educational material for teachers of secondary schools and colleges to promote a more holistic view (e.g. hydrological atlas of Austria)
• A comprehensive meta-database for decision makers
• Sturgeon as „PR-material“ (flag animal) to raise public awareness of the necessity of interdisciplinarity (linking hydrology and limnology)

Interdisciplinarity within institutions vs. cooperation within projects?
7.4 Implementation of science: Joint limnology/hydrology consulting – a network between universities, private enterprises and NGOs

Reported by Virgil Iordache

As a general framework for discussing the role of universities and SMEs, we briefly characterize the positions of the main actors involved in the implementation of science (Fig. 1).

![Diagram](image)

**Figure 1.** Some actors involved in the development and implementations of environmental regulations. Arrows indicate usual information fluxes.

The tasks of the universities are in principle to contribute to the development and improvement of the existing evaluation instruments and to assist with regard to the interpretation of the current instruments. However, when comparing the countries of the Danube Basin one can notice the following:

- In the western, richer countries, universities perform the two roles that they should play in principle. There is an institutional cooperation between universities, private agencies and governmental bodies with regard to the interpretation and implementation of environmental directives. It seems that this cooperation is possible due to a lobbying pressure of the strong civil society existing in these countries. At the level of the SMEs there are associations of users that are open to ecological issues and can function as “good example organizations” for the eastern countries. Another positive aspect in these countries is the cooperation between the sectoral water experts and the ecology experts with regard to the management of the water bodies (e.g. ATV-DVWK in Germany). However, even if
there is cooperation between scientists there are still difficulties in transferring the results of this cooperation to legislation.

- In the eastern, poorer countries, universities are not involved in the interpretation or in the development of the existing regulations. Only some personal involvement of the scientists seems to exist, without an institutional involvement. SMEs (consultancy companies) of these countries just implement the regulations (e.g. perform EIAs), without being involved in applied research related to this interpretation. For instance, the governments of these countries delegated the interpretation and implementation of the WFD to specialized national companies which have the monopoly on water resources commercialization. This situation might be due to the fact that the governments of these countries aim only at internalizing the existing western regulations and do not take into account the opinions of the own scientific community. However, the cooperation model between water experts and ecology experts was not internalized. There is also a trend to postpone the implementation of the internalized European laws, in order to protect the economy from the costs associated with the implementation of the legislation.

In this context, the best strategy of eastern universities to get involved in the development and improvement of environmental regulations is to cooperate with western research institutions involved in this kind of applied research. The most advanced area at this moment is the development of the ecological impact assessment methodology (EcIA), as referring explicitly to ecological systems and their intrinsic natural variability. Already expressed in regulations, but equally advanced and important is the strategic impact assessment (SIA). SIA is not yet internalized in the eastern countries (Fig. 2).

![Figure 2](image.jpg)

**Figure 2.** The relationship between the development of environmental assessment procedures in Western and Eastern European countries. Western universities and SMEs are actively involved in the development of new procedures, while in the east this involvement is much smaller. Eastern governments intend to copy the current regulations from western countries in the frame of acquisition. EIA = environmental impact assessment, EcIA = ecological impact assessment, SIA = strategic impact assessment.

The group identified three research directions:

- **Research direction 1.** Development of transboundary consortiums dealing with EcIA and SIA. Goal No.1 could be transforming EIA towards EcIA, and goal No.2 to develop SIA
for the Danube Basin, in particular to clarify how species with requirements for large ecological systems are affected by the projects and policies with regional impacts (e.g. dams, but not only).

- **Research direction 2.** Cross-country comparison of the markets involved in environmental assessment. The hypothesis could be that the structure of the market is related to the strength of the civil society: the role of the public institutions decrease as the influence of the civil society increase

- **Research direction 3.** To establish if it is possible and desirable to standardize the implementation of EIA in the EU? For instance EAWAG (SWITZERLAND) developed the most advanced procedure for impact assessment of hydropower (Label “naturemade star” for green hydropower). Could this be equally applied to the Gabčíkovo or Iron Gate reservoirs?

With regard to education and professional requirements for environmental assessment, some relation to Group 3 was identified: The traditional situation is that mostly hydrological engineers and chemists were involved in this area. The traditional situation is slowly changing by including young hydrologists-ecologists hybrids, but the change should be accelerated. However, this type of human resource will be increasingly required also by SMEs, because of the emerging market associated with the implementation of WFD and of the other European environmental regulations.
8. Tentative Project Ideas and Proposal

The plenary discussed about

- the identification and evaluation of common limnological-hydrological interests;
- the elaboration of concepts and tools of cooperation;
- the identification of topics for a joint research project (project ideas) with particular emphasis on river morphology and floodplains.

The following research themes were considered as general topics where hydrology meets limnology:

- Danube and larger tributary wetlands and floodplains with regard to ecological function (limnology: biodiversity, nutrient retention) and water retention (hydrology), and as an urgent applied research topic in respect of flood risk assessment; also the effect of climate change on hydrological regimes would strongly affect the function of floodplains; economic valuation of ecosystems and natural resorts, and cross-cultural comparison of management practices could be considered as a sub-project with regard to practical implementation;

- dams/hydropower, Iron Gate in particular, as severe environmental impact factor with regard to hydrological regime and sediment retention/transport (hydrology) and fish migration, the migration of sturgeons in particular (limnology); Iron Gate dam could be compared to the Altenwörth dam where studies have just been completed; ecohydraulic modeling could be a promising methodological tool to evaluate habitat requirements of benthos and fish;

- the Danube Delta and Black Sea (coastal area) as the final recipient of nutrient and contaminant load (hydrology/limnology) and an important area of brackish zone (limnology);

- the Gabčíkovo hydropower station as a case study (pilot region) to develop methods and tools in ecological assessment (limnology) and sustainable hydrological use (hydrology);

- Particulate organic matter (POM) spiralling along the river continuum/discontinuum could be combined with ecological microbiology (limnology) and flow patterns (hydrology); from a practical point of view, the role of WWTPs could be integrated;

In any Danube River project, special emphasis should be given to:

- the spatial scaling from spots to reaches to stretches to rivers (according to FrisSELL et al. 1986), with respect to changing sensitivity to disturbance and recovery time; larger basins, such as the DRB, must be divided into sub-basins, e.g., the Tisza, Sava, Drava, Inn, etc, tributaries;

- the transboundary issue, especially important with 18 Danube countries;

- the relation to the EU-WFD that is presently being implemented also in the DRB by the ICPDR;

- the general language problems between scientific disciplines as well as between individual countries could be tackled by establishing dictionaries and appropriate definitions;

- scenarios and predictive models have a great potential to link scientific results with political environmental demands;

Reference

Some specific proposals by participants are summarized below:

**Proposed research initiatives for the DRB by Thomas Hein**

For the Danube River Basin, the need for basic research initiatives is required urgently. Projects as the daNUbs project dealing with nutrient transport at the catchment scale are prerequisites for transboundary cooperation and large scale actions. To understand the processes at this large scale, reach-scale nutrient dynamics of the Danube and its tributaries need to be investigated in more detail. Furthermore, the link between functions and structure of lotic networks need to be expanded to all aspects of biodiversity for a sustainable use of this highly endangered ecosystem. An important basic feature of all research initiatives needs to be the linkage between scales and hierarchical structure. Ecosystem modeling can be the tool to solve these challenges and identify the nodes between different spatio-temporal scales. In this context, some research activities can be suggested:

**Catchment scale approaches:**

1. At large scales, evaluating the question how lotic networks can be understood: as linear continua or a set of hydro-geomorphic discontinua. The use of biogeochemical processes can be of importance to identify the basic template in large rivers. Are the net effects found controlled by the local processes of functional process zones, how can the pieces of different tributaries be assembled to get the image of the large river?
2. A specific challenge would be to evaluate the theory of a physical continuum by the use of the prokaryotic community. An enormous potential in the link between ecosystem theory and microbial ecology can be expected.
3. Ecological stoichiometry can be used to trace large-scale transport patterns to local transformation patterns. The role of altered nutrient transport can be related to the uptake in different elements of the river corridor. Human-altered nutrient input decrease generally the N:P ratio. The various impacts on flow pattern, connectivity within the river corridor changed the retention capacity and, thus, effects on aquatic and terrestrial vegetation can be expected. How is nutrient use efficiency impacted? By means of organic matter decomposition the change in carbon use efficiency needs to be discovered for riverine landscapes. These large-scale changes also have an influence on the community structure and biotic interactions in specific functional process zones. The coupling between the structure and function of key ecosystem processes can be followed by the stoichiometry of ecosystem components and their temporal and spatial variability.

**Reach scale approaches:**

1. The role of slackwater areas in different functional process zones, their hydrological and geomorphic interaction and the effect on chemical and biological processes. Is the reach-scale setting and the variability in habitat condition the key factor determining biological activity?
2. Understanding the complexity especially of braided river corridors need to link the temporal dynamics and spatial heterogeneity of geomorphic dynamics and lateral and vertical flow paths to habitat-related ecosystem processes. A detailed understanding is one important prerequisite in designing sustainable restoration projects.
3. A basic issue in various concepts and models is the question what source of carbon fuels food webs – are there differences between the metazoan food web and the microbial loop in lotic system? How is the lotic network linked to processes in the catchment and to what extent do processes in the river corridor determine the community structure? The RCC’s predictions for the importance to downstream food webs of organic matter derived from upstream trophic leakage in large rivers
has been criticized from a lateral floodplain perspective by the flood pulse concept (JUNK et al. 1989; JUNK & WANTZEN in press) and from an autochthonous production standpoint by the riverine productivity model (THORP & DELONG 2002). What integrative view can be found?

References


Hydrology and Limnology - Some ideas that could be discussed - by Norbert Matsché

- Chemical changes in water composition during the passage through a colmation layer.
- Identification of significant water flows by simple parameters like temperature, alkalinity, and dissolved oxygen.
- Stagnant groundwater with poor water quality was only found in zones where no flow occurred (identification by temperature).
- Influence of discharge on the colmation layer and on the significance and direction of bank filtration.
- Chemical changes in impoundments due to accumulation of sediments with high organic content, e.g., production of nitrite by incomplete denitrification in water layers close to the sediment.
- Influence of assimilation on dissolved oxygen and pH changes in water as a function of discharge and retention time in impoundments.
- Strong variations of chemical parameters in cross-section as a function of flow velocity and discharge conditions.
- Influence of impoundments on biological water quality due to variation of available substrate. Influence of sediment transport due to flood events.
- Influence of chemical changes due to assimilation processes on conditions for phosphate precipitation as a function of discharge conditions.
- Variations of transport of particulate matter vs. dissolved substances under flood conditions (increasing and decreasing flow).

Conclusions

At the end of the workshop the participants agreed upon a following tentative draft project proposal that should be further pursued and finalized in a follow-up workshop:

Working Title: Reservoir Management in the Middle and Lower Danube (Iron Gate I and II, Gabčíkovo; Altenwörth/Freudenau) with emphasis on hydrological regime and floodplain function.

Work Packages:

- Floodplain and wetlands (nutrient and water retention, biodiversity);
- Sediments (transport, load, contamination, modeling);
- Nutrients, contamination (Monitoring);
- Sturgeon (migration, natural reproduction, habitats, food sources: benthos);
- Ecomorphology (habitat assessment, mapping);
- Economic and cultural aspects (hydropower, gravel exploitation, shipping, valuing, ecotourism), management practices and attitudes);
- End-users perspective (WFD-implementation, procedure for sound floodplain management, decision suport system, risk analysis, manuals, dictionary).
9. Workshop Assessment and Follow-up Actions

The overall rating of the workshop by all participants was “good, with most expectations fulfilled”. However, many felt the programme was too strenuous. There was indeed not enough time for presentations of non-plenary speakers and for thorough discussions and exchange of opinions. While it was recognized that the dialogue between limnologists and hydrologists is just beginning (actually for the first time in the DRB) and rather difficult, the opinions were controversial whether we did a significant step towards mutual understanding or whether the distance between the two disciplines is still too large. This may best be illustrated by comparing some of the contributions from different scientific backgrounds about one integrating issue, such as the role and impact of dams (see chapters 4.7 – 4.12). It may be that the selection of invited scientists was biased towards hydrology, and limnological aspects were not stressed enough. In any case, the balance between the two disciplines needs to be treated with utmost care when attempting to develop a joint project.

It is planned to further develop the general project idea outlined under chapter 7, and to organize a project team (with some workshop participants and new partners). It is intended to submit a proposal to UNESCO to support a second (kickoff) workshop where the project proposal would be discussed in detail and prepared for submission in an EU-FP or another scientific research programme.

Some workshop participants expressed their willingness to submit a paper to a scientific journal.
10. Annex
10.1 List of Participants

In total: 28
Austria 11
Serbia-Montenegro 4
Romania 4
Germany 3
Bulgaria 2
Hungary 2
Switzerland 1
Slovakia 1

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10.2 Workshop Programme

IAD Workshop (Working Title)
“Hydrology and Limnology – another boundary in the Danube River Basin”

**Aim:** to foster the understanding between two traditional scientific disciplines in view of the catchment approach and sustainable Danube River Basin management.

**Date:** 14-16 October, 2004  
**Location:** Hotel Marc Aurel in Petronell near Vienna

**Number of participants:** selected/limited (20-30)

Tentative Schedule (as per August 31, 2004 – subject to minor change)

**Wednesday 13 October 2004**
Evening: Arrival of participants from remote countries (pick up from airport Vienna)

**Thursday 14 October 2004**
**Topic:** The cooperation between Limnology and Hydrology: Is it good? What is needed?
0930 Welcome coffee  
1000 Opening – Introduction of WS participants  
1015 – 1115 2 impulse presentations for Introduction  
J.BLOESCH: What is the view and expectations of limnologists?  
D.GUTKNECHT: What is the view and expectations of hydrologists?  
1115 – 1215 2 state-of-the-art presentations hydrology & limnology / discussion  
G.BÖLSCHL: The hydrological regimes of the Danube River and its tributaries  
T.HEIN et al.: The limnological concepts of large rivers applied to the Danube River  
1230 – 1400 Lunch  
1400 – 1600 4 state-of-the-art presentations hydrology & limnology / discussion  
N.N.: Hydrological methods: The measurement of flow and discharge  
N.MATSCH et al.: Chemical and biological methods: Sampling, analysis and data processing; species identification and concepts of river characterisation (bio-indices); river typology  
J.JOZSA: Modeling flow and discharge in the Danube River Basin  
M.SCHNEIDER: Water quantity and flow as key parameters for benthos and fish  
1600 – 1630 Coffee break  
1630 – 1900 5 state-of-the-art presentations hydrology & limnology / discussion  
F.SEEBACHER: The catchment approach in implementing Danube River Basin Management; the role of drinking water supply, irrigation, and recreational use; reservoirs; sustainable development  
H.KROISS: River monitoring: where limnology meets hydrology; Chemistry: nutrient and contaminant loads of the Danube River and its tributaries; Biology: concepts of quality assessment  
F.SCHÖLL: Rhine-Main-Danube waterway: hydrological aspects and biological impacts; species exchange (alien species); the role of navigation  
S.PETKOVIC: Iron Gate I and II: technical, hydrological and limnological aspects – sediment transport; reservoirs and dams as disruptors of fish migration  
A.ZINKE: Hydropower station Gabčíkovo: deficits in hydrology (sediment transport, groundwater) and biology (floodplain succession; bank constructions, floodplain disconnection), problems of flood control
1930  Dinner
2100  Relaxed general discussion of keynote presentations (under the influence of wine):
      Hydrology meets Limnology – where, how and when? (Alternatively: Video on floods in the Danube River Basin)

Friday 15 October 2004

Topic: From Theory to Practice: Where are the deficits in applied research?

0800 – 1000  introductory presentations (framework of projects in the DRB)
      V. IORDACHE: Communication in transdisciplinary and transboundary projects
      P. WELLER: Key notes on the EU-WFD
      B. ASAMER: Key notes on the EU-FP6

1000 – 1030  Coffee break
1030 – 1045  Introduction to working groups
1045 – 1230  Group work (4 Groups)
      1) Support of the EU-WFD implementation, mitigation of flooding
         (water politics)
      2) Contaminant load budgets/calculation and modelling in the DRB with regard to the Black Sea as the final recipient (research)
      3) Teaching strategies to improve cooperation between limnology and hydrology (universities as foci to applied science)
      4) Joint limnology/hydrology consulting: a network between universities, private enterprises and NGOs (implementation of science)

1230 – 1400  Lunch
1400 – 1900  Excursion to Danube National Park (scientific introduction & guidance):
      Visit of restoration sites with strong habitat dynamics

1930  Dinner
2100 – 2130  Discussion about excursion: the hydrological & limnological perspective

Saturday 16 October 2004

Topic: Common interests, topics and concepts of cooperation, follow-up

0800 – 0930  Group Reports and discussion
0930 – 1100  Plenary discussion
      - identification and evaluation of common interests
      - elaboration of concepts and tools of cooperation
      - identification of topics for a joint research project (project ideas) with particular emphasis on river morphology and flood plains

1100 – 1130  Coffee break
1130 – 1300  Plenary discussion
      Product(s):
      - Book/special issue of Journal (Large Rivers) including all papers presented;
      - Report of workshop; possibly to be included in the book (summary/outlook chapter);

1300 – 1430  Lunch
1430 – 1600  Follow-up actions; distribution of work; deadlines. WS Summary
1600  Closure of WS

Sunday 17 October 2004

Morning: Departure to airport