UNDP/GEF Danube Regional Project

Strengthening the Implementation Capacities for Nutrient Reduction and Transboundary Cooperation in the Danube River Basin

Monitoring and Assessment of Nutrient Removal Capacities of Riverine Wetlands

Project Component 4.3: Monitoring and Assessment of Nutrient Removal Capacities of Riverine Wetlands

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PREFACE

The long term goal of the DRP is, in short, to strengthen capacities of key Danube stakeholders and institutions to effectively and sustainably manage the Danube River Basin's water resources and ecosystems for citizens of Danube countries.

It is increasingly recognized that wetlands and floodplains provide important benefits both environmental as well as socio-economic. Wetlands and floodplains can be important for flood protection, tourism, fisheries, nature protection as well as for water quality. To some degree, wetlands and floodplains may serve as either a sink or a storage area for pollutants. Given that nutrient pollution is one of the most important transboundary problems within the DRB and the Black Sea ecosystems, it is critical to know under what conditions such benefits as pollution reduction can be optimized (and at what cost.)

A study supported by UNDP/GEF during the UNDP/GEF Pollution Reduction Programme (1997-1999) carried out by WWF determined that over 80% of wetlands and floodplains have been lost during the last 100 years. Given this, there are many considerations to initiate wetland floodplain rehabilitation activities. Important to know is what are the benefits for rehabilitating a wetland/floodplain area (weighed against the costs!)

The purpose of this assignment was to identify and develop appropriate methodologies for assessing nutrient removal in wetland areas. Potential pilot sites were reviewed in an effort to identify appropriate places to test and revise monitoring programmes to measure pollution reduction. One site has been agreed (in Bulgaria) and other possibilities have been identified for a final selection to be made at the beginning of Phase 2.

One challenge is to identify monitoring strategies to fit the varying conditions at sites in different parts of the Danube. Another challenge, is that benefits from changes in wetland management practices might not be observed for years to come beyond the scope of this project. Therefore the goals for phase 2 will be to have pilot monitoring programmes in place, initial lessons learned, although real results will only be available after longer time frames (15-20 years.)

The results of this component are intended both for those involved in making decisions about wetland rehabilitation projects as well as of course, those wetland managers charged with managing wetland/ floodplain areas in order to optimize benefits.

The report was prepared by a team of experts led by the WWF Danube-Carpathian Programme and reflects the views of the expert team. The report and its contents remain the property of the UNDP/GEF DRP and should not be used without providing full credit to the DRP.

For further information about the DRP, objectives, activities, results etc. please visit the DRP webpage at www.undp-drp.org

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LIST OF ABBREVIATIONS

APCP	World Bank/GEF Agricultural Pollution Control Project
CPOM	Coarse Particulate Organic Matter
DDBRA	Danube Delta Biosphere Reserve Authority
DDNI	Danube Delta National Institute
DEF	Danube Environmental Forum
DCP	WWF International Danube-Carpathian Programme
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
DPRP	UNDP/GEF Danube Pollution Reduction Programme
DRB	Danube River Basin
DRP	UNDP/GEF Danube Regional Project
DRPC	Danube River Protection Convention
DS	Dry Substance
DWQM	Danube Water Quality Model
EMIS	Environmental Monitoring and Information System (ICPDR)
EPI	Environment Protection Inspectorate
EPS	Extra Cellular Polymeric Substances
EU	European Union
EC	European Commission
ECO EG	Ecology Expert Group (ICPDR)
ESG	Expert Sub-Group (ICPDR)
FPOM	Fine Particulate Organic Matter
GEF	Global Environment Facility
IAD	International Association for Danube Research
ICDPR	International Commission for the Protection of the Danube River
IRBM	Integrated River Basin Management
NGO	Non-governmental Organisation
MLIM	Monitoring Laboratory and Information Management (ICPDR)
PCU	Project Coordination Unit
POC	Particulate Organic Carbon
POM	Particulate Organic Matter
PRP	Pollution Reduction Programme

REC	Regional Environment Center for Central and Eastern Europe
SS	Suspended Solutes
TN	Total Nitrogen
TOC	Total Organic Carbon
TNMN	Trans National Monitoring Network
TP	Total Phosphorus
UNDP	United Nations Development Programme
WFD	EU Water Framework Directive
WWF	Worldwide Fund for Nature

EXECUTIVE SUMMARY

This report summarises the activities and results from the first phase of activity of Output 4.3 of the UNDP/GEF Danube Regional Project (DRP). It aims to contribute to Objective 4 of the DRP – R*einforcement of monitoring, evaluation and information systems to control transboundary pollution and to reduce nutrients and harmful substances*.

The main purposes of Output 4.3 are:

- To evaluate and identify the most effective monitoring strategies and programmes for assessing nutrient removal capacities of wetlands as a basis for Danube River Basin guidelines in relation to wetland classification;
- To identify and prepare pilot activities that will be carried out in Phase 2 of the DRP; and
- To set the basis for identifying management measures to optimise the nutrient removal capacity of wetlands in Phase 2 (leading to a Danube River Basin wetland management strategy).

A number of activities were carried out to meet these objectives, including a review of literature on wetland functions and wetland management/restoration projects in the Danube River Basin and beyond, the drafting of criteria for selecting pilot sites, the drafting of general principles and guidelines for wetland monitoring schemes in relation to nutrient removal, a workshop of international experts on wetland management and visits to potential pilot sites.

The results of the review of wetland functions and wetland projects demonstrated that such ecosystems can substantially alter the biogeochemical fluxes of river systems. While nutrients are only completely removed from the system during harvest or by denitrifcation, long-term storage within wetlands can lead to reduced pollution loads in the main channel. In most riverine wetlands, sedimentation and denitrification are the dominant process influencing, respectively, P and N cycling. These processes, and the hydrogeomorphological factors that govern them (i.e. flooding), therefore determine whether a specific wetland are functions as a nutrient sink or source. To predict the role that a wetland will play, local environmental parameters must be considered, especially during peak flows. Nevertheless, previous studies along the Danube have demonstrated the potential for riverine wetlands to contribute to the reduction of nutrient pollution in the main river.

Selection of sites for establishment of a pilot monitoring scheme was not straightforward. Selection criteria included a combination of technical factors (e.g. the proportion of main river flow reaching the riverine wetland in question) to logistical ones (e.g. does sufficient baseline information exist and is enough logistical support available?). An initial search for sites suggested that two wetlands in the Lower Danube, both the subject of extensive wetland restoration projects supported by World Bank/GEF funds, might be suitable. Field visits proved that only one of these sites – at Kalimok-Brushlen Protected Area in Bulgaria – offered appropriate conditions for establishment of a pilot monitoring scheme. A second site will need to be found as a matter of priority during Phase 2 of Output 4.3.

Following the definition of general principles and guidelines, work was undertaken at the Kalimok-Brushlen pilot site to define a framework for a monitoring programme aimed at assessing the role the 1,125ha of restored marshland will play in reducing nutrient loads in the Lower Danube. Building on existing plans for monitoring surface waters – and in line with the EU Water Framework Directive and the *Wetlands Horizontal Guidance* – a wide range of parameters have been suggested for monitoring at a range of places and at varying frequencies. These parameters include biological, physico-chemical and hydromorphological quality elements. In addition to suggesting what, where and when to monitor, the report suggests requirements for equipment and detailed methodological procedures with respect to each major group of parameters.

This report concludes with a number of recommendations for taking the work forward including, a) progressing with the suggested activities at the Kalimok-Brushlen pilot site, b) the identification of a second pilot monitoring site, c) the establishment of a Danube River Basin wetland expert network to review findings from the two sites and identifiy ways in which monitoring programmes can be optimised, and d) increased dissemination of the results of this work.

1. INTRODUCTION

1.1. Background

The potentially important role that riverine wetlands can play in improving water quality through removal and modification of dissolved and suspended nutrient pollution has been documented by a number of studies and reports, including several that refer to the Danube River Basin.[1]

In a 1999 report prepared under the UNDP/GEF *Danube Pollution Reduction Programme* (DPRP) the significant loss of wetlands in the Danube River Basin, and the potential affect this had on water quality in the Danube River and Black Sea, was extensively investigated.[2] The report concluded that, "it is an uncontested fact that recent, inundated floodplains have a positive effect on water quality improvement and nutrient input reduction if they are not subjected to intensive agricultural use." The historical loss of riverine wetlands was assumed therefore to have had a negative affect on the water quality in the Danube River and Black Sea. The potentially important role of wetland restoration in an overall Danube River Basin nutrient reduction strategy was noted. However, the authors of the report concluded that the extent to which wetlands remove nutrients "cannot be definitely quantified at the moment due to insufficient and in-homogenous available data."

Despite the lack of suitable data, a review of studies and the authors' knowledge of factors influencing the Danube River Basin led them to proposed ranges for nutrient reduction through wetland restoration: the estimated range of Nitrogen (N) reduction was 100 – 150 kg ha^{-1} $year^{-1}$; that for Phosphorous (P) was 10 – 20 kg ha^{-1} $year^{-1}$. Furthermore, results from simulations using the Danube Water Quality Model (DWQM), using data from 17 wetland restoration projects, indicated that wetlands might deliver reductions in annual nutrient pollution loads for the whole Danube River Basin of 30 kt N and 3 kt P[3].

In order to strengthen the understanding of the role of riverine wetlands in nutrient reduction, further investigations and activities were proposed as part of the UNDP/GEF *Danube Regional Project* (DRP). This report sets out the results from Phase 1 of DRP Output 4.3, *Monitoring and Assessment of Nutrient Removal Capacities of Riverine Wetlands*. The intention is that the conclusions and recommendations set out in this report will form the basis for the establishment of monitoring and assessment programmes of nutrient dynamics in two Danube wetlands to be carried out in Phase 2 of the project between 2004 and 2006.

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[1] e.g.:

Hauer FR, Smith RD. The hydrogeomorphic approach to functional assessment of riparian wetlands: evaluating impacts and mitigation on river floodplains in the U.S.A. Freshw. Biol. 1998; 40: 517-530.

Henry CP, Amoros C. Restoration ecology of riverine wetlands: I. A scientific base. Environmental Management 1995; 19: 891-902.

Tockner K, Pennetzdorfer D, Reiner N, Schiemer F, Ward JV. Hydrological connectivity, and the exchange of organic matter and nutrients in a dynamic river-floodplain systemFreshw. Biol. 1999; 41: 521-535.

[2] Evaluation of Wetlands and Floodplain Areas in the Danube River Basin, Final Report, May 1999. Report prepared by WWF Danube-Carpathian Programme and WWF-Auen Institute (Germany) for Programme Coordination Unit UNDP/GEF Assistance

[3] van Gils J. (1999). Danube Water Quality Model Simulations in Support to the Trans-boundary Analysis and the Pollution Reduction Programme, Danube PCU UNDP/GEF Assistance, prepared by Jos van Gils, Delft Hydraulics, Delft, The Netherlands.

1.2. Structure of this report

For reasons of clarity and logic, the structure of this report does no strictly adhere to the structure of the original Terms of Reference as described in Chapter 2. Nevertheless, it should be emphasized that all major tasks were carried out are reflected herein.

Following this introduction, Chapter 2 of this report sets out the rationale, objectives and specific activities for Output 4.3, including the main objectives. Chapter 2 also includes a summary of the methodology for the work.

Chapter 3 of the report reviews the scientific and project-based literature on riverine wetlands and reduction of nutrient pollution. The chapter starts with a definition of what "riverine wetlands" means within the context of this report. It then summarises the main mechanisms involved in nutrient dynamics between the main channel and riverine wetlands, and within riverine wetlands, with particular reference to transport, transformation and storage, removal and release.

Chapter 4 is more geographically specific, describing briefly the nutrient balance of the Danube River Basin in terms of emissions to the river system and emissions from the river system to the Black Sea. It also reviews the conclusions from the DPRP regarding the potential role of riverine wetlands in removing nutrients from the Danube. It concludes with an example of the estimated effects on nutrient pollution levels of one of the largest riverine wetland restoration projects in the DRB – at Regelsbrunn in Austria.

Chapter 5 describes the process for selecting pilot sites at which the nutrient removal capacity of wetlands can be assessed in greater depth, including some of the difficulties encountered in identifying suitable sites.

Chapter 6 sets out general principles for monitoring the nutrient removal capacity of wetlands. Such general principles can be established for monitoring but specific measures and activities can only be effectively determined based upon site considerations. Chapter 7 then takes the principles from Chapter 6 and develops them further to the specific pilot site identified for follow-up activities in Phase 2 of Output 4.3.

Chapter 8 sets out the conclusions that can be drawn from Phase 1 of Output 4.3 and sets out recommendations for action in Phase 2.

Further details of the project team, and acknowledgements to other individuals who helped with Output 4.3 activities, can be found in Annex 1 of this report.

2. RATIONALE, OBJECTIVES AND ACTIVITIES

2.1. Rationale

This report has compiled under the auspices of the UNDP/GEF *Danube Regional Project* (DRP). It forms part of the work undertaken to meet Objective 4 of the DRP, *Reinforcement of Monitoring, Evaluation and Information Systems to Control Transboundary Pollution and to Reduce Nutrients and Harmful Substances*. More specifically, this report is the main result of Phase 1 activity under Ouput 4.3, *Monitoring and Assessment of Nutrient Removal Capacities of Riverine Wetlands*.

Numerous wetland rehabilitation activities have been, and are being, undertaken in the DRB. Some of these activities form part of the GEF Partnership Programme in which monitoring is included or foreseen as a component. Therefore, before initiating a new observation programme, a common methodology and approach for monitoring wetlands in the DRB should be agreed. This should involve surveying current monitoring approaches, bringing together experts to determine a harmonized methodology for measuring nutrient removal in DRB wetlands and assuring that such a harmonized methodology is implemented.

Output 4.3 was designed to meet the need for a quantified and consistent approach to the assessment of the nutrient removal capacities of Danube River Basin (DRB) wetlands. The central objective of the work was to demonstrate the possibilities for understanding and optimizing nutrient removal processes, alongside other benefits derived from wetlands, such as maintenance and enhancement of biodiversity and/or flood mitigation, through better wetland management. The intention was to define the technical and economic parameters for efficient wetland management, making use of existing data and expertise about nutrient removal in riverine wetlands in the Danube River Basin, the rest of Europe and beyond. It was expected that this could contribute to further prioritization of wetland rehabilitation projects based on anticipated nutrient removal benefits.

In a broader context, Output 4.3 supported a larger GEF need for targeted research. Based on this, successful results were to be disseminated worldwide so that the general methodology could be adapted to site-specific conditions based on accepted wetland classification schemes (e.g. the Ramsar Wetland Classification).

2.2. Objectives

Three main purposes were identified for the work to be completed under Phase 1 of this Output:

- To evaluate and identify the most effective monitoring strategies and programmes for assessing nutrient removal capacities of wetlands as a basis for DRB guidelines in relation to wetland classification;
- To identify and prepare pilot activities that will be carried out in Phase 2 of the project; and
- To set the basis for identifying management measures to optimize the nutrient removal capacity of wetlands in Phase 2 (leading to a DRB wetland management strategy.)

Note that, while there is no explicit consideration in this report of the basis for a DRB Wetlands Strategy, it is hoped and expected that the results from Output 4.3, together with those from other DRP outputs and from other relevant activities such as the review of Annex 3.3 (regarding wetlands) of the ICPDR Joint Action Programme, will provide such a basis.

2.3. Activities

During the inception phase for Output 4.3, the following tasks were identified as being necessary the fulfillment of the project objectives:

Review wetland restoration projects in and outside of the DRB that have addressed the nutrient removal capacity of riverine wetlands (special focus was given to the methodology used, the costs and the results).

Review existing projects related to wetland restoration within the DRB and define how they could provide guidance and information on nutrient removal capacity in relation to their respective classification (i.e. the Ramsar Wetland Classification). This activity was conducted in the form of both a desk survey and direct contact with national experts and the managers of relevant wetland projects. Special focus was given to other DRB wetland projects supported by GEF through either the World Bank or UNDP.

Compare existing projects related to wetland restoration with regards to a) the consistency of available data, and b) the potential for the collection of additional data that could contribute to Output 4.3 at minimal additional cost.

Draft general guidelines for the assessment and monitoring of the nutrient removal capacity of DRB wetlands.

Pre-select at least two representative pilot sites (if possible of different wetland types according to the Ramsar Wetland Classification) where analysis of the nutrient removal capacity could be carried out in Phase 2 of Output 4.3, and further into the future.

Draft specific guidelines and recommendations for the selected pilot sites. Special focus was to be given also to the outcomes of DRP Output 1.4, *Integrated Land-use Assessment and Inventory of Protected Areas* to ensure that the results of the components are consistent and complementary.

Organize a workshop including international and national experts on wetland management, including representatives of the possible pilot sites, to discuss and review both the general guidelines as well as the recommendations given for the pilot sites. This workshop was to include the relevant experts of the ICPDR Secretariat and members of the relevant ICPDR Expert Groups.

Based on the outcomes of the workshop, finalize the general and the specific guidelines and recommendations for the selected pilot projects, including a work plan and a budget for Phase 2 activities.

Based on these activities, a report was planned that would include:

- information on current knowledge of quantitative as well as qualitative removal of nutrients in riverine wetlands (in relation to classification where appropriate);
- a description of methodological and monitoring approaches (including requirements, benefits, costs, constraints etc);
- general guidelines and recommendations for the assessment of nutrient removal in the Danube River Basin;
- Specific guidelines and recommendations for the selected pilot sites in the frame of the proposed monitoring programme; and
- and outline for developing the wetland management strategy in Phase 2.

The remaining chapters of this report summarize the results of these activities.

A summary of the inception meeting held to determine these activities is in Annex 2. A note of the Wetland Managers' Workshop held to discuss and review the general guidelines and recommendations for selecting pilot sites (activity 7 above) is in Annex 3.

3. PROCESSES GOVERNING NUTRIENT DYNAMICS IN FRESHWATER ECOSYSTEMS

3.1. The scope of this review

Wetlands perform many functions that are useful to society. They mitigate flooding, maintain and improve biodiversity, provide pathways for discharge and/or recharge of groundwater and support economic activities such as agriculture, forestry and tourism. Wetlands can also influence water quality.

Within river corridors, riverine wetlands have been recognized globally for their value in nutrient removal[4]. Wetlands have been investigated as buffer zones and retention areas which control fluxes of matter between terrestrial and aquatic interfaces (van der Peijl & Verhoeven, 2000)[5]. Surface water and groundwater fed natural wetlands have been found to affect the nutrient transport along rivers as well as nutrient input into lakes and estuaries (Thompson & Finlayson, 2001)[6].

Due to the capacity of certain wetlands to control nutrient fluxes, efforts have been undertaken to design and construct wetlands for specific environmental processes or functions. Wastewater treatment wetlands (constructed wetlands) have been specifically built to treat municipal effluents through the removal of mainly organic carbon, harmful microbial elements and nutrients from small communal effluents. This cost-effective method to control specific waste water pollution has motivated research on the efficiency of nutrient reduction by wetlands and as the controlling factors involved.

Although much of the scientific literature regarding natural wetlands notes the positive influence that wetlands have on water quality – particularly in removing nutrient pollution – there exists only limited quantitative data on the mechanisms behind this function.[7] Much of the literature relates to constructed wetlands that are smaller in scale, specifically built to act as natural filtration pools and not directly comparable to natural wetlands.[8]

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[4] e.g.

Ambus, P. 1990. Cleaning of agricultural drainage by denitrification in a riparian meadow. Proceedings of 6th Workshop on Nitrogen in Soils, Queen's University, Belfast.

Cooper, A.B. 1990. Nitrate depletion in the riparian zone and stream channel of a small headwater catchment. Hydrobiologia 202, 13-26.

Hill, A.R. 1990. Groundwater cation concentrations in the riparian zone of a forested headwater stream. Hydrol. Proc. 4, 121-130.

Knauer, N. and M ander, U. 1989. Studies on the filter effect of various buffer biotopes along inland waters. Schleswig-Holstein Z. Kulturtechnik Landentwicklung 30, 365-376.

Lowrance, R.R., Leonard, R.A., Asmussen, L.E. and Todd, R.L. 1985. Nutrient budgets for agricultural watersheds in the southeastern coastal plain. Ecology 66, 287-296.

Pinay, G. and Labroue, L. 1986. Epuration naturelle des nitrates transportes par les nappes alluviales: l'aulnaie glutineuse. Comptes rendus de l'Acad. Des Sci. de Paris 302 III, 629-632.

[5] Van der Peijl, M.J.; Verhoeven, J.T.A. Carbon, nitrogen and phosphorus cycling in river marginal wetlands; a model examination of landscape geochemical flows. Biogeochemistry 2000;50: 45-71.

[6] Thompson, J.R.; Finlayson, C.M. Freshwater Wetlands. In Habitat Conservation: Managing the Physical Environment, edited by Warren, A.; French, J.R. John Wiley & Sons Ltd., 2001

[7] Tockner K, Ward JV, Stanford JA. Riverine flood plains: present state and future trends. Env. Cons. 2002;29: 308-330.

[8] Vymazal J. Nutrient cycling and retention in natural and constructed wetlands. Leiden: Backhuys Publishers, 1999

As discussed in Chapters 1 and 2 of this report, optimal management of wetlands relies on a more precise understanding of the mechanisms and processes by which nutrient removal takes place. In particular it is important to understand:

> whether nutrient removal is permanent or time-limited and/or time-varying;
> how different wetland types affect removal capacity;
> the conditions under which nutrient removal takes place; and
> the quantity of nutrients removed.

It is important to note that wetlands act both potentially as sinks for the removal of nutrients from rivers and as sources from which nutrients may enter rivers. Although both roles are important it is the first – the role of wetlands in removing nutrients from rivers - which was the main focus of this project.

As discussed in Chapter 2, one of the activities undertaken during Phase 1 of DRP Output 4.3 was a review of the literature related to nutrient retention by riverine and other wetlands. To facilitate this review a literature database was compiled by the project team. A description of the database and the types of literature analysed is included in Annex 4. One recommendation to emerge from the Wetland Managers' Workshop held in Vienna in March 2003 was that this literature database should be periodically updated with additional information and made available to wetland experts across the DRB and elsewhere as a management support tool.

3.2. What are riverine wetlands ?

Wetland definitions

There have been many attempts to define wetlands. It is not for this report to review these definitions comprehensively but a brief consideration of key elements is worthwhile.

Although they vary slightly in wording many definitions share the same basic characteristics. A key feature is often the presence of water for some or all of the year. For example, Article 1 of the Ramsar Convention[9] defines wetlands as, *"areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six meters."*

Similarly, Lewis (1990)[10] defined wetlands as, "areas that are inundated or saturated by surface or ground water at frequency and duration sufficient to support, under normal circumstances, a prevalence of vegetation typically adapted for life in saturated soil conditions." Three main conditions for existence of wetland are included in this definition:

> the substrate is flooded or saturated with water during the growing season;
> wetland plants - hydrophytes and hygrophytes – are present; and
> hydric soils with anaerobic conditions are present.

Other definitions reinforce the importance of the presence of water but offer a more functional definition of wetlands. For example, the EVALUWET project[11] used the following definition: *'wetlands are heterogeneous but distinctive ecosystems in which special ecological, biogeochemical and hydrological functions arise from the dominance and particular sources, chemistry and periodicity of inundation or saturation by water. They occur in a wide range of landscapes and may*

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[9] Convention on Wetlands of International Importance especially as Waterfowl Habitat, signed at Ramsar, Iran, 2 February 1971

[10] Kusler, J. A. and Kentula, M.E. (eds.), 1990: Wetland Creation and Restoration. The Status of the Science. Washington, D.C., Covelo, California.

[11] *EVALUWET - European Valuation and Assessment Tools Supporting Wetland Ecosystem Legislation* - a research project supported by the European Commission under the Fifth Framework Programme and contributing to the implementation of the Key Action "Sustainable Management and Quality of Water" within the Energy, Environment and Sustainable Development Contract n°: EVK1-CT-2000-00070

support permanent shallow (< 2 m) or temporary standing water. They have soils, substrates and biota adapted to flooding and/or water-logging and associated conditions of restricted aeration'.

The EVALUWET definition is preferred for the purposes of this project because of its emphasis on the functional attributes of wetlands and because it has been drawn up with specific reference to the role of wetlands within the EU Water Framework Directive (WFD)[12]. It is the WFD that will drive water management efforts in the DRB over the coming years including, potentially, wetland management initiatives.

Wetland classifications: riverine wetlands

Inland wetlands may be classified in a number of ways. One such classification divides wetlands into palustrine, riverine or lacustrine ecosystems, according to how the wetland is supplied with water. In riverine and lacustrine systems, wetlands are influenced by the water level of rivers and lakes. In palustrine wetlands, water is supplied via groundwater, rain, snow or during periods of floods. Further details on this classification are set out in Annex 5.

This report concerns only riverine wetlands. Riverine wetlands may be located in a narrow zone along channels with moving water and near deepwater habitats (Figure 3.1).

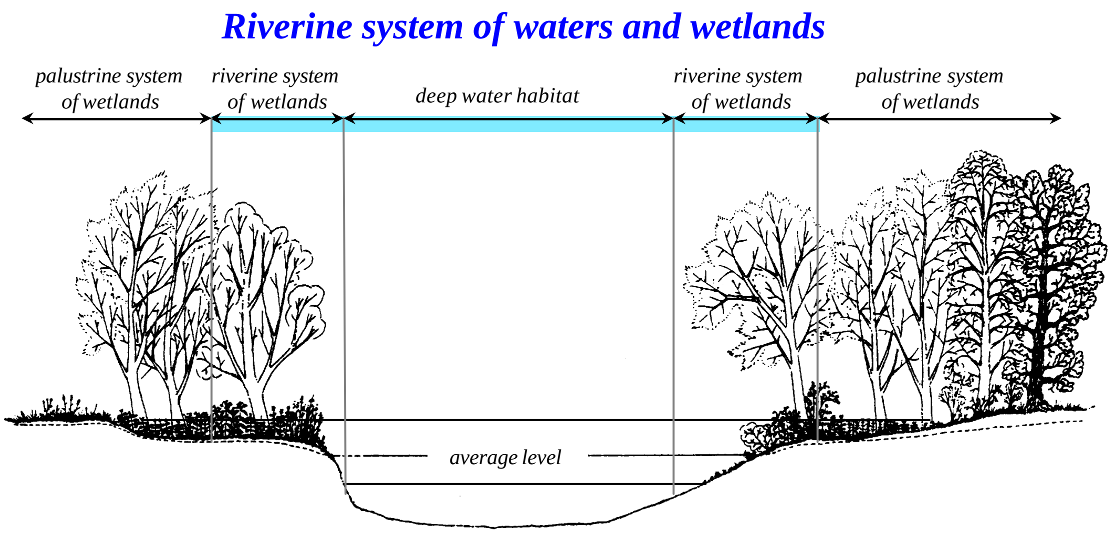

Figure 3.1: A schematic example of a riverine wetland

The average depth of the channel in riverine wetlands is normally at least 2m in some parts. Wetlands along shallower channels, and those in which vegetation covers less than 50% of the area, belong to the palustrine class. Riverine wetlands may be connected, or have had an historical connection, with palustrine and/or lacustrine ecosystems. In this sense, riverine wetlands may include the floodplain and even the former floodplain which is no longer connected by surface water to the main channel because of anthropogenic interference (e.g. construction of flood control dykes). Thus floodplain and former floodplain ecosystems can be regarded, *sensu lato*, as riverine wetlands.

3.3. Nutrient dynamics between the main channel and riverine wetlands: an overview of basic processes

Because riverine wetland ecosystems are complex, no two sites are identical. For example, there may be considerable variation in vegetation type from softwood forests to hardwood forests to

[12] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy

meadows. Each of these plant communities can influence the nutrient reduction capacity of wetlands. However, some general principles and characteristics can be described, especially regarding the processes by which riverine wetlands affect the nutrient content of the rivers, from, and into which, they drain. There are four basic processes by which this occurs: transport, storage, removal and release.

Transport

Nutrient removal in wetland systems is limited by the amount of nutrients transported into the wetland. In order to study the efficiency with which wetlands remove nutrients, it is necessary to consider the amount transported into the wetlands compared to the nutrient load transported in the river itself.

Nutrients are transported in river systems in dissolved and/or particulate forms. In upstream parts of river systems, the dissolved form of nitrogen is most prevalent. Phosphorus is mainly transported in particulate forms. In downstream portions of big rivers, such as the Danube, the particulate forms of nitrogen may increase. In addition to water-related nutrient fluxes for nitrogen there is both atmospheric deposition and biotic N-fixation that have to be considered as inputs into the wetlands systems.

Monitoring strategies need to focus on the transport of nutrients into and out of wetlands. The transport of nutrients can occur under different conditions or via different pathways, including:

- Transport during low flow and mean flow conditions;
- Transport during high flow or flood conditions;
- Transport by groundwater or bank filtration; and
- Atmospheric deposition and N-fixation.

Transport at low flow and average flow conditions

Generally during low and average flow conditions in a river, the sum of dissolved fractions of nutrients transported in river systems predominates over particulate forms. Nevertheless, in downstream stretches of the Danube, organic particulate forms of nutrients may play an important role during low flows. Concentrations of the dissolved fractions of nutrients usually do not change very much in relation to the discharge (e.g. Figure 3.2). Transport into a wetland system during low and average flow happens only where there remains a hydrological connection to the main channel. The potential nutrient retention (removal or storage) of wetlands is therefore limited by discharge (e.g. para potamons) in these channels.

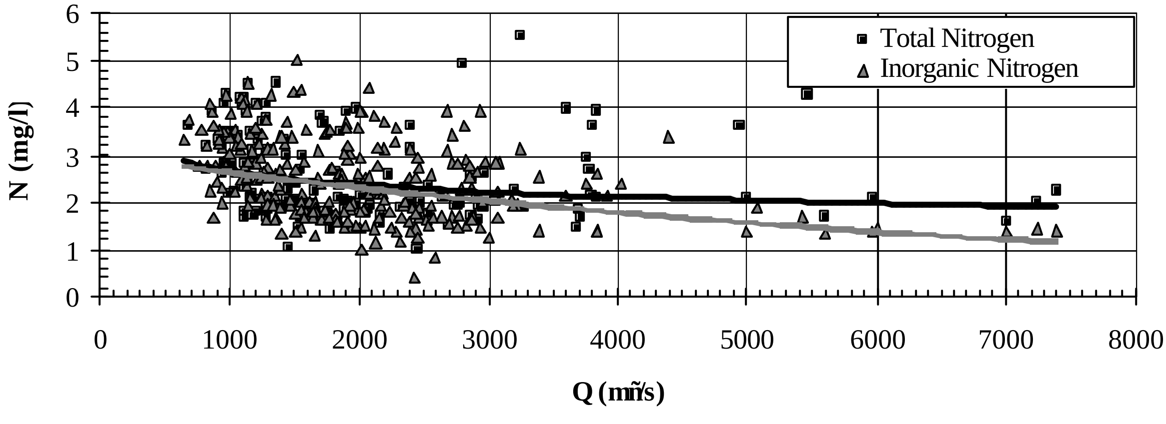

Figure 3.2 Discharge versus nitrogen concentration in the Danube, Vienna, 1978-1997 (Zessner, 1999)[13]

[13] Zessner, M., 1999: Bedeutung und Steuerung von Nährstoff- und Schwermetallflüssen des Abwassers, Dissertation, Wiener Mitteilungen, Band 157, Wien.

Transport at flood conditions

Transport of suspended solids, and therefore of particulate nutrient matter, is highly dependent on the flow regime of the river. Concentrations of suspended solids usually rise as flows increase. For a single event, the increase in suspended solid concentration with increasing flow and the decrease in concentration with decreasing flow usually follow a pattern of hysteresis. This means that the suspended solid concentration at a certain discharge on the rising limb of a hydrograph will be greater than the concentration at the same discharge on the falling limb.

The effect of a high flow event on transported loads also varies with season. Typically, the transportation of suspended solids rises at a proportionally faster rate with increasing discharge. Therefore, the transport of suspended solids happens primarily at high flow and flood conditions. During flood events, large suspended solid loads can be transported considerable distances downstream within a relatively short period (a few days). However, the magnitude of the increase in suspended solid load depends on the discharge dynamics (e.g. the relation between discharge at low, average and high flow situations). In general, the increase in the amount of total phosphorous in suspension at high flow conditions is higher in upstream reaches than in downstream reaches. For example, data from the Danube in Vienna (a mid- to up-stream location) illustrate the effect of this dynamic (Figure 3.3). The increase in phosphorus in suspension downstream was not significant.

During flood events nutrients are transported to all flooded areas within wetlands. This includes temporarily connected channels as well as sites with permanent surface hydrological exchange with the main channel. Monitoring transport of suspended solids, and nutrients bound to those solids, into wetlands during flood conditions is therefore of particular interest.

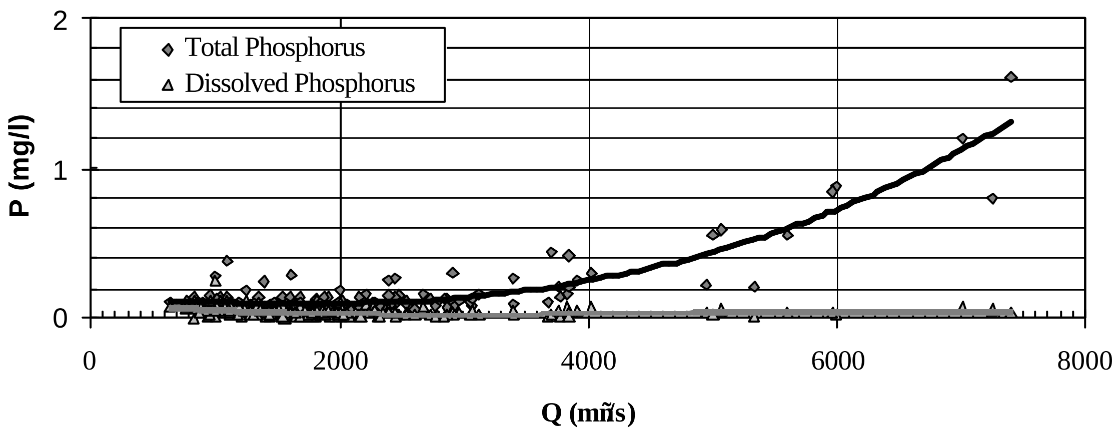

Figure 3.3: Discharge versus phosphorus concentration in the Danube, Vienna, 1991-1997 (Zessner, 1999)[12]

Transport by groundwater or infiltrating water

In addition to the input by surface water, nutrients may be transported into wetlands by groundwater (from the catchment) or by bank filtration (from the main channel or other channels). Nitrate is primarily transported this way over longer distances.

Transport of ammonia and phosphate might be more prevalent under anaerobic conditions. Under aerobic conditions ammonia and phosphate are absorbed, precipitated or metabolized in the ground.

Atmospheric deposition and N-fixation

Deposition is nutrient input from the atmosphere. Average values for atmospheric deposition in Austria are about 20 kg N ha^{-1} $year^{-1}$ which is more than the average removal by a forest ecosystem.

N-fixation is performed by bacteria living in symbiosis with leguminous plants or specific trees. For example, alder (*Alnus glutinosa*) is a tree species which host these symbiotic bacteria. The amounts fixed depend on the presence of these plants. Free-living bacteria are able to fix up to 30 kg N ha^{-1} $year^{-1}$. Generally, N-fixation is higher when nitrogen is limited.

Transformation and storage

Transformation of nutrients is a conversion from one nutrient compound into another. Storage can either take the form of temporary or long-term retention in a riverine wetland. Most nutrient transformation and/or storage in riverine wetlands is only temporary. However, the retention of nutrients in riverine wetlands and the timing of nutrient subsequent releases to the main channel may affect water quality in the main channel.

The main transformation and storage mechanisms and processes are sedimentation, precipitation, adsorption to and filtration through sediments, algal uptake, uptake by terrestrial plants and heterotrophic growth.

<u>Sedimentation</u>

The transport of suspended solids depends on flow velocity. In zones with reduced flow velocity sedimentation takes place. This may happen in the channels (e.g. para potamons) of riverine wetlands or in flooded areas. Only particle-bound nutrients are affected. These nutrients may be further transformed through mineralisation, remobilisation/solution, re-suspension, etc.

<u>Precipitation</u>

Phosphate may be precipitated mainly as strengit ($FePO_4$), variscit ($AlPO_4$), struvit ($MgNH_4PO_4$) or apatit ($CA_{10}(PO_4)_6(OH)_2$). In waters that are rich with lime apatit precipitation induced by macrophytes may play an important role with respect to the phosphorus cycle.

Algal growth leads to an increase in CO_2 consumption. This leads to an imbalance of the calcium carbonate–calcium bicarbonate equilibrium. The precipitation of calcite occurs, but calcium may be precipitated as apatit (e.g. dihydroxyapatit $Ca_{10}(PO_4)_6(OH)_2$) if ortho-phosphate is available (Figure 3.4). The growth of 1g of algae biomass may induce a precipitation of up to 2.3g of phosphorus in this manner. This significantly increases the phosphorus uptake by algae (Kreuzinger, 2000)[14].

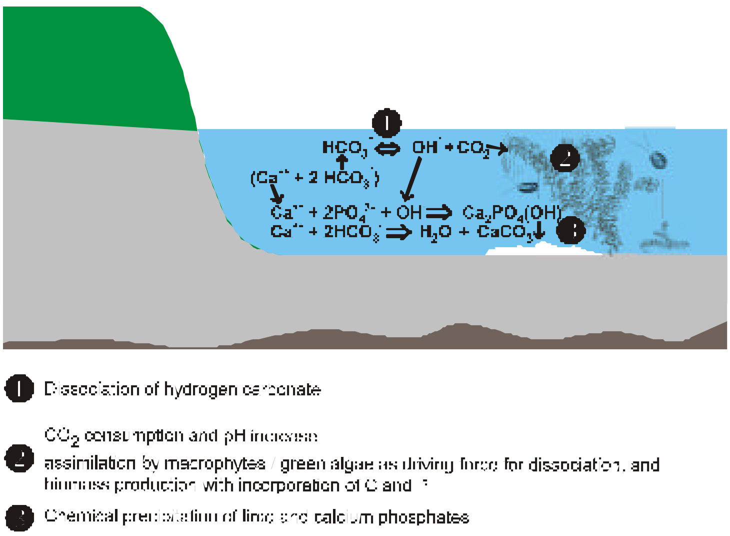

Figure 3.4: Apatit precipitation (Kreuzinger, 2000)[9]

Iron or aluminium precipitation occurs when water infiltrates the soil and groundwater, underground and into groundwater. Together with ferric or aluminium ions phosphate may be

[14] Kreuzinger N. (2000) Wechselwirkung von physikalischen, chemischen und biotischen Prozessen in aquatischen Systemen, Dissertation, Institut für Wassergüte und Abfallwirtschaft, Technische Universität Wien

precipitated. Aerobic conditions are necessary, as is the availability of ferric or aluminium ions, which are prevalent in the soil and sediment subsurface. In general this process is only significant when water infiltrates into the bed layer and or subsurface layers (groundwater).

Adsorption and filtration

Polyphosphates, organic phosphorus compounds and ammonia can be adsorbed at the surface of sediments (e.g. as clay particles, extra cellular polymeric substances (EPS)). This has important ramifications with respect to infiltration into groundwater. Suspended substances and particulate organic matter (POM) containing nutrients may be retained by filtration when infiltration occurs from wetlands channels into groundwater.

Algal uptake

For algae growth equivalent to 1g of dry substance biomass (DS) an average of about 8mg of P and 60mg of N are taken from the dissolved fraction in the water. The phosphorus take up by macrophytes might be much smaller (e.g. 2.3 mg P g^{-1} DS; Humpesch ed., 1998)[15]. The nutrients taken up by algae are stored as algal biomass. After dying off the nutrients are transported to the sediments through sedimentation processes (see above). In addition to nutrient availability, other important factors controlling this process include temperature and light. Thus the intensity of algal biomass production is highly dependent upon seasonal changes and by suspended solid concentrations which might limit the availability of light for algal growth. Nitrogen is released with degradation of algal biomass. Phosphorus is either precipitated and adsorbed to sediments under aerobic conditions, or is released under anaerobic conditions.

Plant uptake

If transported to the terrestrial part of a riverine wetland (e.g. through transport and sedimentation during a flood, transport by groundwater, or direct uptake from surface waters), nutrients can be taken up by terrestrial plants. The nutrient uptake from plants in forest ecosystems has been estimated to be at around 100 to 150 kg N ha^{-1} $year^{-1}$ and 3 – 10 kg P ha^{-1} $year^{-1}$. Fertilised agricultural systems have uptake rates between 130 and 200 N ha^{-1} $year^{-1}$ and about 15 – 20 P kg ha^{-1} $year^{-1}$.

Plant residuals (e.g. leaves) and other organic matter undergo processes of degradation, humidification, mineralization and release and are often temporarily stored in soils. However, the direct input of falling leaves into water can be considerable. Again seasonal variation is important because the uptake by plants takes place in the growing season and leaf deposition at the end of the growing season.

In contrast to algae, terrestrial plants capture more stable particulate organic matter (POM) for storage. In addition the presence of trees in wetlands areas may influence the storage of nutrients in wetlands through the formation of debris dams and consequent changes in hydraulic and hydrological conditions.

Heterotrophic growth

Recent studies have pointed to the importance of the hyporheic zone for nutrient cycling and organic matter processing in small streams with constrained mixing zones. For example, the hyporheic zone of a piedmont stream contributed about 40% of the total ecosystem respiration (Battin et al. 2003)[16]. The degree to which the hyporheic zone affects stream ecosystem function has been ascribed to physical variables, biogeochemical processing rates, temperature, nutrient and oxygen supply, and the proportion of the total discharge flowing through the hyporheic zone. For large rivers and riverine wetlands, the exchange with the hyporheic zone also increases

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[15] Humpesch U.H., ed. (1998) Neue Donau 1997– Die Prognose hält; Zwei Jahre Teilstau Erfahrung; Gutachten im Auftrag der Stadt Wien, MA45.

[16] Battin TJ, Kaplan LA, Newbold JD, Hendricks SP. A mixing model analysis of stream solute dynamics and the contribution of a hyporheic zone to ecosystem function. Freshw. Biol. 2003;48: 995-1014.

nutrient retention. Of major importance for matter processing and nutrient uptake is the biofilm on the riverbed and at the interface of the hyporheic zone. In addition, macrozoobenthos grazing on biofilm can intensify the nutrient transformation. Biological degradation of coarse particulate organic matter (C-POM) to fine particulate organic matter (F-POM) at the sediment surface will increase nutrient transport to deeper areas of the hyporheic zone and increase the substrate supply there.

Removal

Removal is the final elimination of nutrients from a river into a riverine wetland ecosystem in such a way that no future removal from the wetland back to the river will occur. In this sense only de-nitrification and harvest can be considered as removal. Storage of nutrients over long periods of time (e.g. decades) may also be considered as removal, depending on the time horizons under consideration in management plans.

Denitrification

Denitrification in general is the reduction of nitrate. Several processes are known. The most important process in case of nitrogen removal in riverine wetlands is denitrification by heterotrophic microorganisms. Where dissolved oxygen is absent, nitrate is reduced to gaseous N_2. Depending on conditions of de-nitrification N_2O may also be produced. From stechiometric considerations it can be seen that for the denitrification of 1g of NO_3 to N about 1g total organic carbon (TOC) is consumed by bacteria[17]. The availability of organic carbon and temperature are important factors with respect to the intensity of this transformation.

In riverine wetlands, the carbon source from denitrification may consist of organic substances transported into the system from the river. More important is algae production in wetlands. Up to 60mg of N are taken in for the production of 1g algal biomass. This algal growth leads to an input of about 330mg TOC into the water. Degraded under anaerobic conditions this may lead to a denitrification of up to 330 mg NO_3-N, which is significantly more than the nitrogen consumed for algae growth. In addition to the availability of TOC, scarcity of oxygen is also a controlling factor in this process. Even if soluble oxygen is measured in the water phase, denitrification might take place in locations where the transport of oxygen is restricted. Bottom sediments are important in this respect. Even if there is enough oxygen on the surface of the sediments, transport into deeper zones of sediment is restricted. This is not the case for the transport of nitrate, and conditions for denitrification are therefore better in deeper sediments.

In addition to heterotrophic denitrification, autotrophic denitrification may be of importance in sediment and subsurface zones in the presence of pyrite in oxygen-depleted circumstances. For each gram of NO_3-N removed about 0.7g of pyrite is needed[18].

Harvest

Harvest is the removal of plants or their products from the riverine wetland ecosystem. This type of removal occurs if plants are mowed, eaten by grazing animals or harvested for wood production or consumption. The removal of nutrients by grassland harvest can be remove 30 – 50kg N ha^{-1} $year^{-1}$ and 7 – 9kg P ha^{-1} $year^{-1}$ for each cut. By comparison, average values from wood harvest in forests are 5kg N ha^{-1} $year^{-1}$ and 0.5kg P ha^{-1} $year^{-1}$.

Long term storage

Sediments (in the form of suspended solids, plant/algae residuals and precipitates) and adsorbed nutrients can be stored in wetlands systems over long periods of time. If this process is continuous within the time horizon considered in management planning, this kind of storage effectively can be considered removal. In this case the sediments are retained in the wetland through siltation

[17] Nowak O. und Svardal K. (1989) Nitrifikation und Denitrfikation, Wiener Mitteilungen Band 81, Wien, in german

[18] Kunkel R., Wendland F. und Albert H. (1999) Zum Nitratabbau in grundwasserführenden Gesteinsschichten des Elbeeinzugsgebietes, Wasser & Boden, 51/9, 16-19, in german.

and/or the nutrient concentrations in sediments increase. Siltation may eventually lead to the loss of wetlands.

Release

Nutrients stored in wetlands are usually released over time. One of the principle means of release is through erosion of the sediment/soil layer and subsequent transport downstream by surface runoff and channel flow. This happens at flood conditions and during heavy rainfall. In addition, re-suspension can take place, involving the release of bottom sediments in a riverine wetland channel. Re-suspension increases with higher flow. Stored nutrients may also be transformed into dissolved forms by mineralization, solution and desorption. Transport of dissolved forms from riverine wetlands occurs either via surface waters or groundwater.

3.4. Nutrient dynamics within riverine wetlands

The major components of nutrient cycling in wetlands are given by Misch & Gosselink (Fig 3.5). Hydrological exchange conditions control inputs and outputs. Biotic and abiotic factors within the wetlands control the efficiency of nutrient transformation and storage.

It is worth noting that natural and constructed wetlands are quite different in terms of nutrient dynamics and in the predictability of transformation (Turner, 1999)[19]. In general, natural systems diffuse comparatively low nutrient concentrations over large areas while engineered systems are designed and developed to accommodate high concentrations typical for sewage or agricultural runoff over small treatment areas. These differences and other management considerations need to be taken into account in analysing wetland systems and their efficiencies in terms of nutrient retention. For the most important nutrients, N and P, the transformation processes involved, and the abiotic and biotic conditions that govern those transformation processes, are quite different.

Plant uptake and microbial denitrification

The effective absorption of nitrate within riverine wetlands[20] is dependent upon whether there are conditions conducive to denitrification and the maintenance of stable habitat structure. Studies have identified vegetation uptake and microbial denitrification as the primary mechanisms responsible for N removal in these systems (Haycock et al. 1993)[21]. These two primary storage, transformation and/or removal processes provide an effective buffer that protects aquatic habitats from excessive nutrient uptake.

[19] Turner RE. A comparative mass balance budget (C, N, P and suspended solids) for a natural swamp and overland flow systems. In Nutrient cycling and retention in natural and constructed wetlands, edited by Vymazal J., 61-72. Leiden: Backhuys Publishers, 1999

[20] According to the definition is area of riverine wetlands along a narrow zone of the channel. Here the emphasis is on riverine wetlands with connected (currently or formerly) palustrine and/or lacustrine systems in the whole catchment. In this sense riverine wetlands included remnant and former floodplains.

[21] Haycock, Pinay, Walker. Nitrogen retention in River Corridors: European Perspective. Ambio 1993;22(6), 340-346

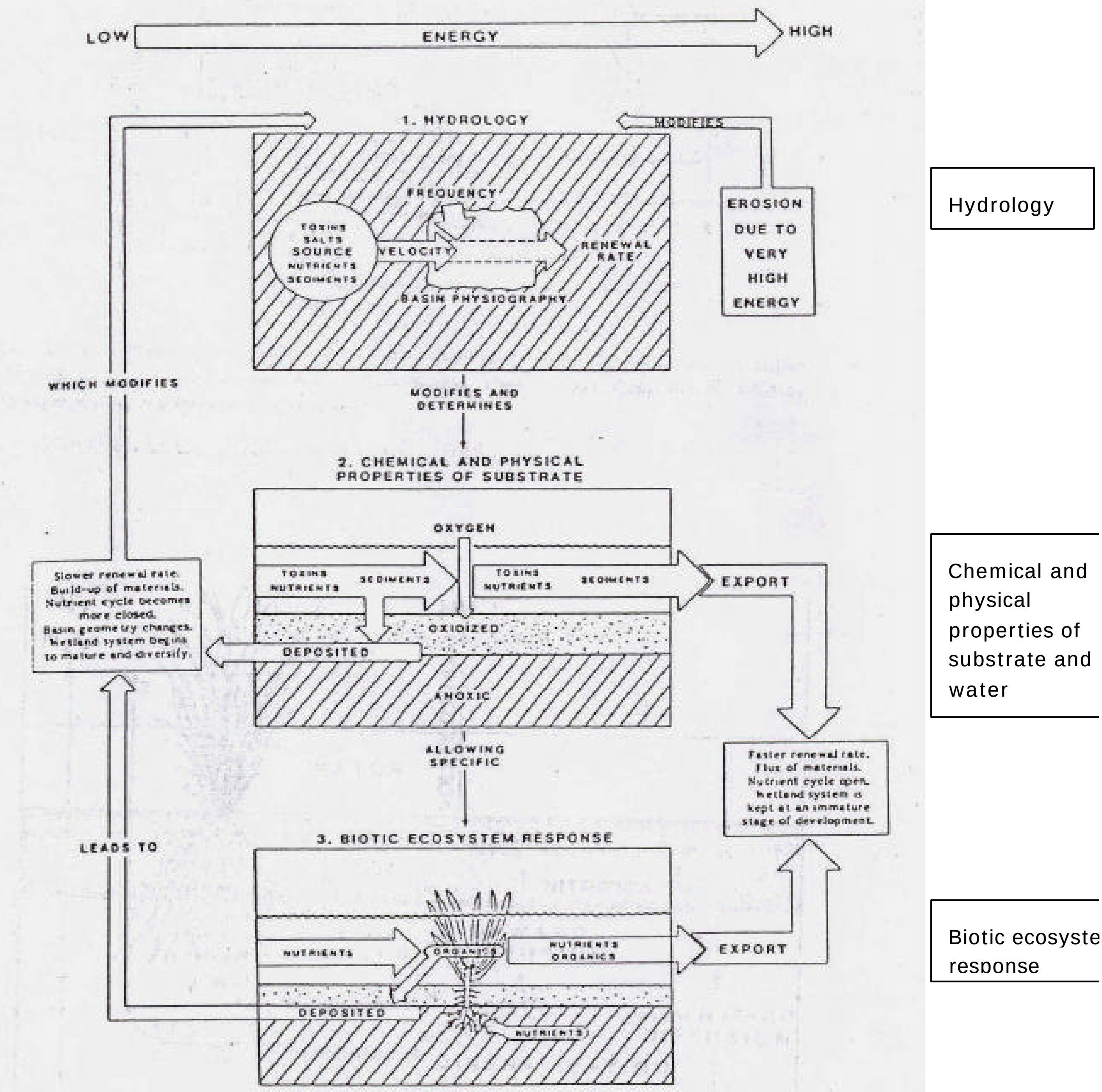

Abb. 22: Conceptual model that shows the direct and indirect effects of hydrology on wetlands. *(From Wicker et al., 1982, p. 84, after Gosselink and Turner, 1978)*

Quelle : Mitsch und Gosselink 1986, S. 57.

Figure 3.5: Conceptual model of the hierarchical structure of processes determining the ecosystem function of wetlands (Mitsch & Gosselink, 1986).[22]

[22] Mitsch WJ & Gosselink JG. Wetlands, Third edition. John Wiley & Sons, 2001

The uptake of nutrients by vegetation within riverine wetlands is variable in space and time. Vegetation uptake in riverine wetlands reaches a maximum during the summer – normally the driest, lightest and warmest period of the year in temperature latitudes. Microbial denitrification in riverine wetlands in this period may be at minimum (Pinay et al. 1994[23]) because soil moisture levels are low and soils are well-aerated. During autumn and winter, when soil moisture stimulates anaerobic processes, denitrification is the principle process maintaining the buffering capacity of riverine wetlands. Soil temperature is sufficient in many cases (>4ºC) to sustain denitrification (Bremner & Shaw 1958)[24], especially deep in the soil profile (mean ~ 10ºC).

Nutrient removal within riverine wetlands is limited when saturation of the soil may not last long enough to provide the anaerobic environment necessary for denitrification process to influence nitrate loads; and/or when organic carbon availability provided by root exudates and leaf litter is not sufficient to sustain microbial respiration (and therefore denitrification) on a long-term basis.

Ultimately nutrient removal is limited by nutrient inputs, which are in turn related to the position of the riverine wetland within the river basin. In small streams, nutrients may be delivered to riverine wetlands by hydrological flows from adjacent upland areas. In large rivers, nutrients are delivered to riverine wetlands primarily during flood events.

Phosphorus dynamics in riverine wetlands

Many riverine wetland ecosystems are less effective as P sinks than other ecosystem types (Vymazal, 1999 [8]). Phosphorus in wetlands is mainly (>95%) stored in the soil and leaf litter components of the subsurface layer so understanding the role of wetlands in P storage and/or removal requires assessing the interaction between soil and water.

Microbial and vegetative uptake along with sorption and precipitation regulate long-term P retention in wetlands. Mineral sediment deposition of particle-bound P leads to long-term storage and is dependent on surface water input and nutrient inputs. Unlike N and C, neither the organic nor the inorganic form of P can be lost in exchange with the atmosphere. Instead, an accumulation of P is frequently found in wetlands soils. The tendency towards release or storage of P depends on the overlying water column and associated biogeochemical processes (Reddy & D'Angelo, 1994)[25]. These processes include adsorption/desorption reactions, precipitation, mineralization of organic P, and diffusion of P from the soil to the water and vice versa.

The P storage capacity of a riverine wetland is determined by the physical and chemical soil characteristics and the amount of inorganic P entering the wetland. In natural wetlands, the sorption potential of a predominantly mineral soil appears to be higher than that of an organic-rich freshwater swamp soil (Masscheleyn et al., 1992)[26]. Where the sorption capacity of an organic-rich freshwater soil is limited, a higher transformation rate from inorganic to organic P is found. At low P loadings, wetlands have been found to release rather than to retain P. This emphasises the buffering capacity of wetlands. A mass-loading model for North American wetlands used for wastewater treatment identified a proportional relationship for P storage and loadings entering the wetlands until a threshold loading mass is reached (Richardson et al., 1997)[27]. Higher loadings resulted in an increase of released P concentrations, with an estimated threshold loading in the

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[23] Pinay, G et al. The role of denitrification in nitrogen removal in river corridors. Global Wetlands: Old World and New; WJ Mitsch ed, Elsevier Science B.V. pp 107-116, 1994

[24] Bremmer, J.M. and Shaw, K. 1958. Denitrification in soil. 1: Method of investigation. J. Agric. Sci. 51, 22-39.

[25] Reddy, D'Angelo. Soil processes regulating water quality in wetlands. Global Wetlands: Old World and New; W.J.Mitsch eds., Elsevier Science B.V., pp 309-324, 1994.

[26] Masscheleyn PH, Pardue JH, DeLaune RD, Jr. WHP. Phosphorus release and assimilatory capacity of two lower Mississippi valley freshwater wetland soils. Water Resources Bulletin 1992;28: 763-773

[27] Richardson CJ, Qian S, Craft CB, Qualls RG. Predictive models for phosphorus retention in wetlands. Wetlands Ecology and Management 1997;4: 159-175.

range of 1g m^{-2} yr^{-1}. However natural wetlands may exhibit different threshold capacities for P retention (Turner, 1999)[28].

Soil conditions affect the mechanisms of P retention. For example, in acidic soils P retention is controlled by aluminium and ferric phosphates if the activities of these cations are high. In alkaline soils P fixation is governed by the availability of calcium and magnesium compounds. The availability of P is highest in soils with slightly acidic to neutral pH and depends on the redox potential (Reddy & D'Angelo, 1994)[29]. Decreasing the potential for redox conditions leads to a decline in the P retention capacity of the soil surface.

In constructed wetlands, P storage can be estimated by hydrologic transport models in short-term experiments (e.g. Ho & Notodarmojo, 1995)[30]. Removal capacities for P in constructed wetlands are found to decrease with the age of the wetlands (Vymazal, 1999 [8]). One reason for this is the decline in available adsorption sites in the soil during constant flow conditions. In experimental settings of constructed wetlands, P removal was stimulated by pulsing the hydrologic loading and during frequent changes of soil conditions (Busnardo et al., 1992)[31]. Phosphorus removal by harvesting usually accounts for less than 10% of the total P removal in constructed wetlands (Vymazal, 1999 [8]).

Nitrogen dynamics

Nitrogen transformation and removal in wetlands is mainly caused by denitrification (Brettar et al., 2002; Haycock et al., 1993; Johnston et al., 1997)[32]. Other processes, including biological uptake, sedimentation and adsorption, lead to storage effects and internal N cycling within the wetlands (Hanson et al., 1994)[33].

The process of denitrification requires zones of fluctuating oxygen and a supply of organic matter. The process is controlled by groundwater and surface water exchange conditions (Dahm et al., 1998; Pinay et al., 1994)[34]. Of special significance is the link between hydrological dynamics and the biogeochemical processes which occur in the soil layers among varying saturated and unsaturated zones. Denitrification can occur in the groundwater/surface water layer and in deeper depths with groundwater discharge when there are high concentrations of organic matter (Hill et al., 2000)[35]. This suggests that denitrification is frequently carbon-limited. Denitrification

[28] Turner RE. A comparative mass balance budget (C, N, P and suspended solids) for a natural swamp and overland flow systems. In Nutrient cycling and retention in natural and constructed wetlands, edited by Vymazal J., 61-72. Leiden: Backhuys Publishers, 1999

[29] Reddy, D'Angelo. Soil processes regulating water quality in wetlands. Global Wetlands: Old World and New; W.J.Mitsch eds., Elsevier Science B.V., pp 309-324, 1994.

[30] Ho GE, Notodarmojo S. Phosphorus movement through soils and groundwater application of a time-dependent sorption model. Wat. Sci. Tech. 1995;31: 83-90.

[31] Busnardo MJ, Gersberg RM, Langis R, Sinicrope TL, Zedler JB. Nitrogen and phosphorus removal by wetland mesocosms subjected to different hydroperiods. Ecological Engineering 1992;1: 287-307.

[32] Brettar. I, Sanchez-Perez J-M, Trémolìeres M. Nitrate elimination by denitrification in hardwood forest soils of the Upper Rhine floodplain - correlation with redox potential and organic matter. Hydrobiologia 2002;469: 11-21.

Haycock, Pinay, Walker. Nitrogen retention in River Corridors: European Perspective. Ambio 1993;22(6), 340-346

Johnston CA, Schubauer-Berigan JP, Bridgham SD. The potential role of wetlands as buffer zones. In Buffer zones: Their processes and potential in water protection, edited by Haycock N. E., T. P. Burt, K. W. T. Goulding and G. Pinay, 155-170. Hertfordshire: Quest Environmental, 1997

[33] Hanson GC, Groffman PM, Gold AJ. Denitrification in riparian wetlands receiving high and low groundwater nitrate inputs. J. Environ. Qual. 1994;23: 917-922.

[34] Dahm NC, Grimm NB, Marmonier P, Vallet HM, Vervier P. Nutrient dynamics at the interface between surface waters and groundwaters. Freshw. Biol. 1998;40: 427-451.

Pinay et al. The role of denitrification in nitrogen removal in river corridors. Global Wetlands: Old World and New; W.J.Mitsch eds., Elsevier Science B.V., pp 107-116, 1994.

[35] Hill AR, Devito KJ, Campagnolo S, Sanmugadas K. Subsurface denitrification in a forest riparian zone: Interactions between hydrology and supplies of nitrate and organic carbon. Biogeochemistry 2000;51: 193-223.

efficiently removes nitrate only when there is a frequent supply of organic matter, as is often found in riparian zones, floodplains and riverine wetlands.

Vegetation growth is of great significance in terms of N removal. Consequently, in constructed wetlands, the establishment of suitable abiotic soil conditions and the creation of micro-zones suitable for organic matter release has been shown to increase the capacity to remove N from the system (Meshram et al., 1994; Reddy & D'Angelo, 1994)[36]. The N removal capacity of riverine wetlands can reduce instream transport and buffer local N input from the surroundings and thereby affect N cycling in rivers (Dahm et al., 1998)[33].

3.5. Conclusions

Riverine wetlands can substantially alter biogeochemical fluxes of river systems. In a restored wetland along a small Danube tributary, the Wien stream in the upper DRB, a significant contribution to the self-purification capacity of the stream itself was found (Hein, 2002)[37]. In addition, riverine wetlands can limit or slow the input of non-point sources of nutrients into rivers from urban and agricultural sources. But these ecosystem services are especially vulnerable to disturbance from human impacts such as excessive pollution (Johnston et al., 1997)[38].

Nutrient transport in running waters can be described by a spiral model symbolizing the interaction between transport and storage along path of the downstream passage of nutrients (Newbold 1992)[39]. Riverine wetlands can decrease the flow rate of water, increase the area of soil and vegetation in contact with the water and increase nutrient storage time. In doing so, riverine wetlands shorten the nutrient spiral lengths (Ward, 1989)[40]. Where large wetland areas are inundated in downstream reaches, nutrient storage can increase substantially.

The spatial and temporal hydrological dynamics, in combination with the hydrogeomorphological setting of riverine wetlands, control nutrient transport and the ecosystem function of nutrient transformation, storage and/or removal. Nutrients entering a riverine wetland may be transformed, stored or transported within the time frame of hydrologic exchange.

Nutrient standing stocks are largely a function of plant biomass in riverine wetlands (Oorschot, 1996)[41] and positively affect nutrient storage and removal capacity (Niswander et al., 1995)[42]. In most riverine wetlands sedimentation (e.g. Cooke, 1994)[43] and denitrification are the dominant processes influencing, respectively, P and N cycling. These processes therefore determine

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[36] Meshram J, Juwarkar AS, Juwarkar A, Sankale LU. Nitrogen and phosphate removal using wetland. Jr. Ind. Poll. 1994;10: 17-20.

Reddy, D'Angelo. Soil processes regulating water quality in wetlands. Global Wetlands: Old World and New; W.J.Mitsch eds., Elsevier Science B.V., pp 309-324, 1994

[37] Hein T. Restrukturierung der Retentionsbecken: Bedeutung für den Nährstoffhaushalt und die Selbstreinigungskapazität des Wienflusses - Restructuring the retention basins: their importance for the nutrient balance and the self-purifying capacity of the Wien River (in german with English translation). Perspektiven 2002;1/2, 18-25.

[38] Johnston CA, Schubauer-Berigan JP, Bridgham SD. The potential role of wetlands as buffer zones. In Buffer zones: Their processes and potential in water protection, edited by Haycock N. E., T. P. Burt, K. W. T. Goulding and G. Pinay, 155-170. Hertfordshire: Quest Environmental, 1997.

[39] Newbold JD. Cycles and spirals of nutrients. In The Rivers Handbook, 379-399, 1992.

[40] Ward, JV. Riverine-wetland interactions. Freshwater wetlands and wildlife. R. R. Sharitz and J. W. Gibbons. Tennessee, USDOE Office of Scientific and technical information: 385-400, 1989

[41] Oorschot. Effects of the vegetation on Carbon, Nitrogen and phosphorus Dynamics in English and French Riverine Grasslands. PhD Thesis, University of Utrecht, Faculty of Biology, 1996.

[42] Niswander SF, Mitsch WJ. Functional analysis of a two-year-old created in-stream wetland: Hydrology, phosphorus retention and vegetation survival and growth. Wetlands 1995;15: 212-225.

[43] Cooke JG. Nutrient transformations in a natural wetland receiving sewage effluent and the implications for waste treatment. Wat. Sci. Tech. 1994;29: 209-217.

whether a specific riverine wetland area functions as a nutrient sink or a source under given circumstances.

Increasing the overall storage and removal capacity of riverine wetlands requires the establishment or restoration of a broad range of habitats - such as inshore structures, riparian zones and side-arms - so as to ensure that hydrological exchange, nutrient transformation and storage continues throughout the year. (Brunet et al., 1994[44]; Hein et al., 2003[11]). In downstream reaches, inundation areas control the retention capacities for phosphorus during high flows. To predict the overall nutrient storage and removal capacities of riverine wetlands, local environmental parameters must be considered and peak times for biogeochemical activity identified.

[44] Brunet RC, Pinay G, Gazelle F, Roques L. Role of the floodplain and riparian zone in suspended mater and nitrogen retention in the Adour River, south-west France. Regulated Rivers: Research & Management 1994;9: 55-63.

4. A SUMMARY OF THE NUTRIENT BALANCE IN THE DANUBE RIVER BASIN AND THE POTENTIAL ROLE OF RIVERINE WETLANDS IN REMOVING NUTRIENTS FROM THE DANUBE RIVER

4.1. Nutrient emissions to the Danube River

Total emissions of nitrogen and phosphorous in the Danube River Basin (DRB) have been estimated as follows:

> 1988/89: 1000 - 1300 kt N a^{-1} and 130 - 180 kt P a^{-1}
> 1992: 850 – 1150 kt N a^{-1} and 110 – 150 kt P a^{-1}
> 1996/97: 750 – 1050 kt N a^{-1} and 90 – 130 kt P a^{-1}.

Emissions by source sector and pathway

Tables 4.1 and 4.2 show the main source sectors and pathways for nitrogen and phosphorus within the Danube Basin. The tables show the importance in the DRB of the nutrient input from agricultural sector. Almost half of all nutrient loads (N and P) originate from agriculture (note that, in addition to direct emissions from agriculture to ground- and surface waters, NH_3 emissions from agriculture to the air are also significant). By comparison, private households contribute 21 % of N and 29 % of P; and industry contributes 13% of N and 18 % of P.

Table 4.1: Sources and pathways of N in the Danube River Basin in 1996 (Zessner, van Gils, 2002)[45]

Pathways	Sources (by %)				
	Agriculture	Households	Industry	Others	Total
Erosion/runoff	18	0	0	5	23
Direct discharges	5	4	6	0	15
Groundwater	23	5	0	14	42
Sewage treatment plant	1	12	7	0	20
Total	47	21	13	19	100

The most important pathways for N are groundwater (42 %) and direct discharges to the river. Erosion/runoff and sewage treatment plant effluents contribute more or less equal shares of N. With respect to P, the most important pathways are erosion/runoff (36 % mainly from agricultural areas) and sewage treatment plant effluents (33 %).

[45] Zessner, M. and van Gils, J., 2002: Nutrient fluxes from the Danbue Basin to the Black Sea, Water Science and Technology Vol 46 No 8 pp 9-11

Table 4.2: Sources and pathways of P in the Danube River Basin in 1996 (Zessner, van Gils, 2002) [46]

Pathways [in %]	Sources (by %)				
	Agriculture	Households	Industry	Others	Total
Erosion/runoff	32	0	0	4	36
Direct discharges	9	7	8	0	24
Groundwater	3	2	0	2	7
Sewage treatment plant	3	20	10	0	33
Total	47	29	18	6	100

Point versus diffuse emissions

In the surface waters of most countries N stems primarily (>60 %) from non-point sources. For P, about 40 % of the total load originates from such diffuse sources. Measures to reduce this load would therefore need to focus on improving agricultural practices. However, even if the use of best available agricultural techniques becomes widespread in the DRB, the existing long-term phosphorus stock will likely determine erosion/runoff of P for some time to come. Erosion/runoff of P from this source today already contributes one third of the surface water load. Present and future nutrient management should therefore continue to consider accumulated P in soils.

Emissions by country

Table 4.3 summarises estimated average emission values by country. Note that these estimates are accurate to ±20 %. The table shows that Romania, Hungary, Serbia and Montenegro, Germany and Austria are the main contributors of the nutrient emissions in the Danube River Basin. This is largely extent because these countries comprise the majorities of both land area and population in the DRB.

A comparison of specific values (per inhabitant or per area) shows that countries with a highly developed wastewater management infrastructure, such as Germany and Austria, emit relatively low amounts of P. However, emissions of N from these countries are relatively high compared to emissions from other countries. This result emphasises the importance of nitrogen losses from agricultural production.

It can be seen from the data that the decreasing tendency in emissions between 1988 and 1992 (EU/AR/102A/91, 1997)[47] was continued from 1992 to 1996 (Kroiss & Zessner, 1999)[48]. The reduction of manure discharges in Romania and Bulgaria after the closure of large animal farms at the beginning of the 1990s is the main reason for this decrease. Further reductions resulted from

[46] Zessner, M. and van Gils, J., 2002: Nutrient fluxes from the Danbue Basin to the Black Sea, Water Science and Technology Vol 46 No 8 pp 9-11

[47] EU/AR102A/91, 1997: Nutrient Balances for Danube Countries– Final Report, Institute for Water Quality and Waste Management, Vienna University of Technology and Department of Water and Wastewater Engineering, Budapest University of Technology in the framework of the Danube Applied Research Programme.

[48] Kroiss, H., Zessner, M., 1999: Update of estimations of nitrogen and phosphorus emissions to surface waters in the Danube Basin for the year 1996/97, TU-Vienna, Insitut for Water Quality and Waste Management, working paper in the framework of the River Danube Pollution Reduction Programme on behalf of UNDP-GEF

improvements in wastewater treatment in Germany and Austria. In addition, the intensity of agricultural production was significantly reduced after the economic breakdown in many countries. Combining improvements in economic situations while reducing nutrient emissions will be a significant challenge for DRB countries.

Table 4.3: Major features of individual countries and nitrogen and phosphorus emissions to surface waters in the Danube Basin

	D	A	CZ	SK	H	SL	CR	BH	SM	RO	BG	MD	UA	DRB[1]
Area in DRB (10^3 km^{-2})	56	81	21	47	93	16	35	39	89	238	46	13	26	817
Population in DRB (millions)	9	7.5	2.8	5.1	10.3	1.7	3.2	2.9	9.0	22.7	3.9	1.1	2.8	85
Runoff to the Danube (km^3 a^{-1})	29.5	44.8	2.5	3.9	8.8	6.3	13.0	17.8	23.0	35.6	7.5	1.5	8.6	203
N (kt a^{-1})														
1988[2]	108	106	38	65	125	29				414	47	20	35	1234
1992[2]	109	102	36	62	86	23				314	41	13	34	1025
1992[3]	123	100	32	56	85	24				314	41	13	34	1028
1996/97	120	96	32	54	82	24	35	37	106	231	34	13	34	898
P (kt a^{-1})														
1988[2]	10.3	10.3	4.0	6.5	17.3	2.5				62.4	8.1	2.7	7.1	164
1992[2]	8.7	8.7	3.9	6.0	16.6	2.4				46.1	7.3	2.3	5.7	135
1992[3]	7.8	8.2	3.5	5.6	14.0	2.8				44.4	7.9	2.3	5.7	128
1996/97[3]	7.1	6.8	3.5	5.6	13.2	2.8	4.2	5.2	17.8	27.7	6.1	2.2	5.7	108

[1] For the years 1988 and 1992 the sum of the country results (without CR, BH and SM) was multiplied with 1,25 to come to an estimate for the total Danube River Basin (DRB)

[2] From ARP Project EU/AR/102A/91, „*Nutrient Balances for Danube Countries*“ (1997)[49]

[3] (Kroiss, Zessner, 1999)[50]; New estimate for 1992 and 1996 based on additional information from data collection in the framework of RDPRP, EMIS/EG inventory and UBA-Berlin (1999)[51]

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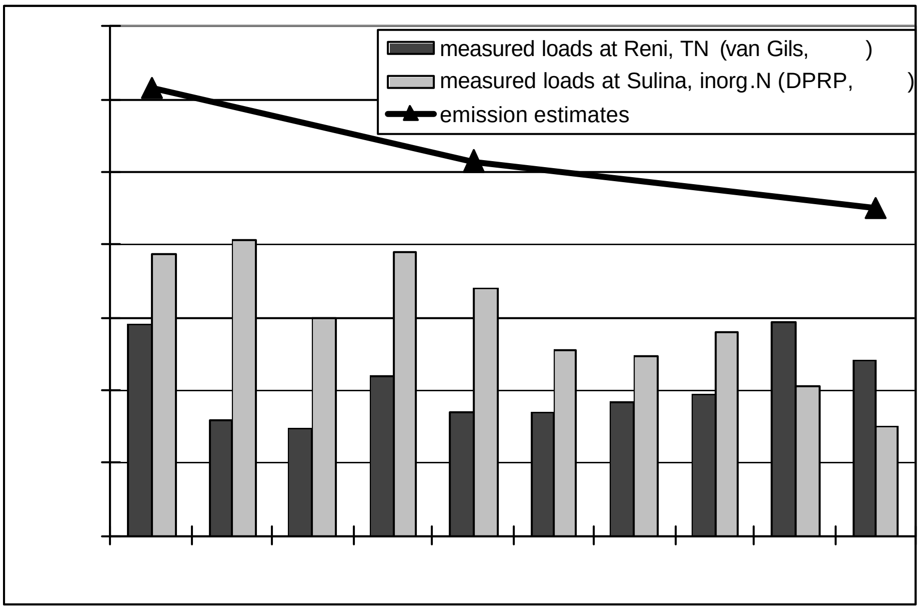
[49] EU/AR102A/91, 1997: Nutrient Balances for Danube Countries – Final Report, Institute for Water Quality and Waste Management, Vienna University of Technology and Department of Water and Wastewater Engineering, Budapest University of Technology in the framework of the Danube Applied Research Programme.

[50] Kroiss, H., Zessner, M., 1999: Update of estimations of nitrogen and phosphorus emissions to surface waters in the Danube Basin for the year 1996/97, TU-Vienna, Insitut for Water Quality and Waste Management, working paper in the framework of the River Danube Pollution Reduction Programme on behalf of UNDP-GEF

[51] UBA-Berlin, 1999: Nährstoffbilanzierung der Flußgebiete Deutschlands, Umweltbundesamt, Forschungsbericht 296 25 515, UBA-FB 99-087.

4.2. Nutrient removal by the Danube River

Figure 4.1 compares estimated emissions to the DRB river system over ten years with measurements of the nutrient load in the Danube before it enters the Black Sea. The Reni sampling station is situated on the Danube just before the Danube Delta. The sampling station at Sulina is located in one of the three main channels within the Delta, 5 km upstream in distance from the discharge to the Black Sea. Measured nutrient concentrations were multiplied with the flow at Reni to estimate annual load.



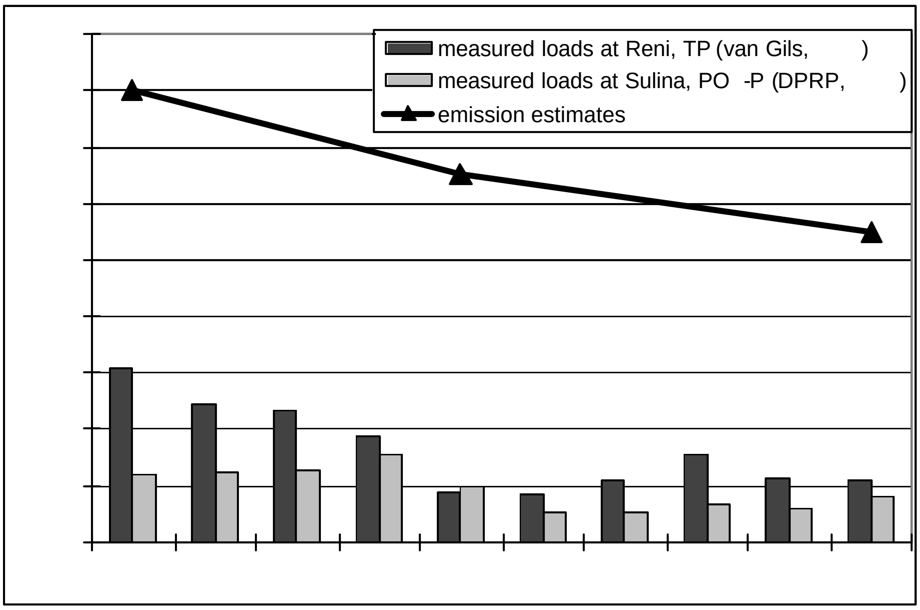


Figure 4.1: Emissions estimates for the DRB and load measurements in the Danube for N and P (van Gils, 1999[52]; DPRP, 1999)[53]

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[52] van Gils. J,. 1999: Danube Water Quality Model simulations in support to the Trans-boundary Analysis and the Pollution Reduction Programme, Danube PCU UNDP/GEF Assistance, prepared by Jos van Gils, Delft Hydraulics, Delft , The Netherlands.

Notwithstanding uncertainties about the emission estimates and instream load measurements, Figure 4.1 indicates that there is a clear difference between emissions into the DRB river system and transported loads to the Black Sea. It is clear that, between emission to the Danube and entry of the Danube into the Black Sea, large amounts of both N and P are being retained and/or removed. For the whole Danube Basin about 50% of all N emitted to the river system is retained or removed in the river system (about 400 – 500 kt N a^{-1}). The percentage of P retention is even higher (up to 80 %, or 90 kt P a^{-1}). Note though that the instream load measurements for P may have underestimated the actual loads.

Behrendt (2000[54]) showed a correlation between the retention of a region, expressed as relation between instream loads and emissions, and the area-specific runoff (l s^{-1} km^{-2}) or the hydraulic load (m a^{-1}). Stated simply this means that river basins with smaller (area specific) runoff and a higher water surface area exhibit greater retention/removal of nutrients. For P the correlation of retention (TP-transport/TP-emissions) is better with respect to the specific runoff (Figure 4.2). For N the correlation of the retention (DIN-transport/TN-emission) it is better with respect to the hydraulic load (Figure 4.3).

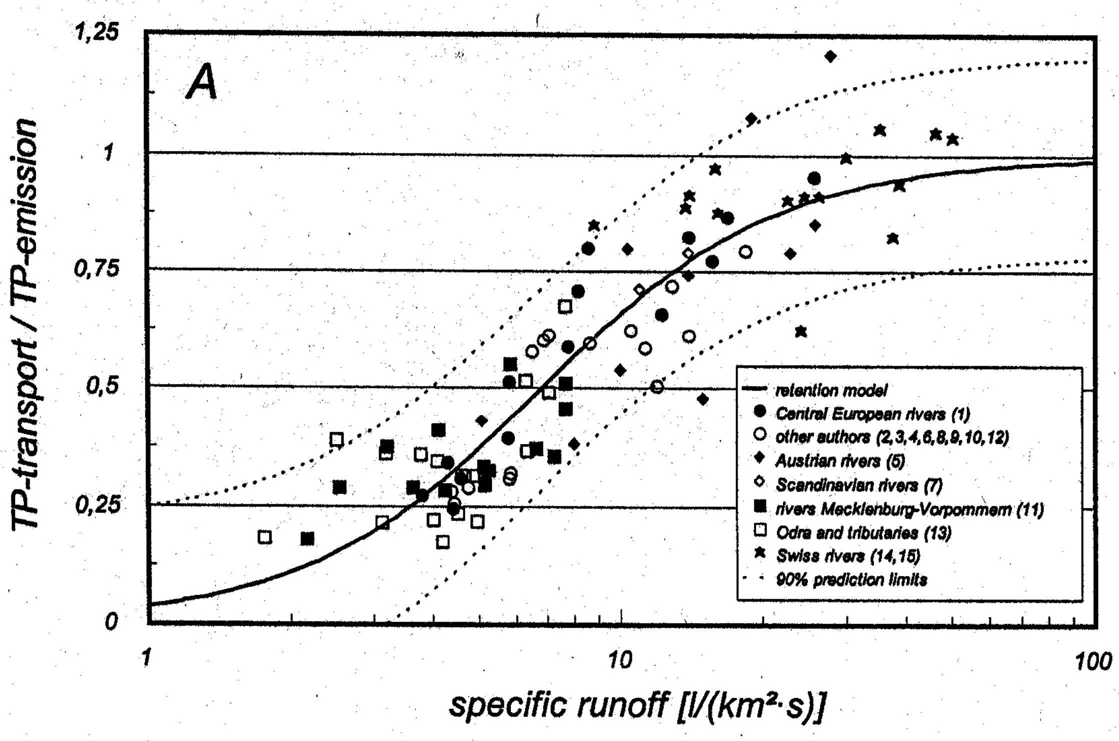


Figure 4.2: The relationship between P-retention (TP-transport/TP-emission) and specific runoff of catchment areas (Behrendt, 2000)

[53] DPRP, 1999: Danube Pollution Reduction Programme: Causes and effects of eutrophication in the Black Sea , Summary report, Programme Coordination Unit, UNDP/GEF Assistance prepared by Joint Ad-hoc Technical Working Group ICPDR-ICPBS

[54] Behrendt, H., Huber, P., Kornmilch, M., Opitz, D., Schmoll, O., Scholz, G. and Uebe, R., 2000: Nutrient Emissions into River Basins of Germany, Umwelt Bundesamt Texte 23/00, ISSN 0722-186.

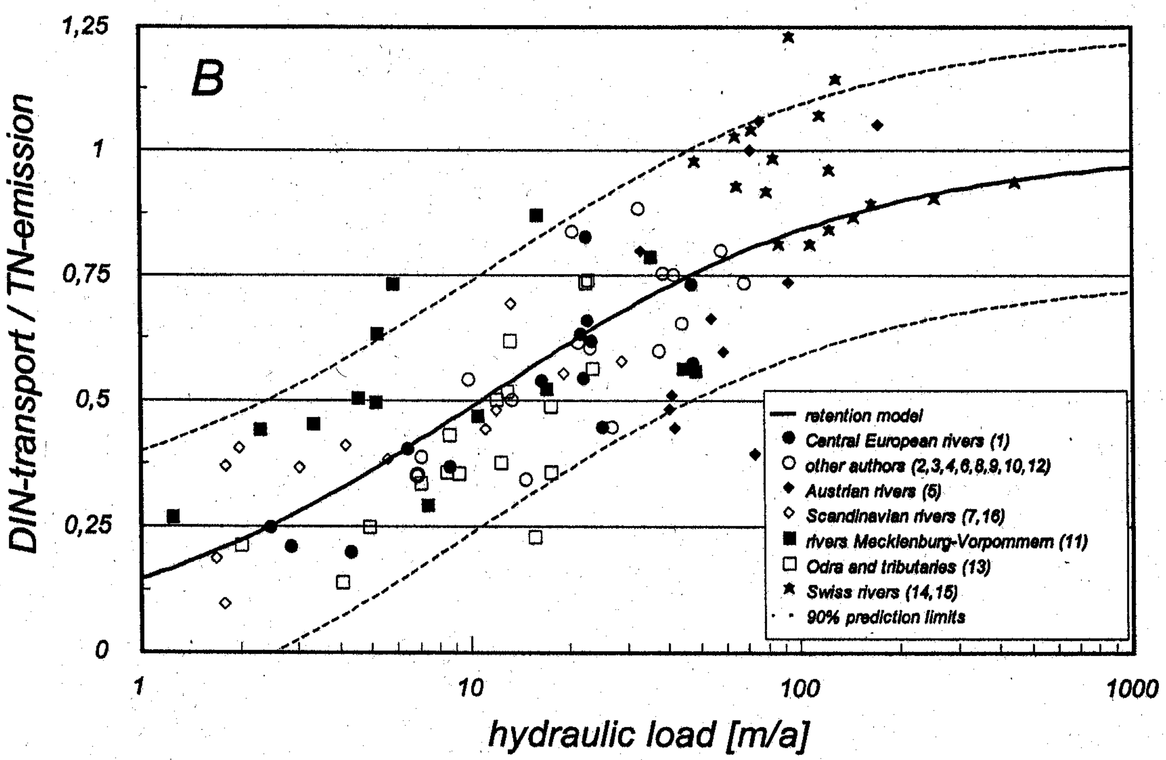


Figure 4.3: The relationship between N-retention (DIN-transport/TN-emission) and hydraulic load of catchment areas (Behrendt, 2000)

According to Behrendt's results, retention happens mainly in the smaller tributaries and not in the main river channel. However, the Danube Water Quality Model (DWQM; van Gils, 1999)[55] has suggested that nutrient retention within the Danube itself is in the order of magnitude of 80 kt N a^{-1} and 15 kt P a^{-1}. For P the main part of the retention in the Danube is assumed to occur in the Irongate dam (about 12 kt P a^{-1}).

4.3. The potential role of riverine wetlands in removing nutrients from the Danube river: lessons from the Danube Pollution Reduction Programme

The Danube Pollution Reduction Programme (DPRP) the DWQM was used to simulate the effect of 17 wetland restoration projects on nutrient loads in the Danube River. The results were compared to the total transported nutrient load and the effect of the implementation of the DPRP on point source emissions. Figures 4.4 and 4.5 illustrate the results of this exercise.

[55] van Gils, 1999: Danube Water Quality Model simulations in support to the Trans-boundary Analysis and the Pollution Reduction Programme, Danube PCU UNDP/GEF Assistance, prepared by Jos van Gils, Delft Hydraulics, Delft , The Netherlands.

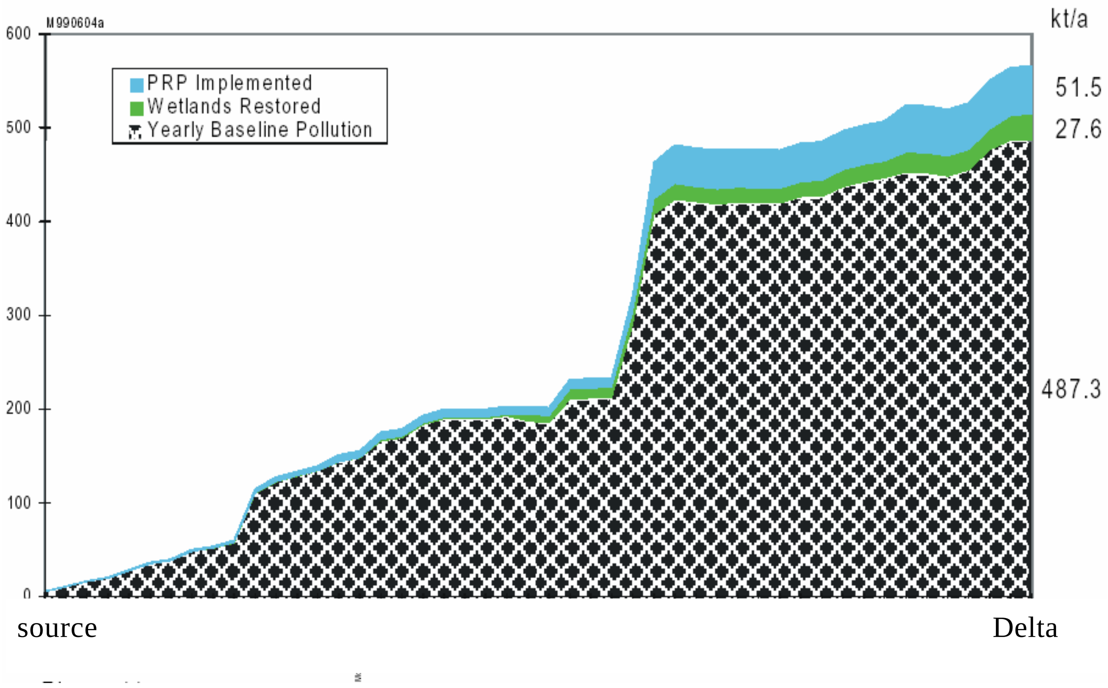
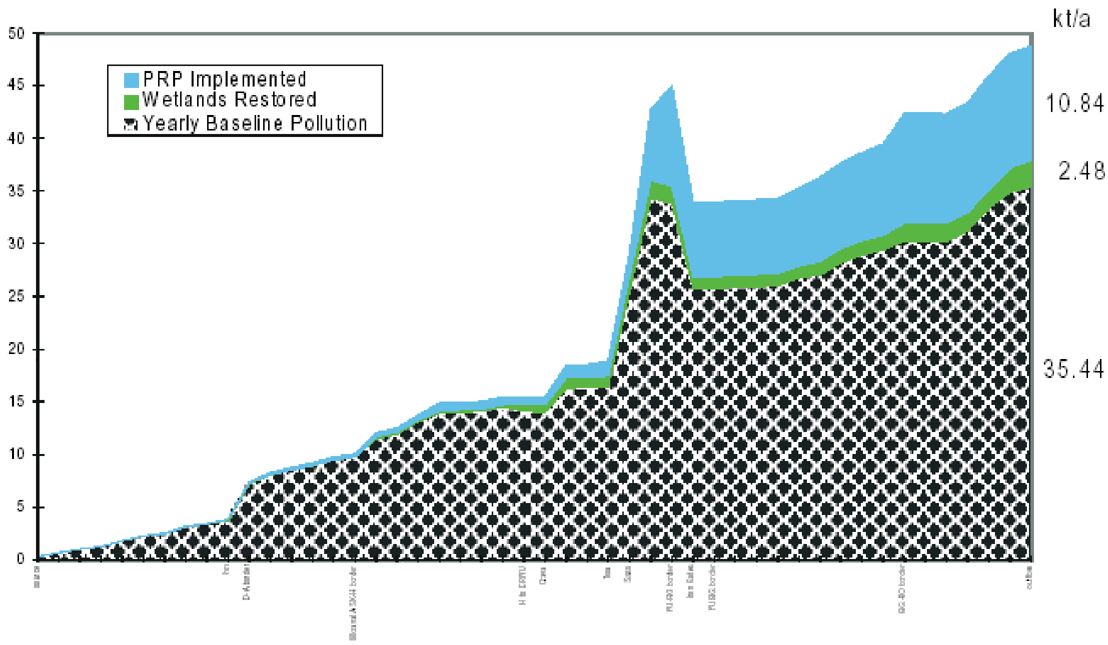


Figure 4.4: DWQM simulation results for potential N-load reduction in restored wetlands along the



Danube River from its source to the Delta (van Gils, 1999)

Figure 4.5: DWQM simulation results for potential P-load reduction in restored wetlands along the Danube River from its source to the Delta (van Gils, 1999)

Based on a total load of 566 kt N a^{-1} and 48 kt P a^{-1} transported in the Danube River, a reduction of about 52 kt N a^{-1} and 11 kt P a^{-1} might be reached by implementation of emission reduction from point sources considered in the DPRP. Reductions of 28 kt N a^{-1} and 2.5 kt P a^{-1} might be reached by implementing the wetland restoration projects. Thus, apart from the other socio-economic and biodiversity benefits that might be derived from a programme of wetland restoration, there could be a significant contribution to the reduction of pollution in the Danube. More recent results from the DANUBs project are not available yet but could be used in Phase 2 of Output 4.3.

Table 4.4 summarises the recent estimates that have been suggested for the potential role of riverine wetlands with respect to nutrient load reductions.

Table 4.4: Comparison of order of nutrient loads and retention in the DRB (kt a^{-1})

	N (kt a^{-1})	P (kt a^{-1})
Emission loads 1996/97	900	110
Instream loads before the Danube Delta 1996/97	450	25
Retention in the whole river system	450	85
Retention in the Danube and its main tributaries (DWQM)	80	15 (3*)
Load reduction from 17 wetland restoration projects (DWQM)	28	2.5

* without Irongate dam

A case study of a Danube riverine wetland: Regelsbrunn, Austria

Between Vienna and Bratislava lies perhaps the last more or less intact floodplain section along a free-flowing stretch of the upper Danube. Along this stretch there still are near-natural hydrological exchange conditions between the main channel and the adjacent floodplains. Because of this potential for natural hydrological exchange, the floodplain segment at Regelsbrunn, located 25km downstream of Vienna, was the site of a major floodplain restoration project (Schiemer et al. 1999)[56]. The main aim of the project was to restore the surface connectivity between the main channel and the side-arm system at medium flows to approximately pre-regulatation levels.

Investigations before and after restoration estimated the impact on the nutrient and matter cycling of the riverine landscape (Tockner et al. 1999[1], Hein et al. 2003[57]). The floodplain segment of Regelsbrunn is 520 ha and is a discrete entity, clearly delineated by high terraces to the south and west. Therefore it offered the opportunity to calculate input-output fluxes (Tockner et al. 1999[1]).

Before restoration the Regelsbrunn floodplain (or side-arm system) was connected with the main channel only through groundwater and bank filtration. Hydrological exchange with the main channel occurred only during short high flow periods (transport phase approximately 4% of the year). After the first restoration phases were completed in 1997, surface connectivity was observed at mean water level. The proportion of total discharge from the main channel into the side-arm now ranges from less than 0.5 % at low water (< 6 $m^3 s^{-1}$) up to 12 % (about 650 $m^3 s^{-1}$) at high water.

Before restoration efforts began, the potential for the Regelsbrunn floodplain to act as a sink or source for matter was assessed for the period from September 1995 to November 1996 (Tockner et al. 1999[1]). The floodplain hydrology during that period was characterized by several flood events and long periods of low flow (mainly during winter). The mean flow level during the observation period was slightly below that of the long-term mean flow and the mean discharge was about 1,800 $m^3 s^{-1}$. It was found that Regelsbrunn served as a major sink for suspended solids (250 mt ha^{-1} $year^{-1}$), particulate organic carbon (POC 2.9 mt ha^{-1} $year^{-1}$) and nitrate (960 kg ha^{-1} $year^{-1}$) during this period, but was a source for dissolved organic carbon (240 kg ha^{-1} $year^{-1}$) and

[56] Schiemer F, Baumgartner C, Tockner K. Restoration of floodplain rivers: The Danube restoration project. Reg. Rivers Res. & Manag. 1999;15: 231-244

[57] Hein T, Baranyi C, Herndl GJ, Wanek, Schiemer F. Allochthonous and autochonous particulate matter in floodplains of the River Danube: Importance of hydrological connectivity. Freshwater Biology 2003; 48 (2), 220-232

algal biomass (0.5 kg ha^{-1} $year^{-1}$). Based on the significant relationship ($r^2=0.84$, $p<0.01$, $n=68$) between suspended solid concentrations and total phosphorus concentrations, an amount of 160 kg ha^{-1} $year^{-1}$ was estimated for the phosphorus retention in the floodplain.

As a result of restoration, the surface connection between the main channel and the side-arm system at mean flow and bankfull flow increased and small-scale fluctuations in flow resulted in more frequent fluctuations between dry and wet periods close to the aquatic parts of the floodplain. Restoration efforts have not affected the inundation area during flooding but, based on the assessment for the years 1997-99, the following tendencies are expected when this occurs:

- The Regelsbrunn floodplain should continue act as a sink for suspended solids because the restoration measures will not significantly alter transport into the floodplain during high flow years.
- Nitrate reduction in the main channel is expected to be of the same order of magnitude with a tendency towards a slight decrease due to reduced retention time at lower flows.
- The long-term effects on the nitrate reduction of increased hydrogeomorphological dynamics induced by restoration are uncertain and still need to be monitored.
- The export of aquatic biomass should increase significantly, mainly in the form of algal biomass (particulate organic carbon - POC) and dissolved organic carbon (DOC). For POC, Regelsbrunn should shift from being a sink to a source, mainly dominated by aquatic material. The estimation for the post-restoration period indicates an increase of 100% of algal biomass export.
- DOC, organic nitrogen and phosphorus export are all expected to increase during periods of mean and high water flow levels.
- The transformation of inorganic, mainly dissolved nutrients to aquatic biomass will be enhanced and export to the main channel will be intensified.

The example of Regelsbrunn points to the potential for nutrient retention within those riverine wetlands that still maintain surface hydrological exchange with the main channel. For the section of the upper Danube downstream of Vienna further projects are planned to restore the area to near-pristine conditions. In terms of nutrient dynamics the following ecosystem functions have already been re-initiated in this floodplain stretch of the Danube:

- The retention of nutrients during high flows;
- The removal of nitrogen through groundwater exchange;
- To some extent, the transformation of nutrients; and
- The provision of aquatic material to plant and animal communities within the main channel downstream.

5. PILOT RIVERINE WETLAND SITES FOR MONITORING AND ASSESSING NUTRIENT REMOVAL

5.1. Selecting pilot sites

In order to develop further information on the role of wetlands in nutrient removal it was intended that, during Phase 1 of Output 4.3, two pilot riverine wetland sites would be chosen at which monitoring and assessment activities could be undertaken in more detail during Phase 2. The pilot sites would ideally together constitute a relatively representative sample of the Danube River Basin (DRB) in terms of restoration issues, river reach, habitat type, and level of infrastructure.

Decisions about the pilot wetland sites were made using two levels of criteria. A pre-selection process, based on nine key questions, determined a small group of potential wetland sites. Thereafter, additional analyses of shortlisted pilot sites was undertaken. Finally, once two wetland sites had been determined, members of the Output 4.3 team visited the sites in question to discuss possible future activities with local experts.

Pre-selection criteria

Possible project sites were only shortlisted if the answers to all the following questions are positive:

- Is sufficient baseline information on geomorphology, wetland habitat types, quantity and quality of surface and groundwater water, biomass production (in particular habitat types) available?
- Logistic support and the capacity to implement a monitoring scheme are necessary. Are there active, credible stakeholders working on restoration issues in the area?
- Is the area somehow typical in the DRB?
- Is there no significant point-source pollution (e.g. large municipal area without waste water treatment or industrial waste products) within the selected river reach?
- No adjustable weirs or pipes should be used to establish the hydrological exchange between the main channel and the adjacent wetlands. Are the exchange conditions near natural between the main channel and the wetland?
- The main source of water (groundwater, surface water) and the temporal variability (frequency and duration) of the exchange need to be estimated. Is the hydrologic exchange regime known?
- Is the size of the area large enough and the proportion of discharge draining the restored wetland significant enough (as a guideline, >1% of mean main channel discharge, >10 % of peak main channel discharge?)
- Will the selection of the area somehow contribute to the body of knowledge on land use practices or interact with any other part of the UNDP/GEF project?
- Can the implementation of a monitoring on nutrient reduction strengthen future plans for wetland restoration with support not only from local stakeholders but also from local/regional/national governmental agencies and authorities?

Following use of these criteria to evaluate potential sites for further monitoring and assessment it became clear that only a few locations fulfilled the criteria.

Additional analyses

During the pre-selection process a number of key questions emerged that needed to be resolved to both select the final pilot sites and design the follow-up monitoring and assessment programme for Phase 2. Of particular importance were the relative benefits and problems of monitoring wetland restoration projects against near natural wetlands. Although the original assumption was that pilot sites should be existing or planned wetland restoration sites, information on the role of wetlands in nutrient retention and removal might be best addressed through monitoring and assessment of near natural wetlands. It was therefore proposed to choose an area(s) that were large enough to combine all three types of projects.

Three additional criteria were also developed to help select the final pilot sites:

- The monitoring and assessment programme should focus on long-term assessment and building of an information base that expands the knowledge and understanding of wetland capacity to influence instream nutrient loads.
- The monitoring and assessment programme should focus on development of a programme of assessment and not use the resources of Phase 2 for purchase of expensive monitoring equipment. For this reason it was important for us to chose pilot sites which have or will have an existing monitoring programme where the resources of the DRP would enhance the assessment capacity. In some instances this could mean additional monitoring but in general the focus should be on designing an assessment system based on already collected data where an existing institution will have long term capacity for data collection.
- It was not intended that the monitoring and assessment programme should provide results in three years. Rather a system should be put in place to provide information and a structure for information collection and interpretation and analysis over a longer period of time.

Based upon this consideration a more detailed analysis was undertaken of a monitoring and assessment project that involves a larger stretch of the Lower Danube (between Romania and Bulgaria). This more detailed analysis led to the decision to focus on two specific sites where wetland restoration projects are in planning (World Bank/GEF projects in both countries) and some intact wetlands exist. Those sites were Kalimok Island in Bulgaria and Calarasi-Raul in Romania.

Results from site visits

Representatives from the Output 4.3 team traveled to Romania and Bulgaria to see the proposed sites and discuss opportunities for monitoring and assessment programmes with local experts. Reports from these visits are in Annex 6.

After the visit to Calarasi-Raul, it was clear that the site was not suitable for a monitoring and assessment programme. The hydrological exchange with the main channel was very limited (less than two months annual exchange period) and the existing wetland habitats were degraded with the majority of land taken by intensive agriculture and drylands. In addition, feedback from Dr Liviu Popescu suggested that there might be general problems of data reliability for overall instream phosphorous and nitrogen monitoring in the Danube Trans National Monitoring Network (TNMN), which would make the evaluation of wetland effect on stream segments based on the TNMN data difficult.[58] However, there was considerable capacity among local experts – including the Danube Delta Institute and the local Environmental Protection Inspectorate – and there was a possibility that wetland restoration activities could begin in the near future. If this proves to be the case, the site could yet remain an option for a monitoring and assessment programme.

The wetland restoration project at Kalimok Island offered the possibility to instigate a monitoring and assessment programme in Phase 2. Although in its present condition the area offered only limited opportunities for nutrient removal, restoration works scheduled to finish in 2005 would enhance the possibilities. There were some obstacles that would need to be overcome, including the lack of baseline data and the need to ensure quality standards in monitoring laboratories.

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[58] Liviu Popescu, personal comments during field mission.

5.2. Conclusions

The site selection process has identified a number of difficulties in establishing a monitoring and assessment process for Phase 2. In particular the site visit to Romania and Bulgaria came to the conclusion that a monitoring and assessment programme in connection with the Calarasi project would be much more difficult than anticipated. An assessment in connection with the Bulgarian wetland restoration project on the other hand appeared both sensible and complimentary to existing plans. This situation means that only one of the two priority pilot projects have been developed in the manner foreseen.

The reasons for the difficulties in carrying out a pilot project in Romania are described in the mission report (Annex 6) but relate specifically to the uncertainties of the restoration project and the limited amount of water that would be entering the restored habitat.

Alternative locations for pilot sites have been considered but have not been evaluated in detail in Phase 1. These include:

> The lower Danube in Hungary (Danube Drava National Park) and the bordering region of Croatia (Kopacki Rit) where both existing high quality wetlands are present and restoration plans are in preparation.

> The Sava River (at the mouth of the Drina River) between Bosnia and Serbia

> The Morava in Slovakia/Austria/Czech Republic

> The Danube between Vienna and Bratislava.

In addition the considerable work going on in the Danube Delta on wetland restoration would offer a basis for pilot activities but this option suffers from the fact that the Delta is not representative of the Danube system.

It is recommended that discussions with experts from these sites be held early in Phase 2 to identify a second pilot site from among those listed. In addition, it will probably be necessary for representatives of the Output 4.3 team to visit one or two of the sites before a final decision can be made on which is best suited to the establishment of a monitoring and assessment programme.

A workshop should be held early in Phase 2, and before investment is made in any pilot site, to refine the work programme for Phase 2 and determine an optimal monitoring and assessment plan. The key experts from each of the potential sites, the project team and the team from the chosen pilot site (Bulgaria) could be involved. In addition, ICPDR experts (e.g. representatives from the TNMN and the Ecological Expert Group), IAD representatives, and representatives of potential organizational coordinators for the ongoing work might usefully attend.

The evaluation of specific pilot sites is invaluable in expanding the knowledge of nutrient removal capacity of wetlands. However, this evaluation should be supplemented by better overall understanding of the nutrient dynamics of the Danube River Basin. It was clear during the site selection process that few people, if any, had an overview of potential wetland restoration sites in the DRB. This highlighted the fact that an organizational basis for supporting work related to these issues in future was needed. It is therefore recommended that an assessment programme for nutrient removal in Phase 2 include not only pilot site activities as originally envisaged but also a mechanism for information exchange and discussion among experts dealing with various aspects of wetlands management and nutrient dynamics.

During the course of the site selection process it became apparent that the large wetland national parks along the Danube (Donau Auen, Danube Drava, Bulgaria Danube, DDBRA) all have a strong interest in the questions related to nutrient removal from wetlands. There is a great deal of interest among persons involved in these parks to meet together in future.[59] It would appear

[59] See Annex 3

sensible that Phase 2 activities help build a network for the informal network of park managers and scientists to formalize meetings and activities (exchanges and joint research) related to the nutrient removal from wetlands and other joint problems of wetland management. Alternatively the ICPDR Ecological Expert Group or the IAD could be encouraged to provide an institutional forum for coordinating work related to this theme in future. Establishing this organizational basis should be a second goal of the introductory workshop proposed for the beginning of Phase 2.

6. MONITORING THE NUTRIENT REMOVAL CAPACITIES OF WETLANDS: GENERAL PRINCIPLES AND GUIDELINES

6.1. Principles for monitoring the nutrient removal capacities of riverine wetlands

The monitoring and assessment programme should focus on long-term assessment and development of an information base that expands the knowledge and understanding of wetland capacity to influence instream nutrient loads.

The basic question for the long-term monitoring is how the discharge and inundation area (the hydrologic exchange with the main channel) affects the nutrient retention. Restoration practices most often act at the structural level and are expected to ameliorate ecosystem function. The coupling between structure and ecosystem function can be addressed by long-term monitoring and regarding the amount of hydrologic and nutrient input the retention efficiency vary (Figure 6.1).

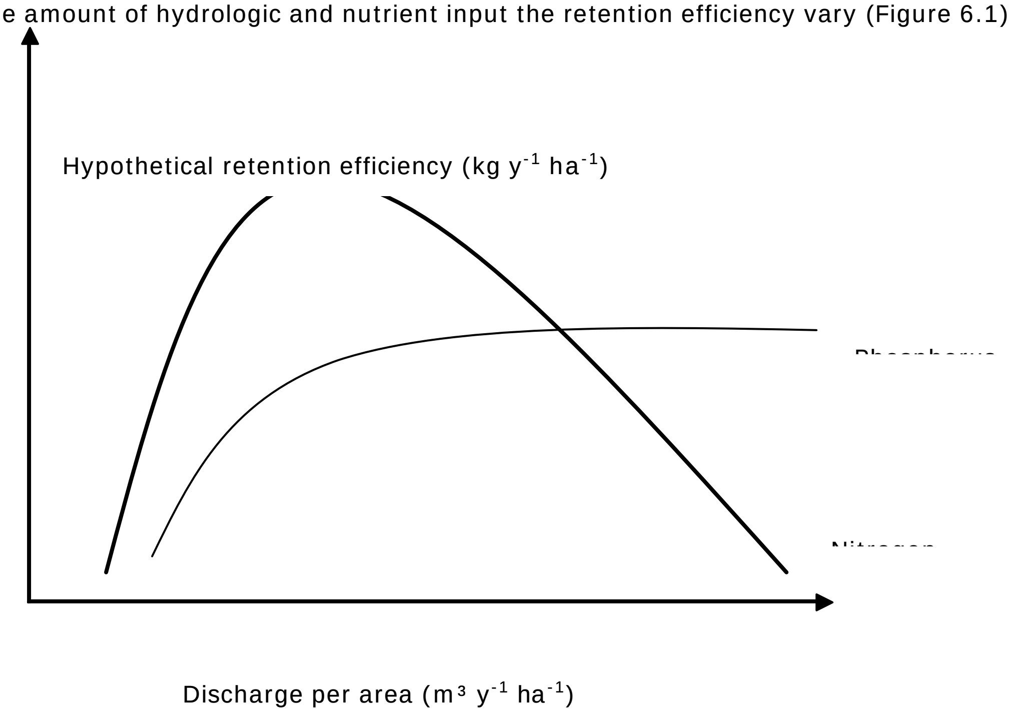

Fig 6.1: A conceptual model of the nutrient retention capacity of phosphorus and nitrogen. The hypothetical relationship reflect 2 theoretical scenarios, at one optimum conditions are found at medium water inputs. Whereas the second relationship demonstrate an exponential increase up to a level where no further effect with increased water inputs can be found. These functions can be applied to different habitat types.

For the design of any restoration project, one issue could be to optimize nutrient retention in riverine wetlands for each habitat type. The question, then, for the monitoring and assessment is to what extent does the hydrologic exchange or any other driving factor influence the retention capacity of N and P? It can be expected that non-linear relationships reflect the ecosystem behaviour with an optimized fit. Following these hypothetical relationships, a monitoring program could determine what water inputs during what flow conditions will lead to maximum nutrient retention without decreasing the biodiversity of wetlands.

With this in mind, the following principles should be taken account of during the design of a monitoring programme for nutrient removal capacity of wetlands.

Costs and site-specific conditions

A monitoring programme very much depends on the money available and the local situation and cannot be designed in detail on a general level.

Basic information

Detailed information on geomorphology is a prerequisite for hydrological investigations. Detailed information on the relief of the system is needed as well as information on the slope and volume of water courses. Information on the groundwater table as well as depth, conductivity and main geological characteristic of the aquifer should be known.

Hydrology

The monitoring of water flow through the system is the main basis for a nutrient budget. Flow inputs and outputs, including surface water and groundwater at the different flow regimes, should be considered. In addition to discharge, flow velocity and residence time are important parameters. In order to have reliable research results, case studies should be performed where the system is not too complex and nutrient budgets can be calculated. For this reason, the number of relevant surface water connections with the main river should be limited and the groundwater situation should be relative homogeneous. The establishment of hydrological models for surface and groundwater (if relevant) would be advantageous.

Nutrient budget

Monitoring should emphasis the input and output fluxes of nutrients to and from the wetland system. That means the transport of nutrients in and out of the system has to be monitored in detail. The removal from, and the long-term storage in the system, should be estimated as precisely as possible. A clear definition and selection of the system is important. For reference purposes the nutrient fluxes in the main river should be monitored. Monitoring of changes in load in the main river upstream and downstream of a wetland might only in exceptional cases be detectable (i.e. where there is a very big wetland system in relation to the size of the river and extreme events) and could be feasible only in these cases. Retention and transformation processes are not the main focus of monitoring, but the knowledge of these processes will help the interpretation of the input-output studies.

Wetland typology and vegetation characteristics

This information is not a main focus of monitoring of nutrient removal in wetland systems. Nevertheless it is necessary to provide an overview for interpretation of results and transformation of results to similar wetlands for estimations of nutrient removal in wetlands on a basin-wide scale.

6.2. Specific guidelines for monitoring the nutrient removal capacities of riverine wetlands

Hydrology of surface waters

Water level reading should be performed at all relevant inflow and outflow channels and in the main river. The relation of water level to discharge should be known or must be developed to calculate discharges from water level reading. Water level recorders would be preferable at least in the main river and at one main station at a wetland channel. At other stations water level reading should be performed together with water sampling (e.g. normally biweekly and daily at high flow events). If there is a strong correlation between water levels in different channels water level reading at one of these channels is sufficient. Based on water level and discharge data flow velocities and residence times can be deduced from information on relief of the wetland system.

Hydrology of groundwater

The groundwater table can be monitored by recording water level readings of distributed observation wells and the water level of surface waters. Based on groundwater slope, groundwater depth and conductivity the groundwater flow can be estimated. The conductivity of the aquifer is nevertheless a factor of uncertainty so tracer tests might be considered. Groundwater flow can be relevant for exchange between the main river and wetland (exfiltration, infiltration) or as exchange of water within the catchment (discharge from the catchment to the wetland or vice versa). In the case of a riverine wetland adjacent to a large river the catchment of the wetland will be usually be very small as compared to the river basin and thus the contribution of groundwater flow from the catchment to the wetland will not be relevant. All other groundwater flows might be relevant dependent on the local situation. Groundwater monitoring is costly. Thus relevant flows should be estimated in advance based on available information. Depending upon which groundwater flow is monitored, groundwater wells should be located between the main river and wetland channels or between the wetland channels and the catchment. It may be that one water flow (groundwater or surface water in- or outflow) need not be measured and can be derived from the other flow components of the water balance (sum inflow = sum outflow). If water balance is used to calculate an un-measured flow it is not possible the check the accuracy of the other flow measurements by comparing the sum of inflows is equal to the sum of outflows, which must be the case on a long term run if changes of stored water in the wetland can be neglected.

Transport by surface waters

Based on monitoring of water discharges, nutrient loads can be derived from measurements of nutrient concentrations. Nutrient concentrations/loads should be monitored in all relevant surface water connections between the main river and the wetland and as reference in the main river (at the same places where discharge is measured). If one location is representative of others (e.g. different inflow channels and the main river) sampling might only be necessary at one of these locations. The sampling strategy should be designed so that discharge to load (or concentration) functions can be derived for the different locations as a basis for the calculation of yearly loads. This means that event-oriented sampling at high flow/flood conditions is necessary. Sampling frequency at low or average flow conditions should be considered with an interval of about 14 days. At high flow or flood conditions the frequency should be increased to daily samples. The decisive question will be to find appropriate sampling points for collection of representative samples especially at high flow conditions (accessibility, turbulence). No general principles can be established for the location of these points – they must be decided according to site-specific conditions. In exceptional cases (>20 % of main channel flow entering the wetland) it can be considered to monitor the main river upstream as well as downstream of the wetland.

Parameters that should be measured to derive nutrient loads include:

TN, DON, NO_3-N, (NO_2-N), NH_4-N, $TP_{filtered}$, $TP_{not\ filtered}$, PO_4-P

In addition, the following parameters should be measured in order to get information on retention/transformation processes:

SS, POM (FPOM, CPOM), TOC, DOC, Chlorophyll a, O_2, pH, T, conductivity, HCO_3

In cases where the water intake to the wetland is not only from the main river but from the wetland catchment, consideration can be given to use parameters such as Carbamazipine, B, Cl, or Na as tracer for the origin of the water flows in the wetland system.

Isotopes as N^{15} or O^{18} may be considered for monitoring the inflow and outflow of the wetland system for qualitative detection of transformation processes (e.g. enrichment of N^{15} in the water in cases where denitrification takes place, because of selective consumption by bacteria).

Transport by groundwater

Based on knowledge of discharge, groundwater nutrient loads can be derived based on nutrient concentrations at distributed observation wells. Those wells should be monitored where the main groundwater discharge takes place. Sampling frequency depends on the dynamic of the groundwater discharge. A basic assumption is that intervals of 1 – 2 month can be considered.

Parameters that should be measured to derive nutrient loads include:

TN, DON, NO_3-N, (NO_2-N), NH_4-N, TP, PO_4-P

In addition, the following parameters should be measured in order to get information on retention/transformation processes:

TOC, DOC, O_2, pH, T, conductivity, (Fe, Mn) , HCO_3

In cases where water intake to the wetland is from the catchment as well as the main river, parameters such as B, Cl, or Na can be used to trace the origin of water flows.

Isotopes as N^{15} or O^{18} may be considered for monitoring as well as for detection of transformation processes (e.g. enrichment of N^{15} in the water where denitrification takes place because of selective consumption of bacteria).

Deposition, N-fixation

Normally it will be sufficient to estimate nitrogen inputs by deposition and N-fixation based on information on regional nitrogen depositions and information on the number of N-fixating plants, in order to check the relevance of this inputs. Only in exceptional cases more detailed investigations will be necessary.

For example, assume that a wetland size of 1000 ha receives N input by deposition and N-fixation of about 50 t N a^{-1} (50 kg ha^{-1} a^{-1}). Further assume that this wetland is located on a river such as the Danube at Budapest, with a yearly N load of 200 – 300 kt a^{-1} and a N intake into the wetland of 1% of the river load (2000 – 3000 tN a^{-1}). Clearly with such a small proportion of total N load it is not relevant to monitor the deposition and fixation inputs.

Storage / Transformation

The overall retention (time between input and output) is observed by monitoring transport of nutrients into and out of the wetland. More detailed monitoring for quantitative assessment of specific transformation processes is not of major importance. Nevertheless the knowledge about retention/transformation processes will help to explain overall retention and to transfer findings to comparable locations. The main indicators for these processes should be monitored in the input and output fluxes of the wetlands and are specified under "transport". If possible, these indicators should be measured at additional locations inside the wetland as well.

Removal by denitrification

Denitrification is considered to be the most important removal process for nitrogen and emphasis should be put on quantification. Methods exist to quantify denitrification at the laboratory scale but it is difficult to quantify denitrification on the scale of a wetland. Denitrification has to be derived from the quantification of the nutrient budget of input minus output flows over longer periods of time. Thus all other input and output flows must be known as well as changes in stock. Achieving this must be the main emphasis of monitoring. Indicators such as oxygen, DOC, Fe or Mn content or change in N^{15} contents will help the interpretation of results and transformation of results to wetlands with similar conditions for denitrifcation.

Removal by harvest

Usually estimates based on information of harvested areas, the harvested plants, the number of cuts in case of meadows and nutrient uptakes of these plants will be sufficient for good data related to removal by harvest. In general, as for deposition and N-fixation, the relevance of removal by harvest will be small.

This can be demonstrated using the same example of a wetland with a size of 1000 ha with a N input from the main river of 2000 - 3000 t a^{-1}. It is unlikely that more than a third of the wetland vegetation is harvested. The maximum N yield of the harvest can be estimated at 150 kg ha^{-1} a^{-1}. Thus not more than 50 t N a^{-1} are removed by harvest, which is negligible compared to the nitrogen input from the river. It is likely that that the situation for P is similar. Nevertheless relations might be different in specific cases. The share of harvested area might be bigger or the removal per hectare is higher in some wetland types. Thus harvest should not be neglected.

Long term storage

Long term storage is considered to be the main removal process for P. On the one hand storage has to be calculated based on the difference between input and output fluxes over longer periods of time (years). In addition long-term monitoring should focus on long-term changes of morphology/relief of the wetland (e.g. silting of surface waters) and the observation of P (and N and organic matter) contents in soils and sediments of wetlands. Further sediment input during single flood events should be quantitatively assessed by monitoring the area affected by sedimentation, the sediment input per area and the nutrient concentration of the sediments. This should be done based on assessments of effected areas and amount of sediments and sampling of sediment samples soon after flood events.

Wetland typology and wetland vegetation

In order to be able to compare and evaluate results against other locations it is necessary to determine and have a general understanding of wetland typology and wetland vegetation that exists in the area to be monitored. A categorization of the wetland typology can be developed using the classification scheme contained in the Annex 5.

Flood events

An additional issue that should be considered is the monitoring of discharge during flood events. This is important if discharges happen not only in the main channel but over bigger areas. The use of hydrological models to address this issue should be considered. Representative sampling in such events may also be necessary.

7. A MONITORING AND ASSESSMENT PROGRAMME FOR THE KALIMOK-BRUSHLEN PILOT WETLAND SITE, BULGARIA

7.1. Site description

Location

Kalimok-Brushlen Protected Site, covering about 6,000ha, is located 60 km east of Ruse. The extent of the former wetlands is about 14 km (between river km 448 and km 436) by 2.5km - 4.5km. The co-ordinates of the approximate center of the riverine wetland are 44^0 00’ 59” North, 26^0 27’ 11” East.

Land-use and management

Up until the 1950s, the marsh complex was a key part of the region’s valuable fish resources. In the 1950s, a dyke was constructed between Ruse and Tutrakan for agricultural purposes, which cut off fish from their historical spawning grounds. Fish ponds (encircling 560 ha of state-owned land) were constructed, but the operators were declared bankrupt and abandoned the fishponds after the collapse of the state farming system. Most of the original marshlands now proposed for restoration are state-owned and have reverted to reed beds. The adjacent lands to the west of the marsh is mainly in private or local government ownership, the eastern area is mainly in state ownership. Agriculture is the dominant land-use and economic activity in these areas with a focus on cultivation of wheat, maize, orchards, barley and vegetables and on animal breeding. Forestry and fish-ponds also exist. The total population connected to the site is about 23,140 including the municipalities of Slivo Pole and Tutrakan.

The land-use and management of the Kalimok-Brushlen Protected Site is regulated by the Protected Areas Law, the Order of the Minister of Environment and Water for the designation of the Protected Site (No. RD-451, dated July 4th, 2001) and the management plan for the Protected Site.

Wetland restoration

Kalimok-Brushlen Protected Site and Persina Nature Park are project areas within the World Bank/GEF Wetlands Restoration and Pollution Reduction Project (GEF TF 050706 BUL). The project development objective is that local communities and local authorities in both project areas adopt sustainable natural resources management practices. The global environmental objective is to demonstrate and provide for replication of reduction of transboundary nutrient loads and other agricultural pollution flowing into the Danube River while at the same time conserving key target threatened species in the project areas through:

- wetlands restoration and protected areas management programs; and
- support for stakeholders to adopt environmentally-friendly economic activities in the two project areas.

The project will help demonstrate how environmental-friendly rural development activities can improve livelihoods. There are two main project components. At the beginning, in the initial phase of this component, marshland will be recovered and restored in two large sites to demonstrate the use of wetlands for nutrient removal. Additional sites are expected to be identified and restored later during project implementation. The World Bank/GEF funds will finance consultancy services for the elaboration of detailed engineering designs, baseline surveys and the supervision of construction and rehabilitation activities of small infrastructure which will regulate water flows. Grant support is being sought for consultant services pre-feasibility and feasibility studies, design of restoration activities, and needed civil works. The second project component (funded by the EU

PHARE programme) will support long-term project sustainability by preparation of protected areas management plans at the two project sites. It also supports:

- the implementation of priority actions identified in these plans;
- strengthening of monitoring programs for water quality, biodiversity, socioeconomic indicators, and health risks;
- building public awareness and education campaign; and
- strengthening of land and water management institutions.

About 1,125ha of state-owned land in the Kalimok-Brushlen Protected Site are expected to be restored to riverine wetland. The project will also support the construction and rehabilitation of small infrastructure needed for the restoration of wetlands in Kalimok-Brushlen pilot site including sluices, canals, protective dykes and access roads, to allow for controlled flooding that optimizes nutrient trapping, biodiversity restoration, and fish production. In addition to enhancing internationally important biodiversity habitats, it is expected that restoration of wetlands at Kalimok-Brushlen pilot site will reduce nutrient loads to downsteam reaches of the Danube and to the Black Sea (144,000-503,000 kg of nitrates and 15,600-25,400 kg of phosphorus per year).

Hydrology

The results of baseline surveys of hydrological, geological, hydrogeological and geomorphological information is available in digital format as GIS layers from the Project Co-ordination Unit in Sofia. Some hydrological aspects of the optimal scenario developed for restoration of KBPS are listed in Table 7.1.

Table 7.1: Hydrological characteristics of Kalimok-Brushlen pilot site

Flooded area	1,125ha
Flooding level	14.0m ASL
Average depth	0.464m
Capacity (volume)	5.22×10^6 m^3
Surface	11.257km^2
Evapotranspiration	1m^3 s^{-1} during summer months
Retention period	10-14 days during flooding period
Discharge	3.9m^3 s^{-1}
Infiltration (Danube)	0.3209m^3 s^{-1} at maximum water level; 0.09m^3 s^{-1} at mean water level
Groundwater inflow	1.73m^3 s^{-1}
Number of inlets	1
Number of outlets	1
Number of dual inlets/outlets	1
Inlet flow	5.0 m^3 s^{-1} (max 9.0 m^3 s^{-1})

Three connections are planned for construction between the flooding area and main watercourse:

- one typical inlet structure across the great Danube dyke at 442 river km;
- one mixed inlet/outlet structure at 448 river km (the function will depend on Danube water levels and the pressure of storm waters or groundwater table); and
- one typical outlet structure by 436 river km near Tutrakan.

All the restored connections between wetlands and the Danube River will be regulated by specially designated sluices equipped with fish passing facilities suitable for fish communities of carp zone/*Abramis* river zone. Two or more pumping stations will be constructed/reconstructed for flood control by extreme water level and for prevention of the arable area adjacent to the Kalimok-

Brushlen pilot site. Also, a new internal smaller dyke will be constructed round a part of inland boundary of the Kalimok-Brushlen pilot site wetlands to prevent agricultural fields and local infrastructure. This inland dyke will be lined by a parallel drainage canal to control negative groundwater level raising outside the flood area.

The restoration is planned for the next two years. Detailed design will be ready at the end of March 2004 and the construction works will be completed at the end of April 2005. The first flooding is expected after the completion of the construction works.

Wetland habitat typology and vegetation characteristics

The Kalimok-Brushlen pilot site is a typical seasonal floodplain, usually flooded during spring and early summer and drying out in summer or early autumn. There are temporary water bodies and, in the deeper parts, permanent standing waters within the project area. To a certain extent this flood regime already exists even before wetland restoration because of the influence of groundwater and/or storm waters. The main problem now is the lack of surface connection between the wetlands and the Danube River.

There is currently little detailed information about the distribution of wetland types in Kalimok-Brushlen pilot site but the major existing habitats have been summarized using the EUNIS system 60 and in Table 7.2.

Table 7.2: Major wetland habitat types at Kalimok-Brushlen pilot site

Natural habitats	Man-made habitats
Typha beds – dominant water-side (hygrophyte) habitat	Drainage canals and ditches
Reed-beds	Abandoned fish-ponds
Shoenoplectus beds	Poplar plantations
Scirpus beds	
Wet meadows (grassland) including floodplain grazing meadows	
Floodplain marshes (meadows, grassland) – mesotrophic temporary ponds	
Flood riverine forests (*Salix-Populus-Fraxinus-Ulmus*)	
Permanent standing waters (mesotrophic or eutrophic permanent ponds) – habitats covered by plentiful submerged vegetation (*Ceratophyllum*, *Myriophyllum*, etc.) and/or emergent (*Nymphaea alba*, *Potamogeton*, *Nymphoides peltata*, *Trapa natans*, *Hydrocharis morus ranae*)	

One important issue for the Kalimik-Brushlen Protected Site is the potential pattern of habitats which can be expected after restoration of the normal flooding regime and connections with the Danube River. The first change might be the disappearance of some man-made habitats (canals, ditches, abandoned fish-ponds). Detailed monitoring of habitat changes after restoration will be extremely important to assess the level of nutrient removal processes.

[60] See http://mrw.wallonie.be/dgrne/sibw/EUNIS/home.html. Habitat types at European level were developed by the EEA European Topic Center on Nature Protection and Biodiversity. The EUNIS habitatsclassification builds upon previous initiatives (like CORINE-biotopes followed by Palearctic Habitats Classification), but introduces agreed-upon criteria for the identification of each habitat unit and provides a correspondence with other classification-types (the two above-mentioned typologies, CORINE land cover, Habitats Directive 92/43/EEC Annex I, Bern Convention Resolution 4, Nordic Classification System, and other national systems).

7.2. Existing monitoring and assessment activities

The present national monitoring programme for surface waters and groundwater in Bulgaria is administered by the Ministry of Environment and Waters. The programme is close to the requirements for a surveillance monitoring system for assessing long-term trends in chemical water quality (identifying the trends in physico-chemical status). There is a move to enhance monitoring systems in the near future to ensure implementation of the WFD and other EU and national legislation.

Nutrient levels in the Danube River itself are monitored under the auspices of the Trans National Monitoring Network. In Bulgaria this includes five international monitoring stations and six additional stations from the national monitoring network. Wetlands are not monitored and there is no monitoring scheme for other components such as bottom sediments, suspended solids or biological elements but about 20 parameters, including nutrients, are monitored.

At present there are no monitoring activities within the Kalimok-Brushlen pilot site. An integrated monitoring programme is planned within the framework of the EU PHARE component of the restoration project. This will include monitoring of surface and groundwater and of biodiversity in 2004 (including monitoring equipment supply). It will not include specific components aimed at assessing the role of the riverine wetland in removing nutrients from the Danube.

There are two meteorological stations near the Kalimok-Brushlen pilot site (at Tutrakan, 4 km East of the project area; and at Slivo Pole, 12 km South-West of the project area) and hydrometric gauging stations on the Danube River at Ruse, Bulgaria (about 35-40 km upstream the project area) and in Oltenitza, Romania (about 10 km downstream the project area). Data from the Ruse could be easily extrapolated to the project area because there are no tributaries of the Danube River in between.

Table 7.3: Results from field surveillance of nutrients, COD, general physico-chemical parameters in Kalimok/Brushlen area (undertaken during preparation for the World Bank/GEF Wetlands Restoration and Pollution Reduction Project

No	Type of sampling site	Geographic coordinates	Data/Time	Dissolved O_2 mg/l	O_2 saturation %	Temp. ^{0}C	pH	Conductivity uS/cm	T N, mg/l	organic N mg/l	inorganic N mg/l	NH_4-N, mg/l	NO_2-N, mg/l	NO_3-N, mg/l	T P mg/l	PO_4-P mg/l	COD mg/l	Turbidity FNU	Chl. A ug/l
1	Danube River km 458, before K/B	44⁰01'21"N 26⁰18'41"E	03/08/2001 10:50	7,31	91	26,1	7,71	340	1,91	1,069	0,841	0,05	0,021	0,77	0,15	0,04	26	13	6,55
2	Danube River km 448, inlet/outlet	44⁰01'53"N 26⁰25'20"E	03/08/2001 12:50	8,08	101	27,3	7,88	329	1,91	0,758	1,152	0,04	0,022	1,09	0,16	0,038	23	17	9,74
3	Danube River km 436, outlet	44⁰02'39"N 26⁰34'33"E	03/08/2001 18:05	8,88	109	26,5	7,95	345	2,85	0,99	1,86	0,03	0,02	1,81	0,15	0,045	38	11	10,02
4	Main Drainage Canal (Brushlen)	44⁰00'24"N 26⁰19'48"E	03/08/2001 9:30	2,21	24	24,4	6,90	497	2,06	1,82	0,24	0,03	0,01	0,2	0,16	0,018	65	9	6,34
5	Main Drainage Canal	44⁰01'16"N 26⁰25'00"E	03/08/2001 12:10	5,85	72	27,6	7,74	676	1,03	0,624	0,406	0,03	0,006	0,37	0,26	0,016	70	34	49,13
6	Main Drainage Canal (East fish ponds)	44⁰01'34"N 26⁰30'15"E	03/08/2001 16:30	7,06	93	29,1	7,60	709	0,74	0,363	0,377	0,01	0,007	0,36	0,54	0,424	69	6	29,17
7	Main Drainage Canal	44⁰02'26"N 26⁰34'21"E	03/08/2001 18:20	6,79	88	27,6	7,98	693	1,32	1,043	0,277	0,04	0,007	0,23	0,38	0,22	66	8	31,77
8	Drainage Canal	44⁰01'03"N 26⁰24'55"E	03/08/2001 11:55	4,09	48,6	26,2	7,34	598	0,88	0,824	0,056	0,05	0,006	<0.2	0,25	0,072	61	10	77,92
9	Inlet/Outlet channel	44⁰01'40"N 26⁰25'12"E	03/08/2001 13:20	7,36	91	27,2	7,68	397	1,91	0,671	1,239	0,09	0,029	1,12	0,15	0,093	59	6	26,95
10	Brushlen marsh	44⁰00'24"N 26⁰19'47"E	03/08/2001 9:50	1,21	14	24,6	6,95	684	3,09	3,084	0,006	<0.01	0,006	<0.2	0,5	0,068	87	29	26,74
11	Fish pond	44⁰01'36"N 26⁰30'15"E	03/08/2001 16:10	1,85	25	27,5	7,36	699	0,88	0,294	0,586	0,08	0,006	0,5	0,23	0,097	71	8	16,29

A limited degree of water quality surveillance was undertaken during feasibility studies for the World Bank/GEF project, including assessment of current nutrients concentrations in surface waters. The results are summarised in Table 7.3.

This was an isolated study to obtain surface water quality data during the summer period for an initial assessment. It showed that there were some hypoxic areas within drainage canals, wet fish ponds and the remains of Brushlen marsh. The ecosystem in these areas exhibits other signs of degradation such as bad smell of hydrogen sulfide, dead fish cases and low levels of biodiversity. The maximum Total P value was 0.15 mg l-1 and maximum Total N was 2.85 mg/l-1. Nitrate and ortho-phosphate levels reached 1.81 mg l-1 of NO3-N and 0.045 mg l-1 of PO4-P respectively. These values corresponded to TNMN data and indicate that the nutrient status of the Danube River in this reach is low.

7.3. Monitoring objectives

General context for monitoring

All monitoring of the role of riverine wetlands in removing nutrients should contribute to wider objectives. As noted in 3.2 above, of particular importance in the context of Output 4.3 is the need to contribute to successful implementation of the WFD, taking account of the *Wetlands Horizontal Guidance*[61]. This means that monitoring should help to:

- characterize wetlands in terms of pressures, impacts and economics of water uses, including a register of protected areas lying within the river basin district, by 2004 (Article 5, Article 6, Annex II, Annex III of WFD);
- carry out, jointly and together with the European Commission, the intercalibration of the ecological status classification systems by 2006 (Article 2 (22), Annex V of WFD);
- make operational the monitoring networks and programs by 2006 (Article 8 of WFD); and
- based on sound monitoring and the analysis of the characteristics of the river basin, to identify by 2009 a program of measures for achieving cost-effectively the environmental objectives of the WFD (Article 11, Annex III of WFD).

Specific monitoring objectives

In addition, the monitoring scheme proposed here must complement that designed within the integrated monitoring programme being prepared within the framework of Kalimok-Brushlen pilot site restoration projects. The monitoring network as currently proposed does not include wetland areas but the following monitoring sub-programs, to be elaborated within the framework of the integrated program, are relevant to nutrient removal issues:

- Continuous monitoring of quantitative status of surface waters and groundwater to estimate water balance, water regime and dynamics within the wetland area;
- Implement a nutrient-monitoring sub-program for Kalimok-Brushlen pilot site to assess nutrient reduction/nutrient removal capacity and nutrient status of the flood area by 2005;
- Detailed assessment and long-term monitoring of vegetation habitat types according to EUNIS habitat classification with emphasis on habitat changes after restoration works and quantitative habitats distribution;

[61] Horizontal Guidance Document on the Role of Wetlands in the Water Framework Directive, Final Draft Version 8.0, 7th November 2003

- Assessment of sedimentation processes (including sedimentation transportation, flood debris, potential erosion) within the floodplain area;
- Detailed monitoring of fish and fish breeding (species composition, age structure, success of breeding, biomass, realization of small fish in main watercourse, etc.); and
- Monitoring and assessment of waterfowl communities, water vegetation, macroinvertebrates, phytoplankton and zooplankton within the restored area;
- The monitoring must also provide good monitoring information for proper management and operation of the wetlands and contribute to the assessment of long-term environmental processes in Kalimok-Brushlen pilot site and its surroundings after wetland restoration.

7.4. How to monitor nutrient removal

A nutrient removal monitoring network in the Kalimok-Brushlen pilot site should facilitate three types of monitoring: surveillance monitoring, operational monitoring and investigative monitoring.

Surveillance monitoring

The objectives of surveillance monitoring of surface waters are to provide information for:

- Supplementing and validating the assessment procedure detailed in Annex II of WFD 2000/60/EC;
- The efficient and effective design of future monitoring programmes;
- The assessment of long term changes in natural conditions; and
- The assessment of long-term changes resulting from widespread anthropogenic activity.

The results of such monitoring should be reviewed and used in combination with the impact assessment procedure described in Annex II of WFD, to determine requirements for monitoring programmes in the current and subsequent River Basin Management Plans. Surveillance monitoring should be undertaken for at least a period of one year during the period of a River Basin Management Plan. The deadline for the first River Basin Management Plan is 22 December 2009. The monitoring programmes have to start by 22 December 2006 at the latest.

Two sampling sites should be established within Kalimok-Brushlen pilot site for long-term monitoring of Danube River status and one for monitoring a typical wetland site (the most important representative sampling sites):

Surveillance monitoring stations in the Danube River:

- D1 before Kalimok-Brushlen pilot site (after Mishka Island); and
- D5 after Kalimok-Brushlen pilot site (Tutrakan town before sewerage collectors).

Surveillance monitoring station inside Kalimok-Brushlen pilot site:

- B3 the area of East abandoned fish ponds.

Operational monitoring

The objectives of operational monitoring are to:

- Establish the status of those bodies (including, where appropriate, riverine wetlands) identified as being at risk of failing to meet their environmental objectives as set out by the WFD; and
- Assess any changes in the status of such bodies resulting from the Programmes of Measures (implementation monitoring after restoration activities).

Operational monitoring (or in some cases investigative monitoring) will be used to establish or confirm the status of bodies thought to be at risk or at serious changes. It is operational monitoring that will be used to classify the status of those water bodies included in operational monitoring. Operational monitoring should be focused on parameters indicative of the quality elements most sensitive to the pressures to which the water body or bodies are subject.

Operational monitoring stations in Danube River:

- D2 beside inlet channel of K/B wetland;
- D3 beside inlet/outlet channel of K/B wetland;
- D4 beside outlet channel of K/B wetland.

Operational monitoring stations in Kalimok-Brushlen pilot site :

- A1 irrigation canal near Brushlen marsh;
- A2 drainage canal connected to inflow point (inlet channel) of the wetland;
- A3 drainage canal connected to inflow/outflow point (inlet/outlet channel) of the wetland;
- A4 drainage canal connected to outflow point (outlet channel) of the wetland;
- A5 drainage canal in Eastern part of Kalimok marsh, collecting drainage water from surrounding agricultural area;
- A6 drainage canal (former Tarchila Stream) collecting drainage water from the area of Staro selo village;
- A7 main drainage canal comes from Western agricultural area (the area of Babovo, Ryahovo, Slivo pole)
- B1 Brushlen Marsh;
- B2 Kalimok Marsh (abandoned West fish-ponds).

With regard to operational groundwater monitoring stations, all the groundwater-monitoring wells are located in southern inland zone of the Kalimok-Brushlen pilot site to evaluate the groundwater quantitative status (groundwater level) and nutrient status (mainly nitrates). The number of monitoring wells should be précised at first stage of the EU PHARE project.

There are 157 observation wells arranged in 29 groundwater profiles related to K/B protected area. Seven profiles will be flooded after wetland restoration. Ten wells are proposed for regular monitoring of groundwater in the project area (I. Nachkov, Modev S., Galabov M., Slavov V., *Modeling Report*, August 2002).

It is proposed that monitoring of groundwater quality should be implemented using four wells at minimum. The selection of groundwater sampling sites is a crucial part of the monitoring program because of the existing potential risk of the groundwater level rising in neighboring arable lands. Clarification of this issue should be done through detailed future investigations.

Investigative monitoring

Investigative monitoring may also be required in specified cases. These are given as:

- where the reason for any exceedences (of environmental objectives) is unknown;
- where surveillance monitoring indicates that the objectives set under Article 4 of WFD for a body of water are not likely to be achieved and operational monitoring has not already been established, in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives; or
- to ascertain the magnitude and impacts of accidental cases.

The results of the monitoring would then be used to inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures necessary to remedy the effects of accidental events. Investigative monitoring will thus be designed to the specific case or problem being investigated. In some cases it will be more intensive in terms of monitoring frequencies and focused on particular water bodies or parts of water bodies, and on relevant quality elements.

As an example, ecotoxicological monitoring and assessments methods would in some cases be appropriate for investigative monitoring. Investigative monitoring might also include alarm or early warning monitoring, for example, against accidental pollution. This type of monitoring could be considered as part of the programmes of measures required by Article 11.3.1 of the WFD and could include continuous or semi-continuous measurements of a few chemical (such as dissolved oxygen) and/or biological (such as fish) determinands.

Investigative monitoring programs are very specific and it is very difficult to determine all this activities within the Kalimok-Brushlen pilot site at this phase. Investigative monitoring ensures a flexibility of monitoring activities when other monitoring tools are too fixed.

Some potential investigative monitoring programs are presented in Table 7.4.

Table 7.4: Potential subjects, sites and methods for investigative monitoring programmes within the Kalimok-Brushlen pilot site

Investigation	Parameters	Sites and methods
Habitat monitoring and assessment	Land cover Structure, zonation, composition, condition, function of riparian vegetation Changes in time (succession, colonization, extirpation, etc.)	Whole project area (remote sensing methods, field mapping) Selected monitoring polygons (field investigations)
Fish monitoring	Anadromous and resident species (specific populations and life stages, number of outmigrating smolts, number of returning adults, spawning grounds)	Inflow and outflow channels (netting, electro fishing, fish traps/weirs, hydroacoustics, radio tagging) Inside pools (netting, electro fishing)
Indicator species	Indicators for each habitat type and for restoration success (selected species of aquatic invertebrates, algae, plants, fish, birds, mammals)	Field investigations (observations) within the whole project area or using standard observation routes and a set of monitoring polygons
Areas of hypoxia/anoxia or algae blooms in summer period	Oxygen conditions, pH, hydrogen sulfide, macroinvertebrates, dead fish cases, bad smell, chlorophyll a, phytoplankton (composition, biomass, presence of nuisance or toxic species)	Whole project area and/or specific, ponds and pools (portable oxygen/pH meters, investigations, observations, mapping in ha)
Sedimentation and sediment transport	Morphological conditions, bank and channel structure, pond depth variations, quantity of in-coming sediments and out-going sediments, amount and size distribution of large woody debris (i.e., fallen trees);	Ponds and pools (depth profiles); Selected monitoring polygons (sediment types, particular size, profiles) Inflow and outflow channels (structure) Flood debris and bed material load (observations)
Bank stability and erosion		All banks (observations)

7.5. Site selection

The selection of sampling sites is a critical part of a monitoring design. Sample sites normally represent a point in space and provide direct information only on what is happening at that point. Therefore a key objective of site selection is to choose a site that gives information that is representative of conditions throughout a particular type or area of wetlands. Because Kalimok-Brushlen pilot site is hydrologically complex, it is essential to have a fundamental understanding of the area of interest - in this case, the nutrient removal capacity and nutrient transformation process in wetlands - to make this determination.

The following criteria are proposed for monitoring site selection:

- Sites must be accessible, preferable under a full range of potential water and habitat conditions;
- Align water quality sample sites with locations at which flow or water level can be accurately gauged;
- Sites should be representative for the area and wide range of conditions;
- It should select key elements for wetland like inflow/outflow channels, adjoining part of main watercourse (Danube River), the major ponds within the wetland, main infrastructure elements (drainage canals, irrigation canals);
- Monitoring sites have to provide reliable information, which can be interpreted in the field of assessment of nutrient removal capacity;
- Sites should locate in such way to reflect the integrity of waters and wetland ecosystem; and
- Cost-effectiveness of monitoring network designation.

Within the scope of Phase 1 of Output 4.3 field investigations for monitoring site selection have not been possible. A draft list of sites has been proposed by local consultants (Table 7.5). Forthcoming studies within the framework of the EU PHARE project will precise and fix the proper location of each monitoring stations by detailed field investigations.

Table 7.5: Draft list of monitoring sites within the Kalimok-Brushlen pilot site*

No	Code	Location	Type of water body	Monitoring type	Situation after restoration
1	A1	Near Brushlen marsh	Irrigation canal Temporary body	Operational	Irrigation canal Temporary body
2	A2	Canal connected to inflow point (inlet channel)	Drainage canal Permanent body	Operational	Margin of flood area Permanent body
3	A3	Canal connected to inflow/outflow point (inlet/outlet channel)	Drainage canal Permanent body	Operational	Margin of flood area Permanent body
4	A4	Canal connected to outflow point (outlet channel)	Drainage canal Permanent body	Operational	Margin of flood area Permanent body
5	A5	Canal in Eastern part of Kalimok marsh, collecting drainage water from surrounding agricultural area;	Drainage canal Permanent body	Operational	Flood area Permanent body
6	A6	Canal (former Tarchila Stream) collecting drainage water from the area of Staro selo village;	Drainage canal Permanent body	Operational	Drainage canal Permanent body
7	A7	Main drainage canal comes from Western agricultural area (the area of Babovo, Ryahovo, Slivo pole)	Drainage canal Permanent body	Operational	Drainage canal Permanent body
8	B1	Brushlen Marsh;	Marsh Temporary body	Operational	Marsh Permanent body
9	B2	Kalimok Marsh (abandoned West fish-ponds)	Fish pond Temporary body	Operational	Flood pond Permanent body
10	B3	Kalimok marsh (the area of East abandoned fish ponds)	Fish pond Temporary body	Surveillance	Flood pond Permanent body
11	D1	Before K/B wetlands (after Mishka Island)	Danube River	Surveillance	Danube River
12	D2	Beside inlet channel of K/B wetland	Danube River	Operational	Danube River
13	D3	Beside inlet/outlet channel of K/B wetland	Danube River	Operational	Danube River
14	D4	Beside outlet channel of K/B wetland	Danube River branch	Operational	Danube River branch

No	Code	Location	Type of water body	Monitoring type	Situation after restoration
15	D5	After K/B wetlands (Tutrakan town before sewerage collectors)	Danube River	Surveillance	Danube River
16	Groundwater monitoring stations – to be specified (EU PHARE project)		Groundwater	Operational	Groundwater

7.6. Monitoring strategy

Establishing a monitoring network within Kalimok-Brushlen pilot site

All types of water bodies should be covered by a comprehensive monitoring network in compliance with EU requirements (WFD, Habitats Directive, Nitrates Directive, etc.) and international requirements (e.g. Danube River Protection Convention, Helsinki Convention, Ramsar Convention).

The existing monitoring network of off-wetland monitoring stations (gauging stations, meteorological stations and water quality monitoring sites throughout the Danube River that are part of the Bulgarian national monitoring system) should be used wherever possible. However a preliminary inventory and assessment of all the proposed sampling sites should be undertaken to ensure that the locations of existing sampling sites are appropriate. For each monitoring station, a "passport" should be prepared that describes in electronic format general information about coordinates, a description of land use/land cover, habitat type, etc. In doing this, the general requirements of the European Environmental Agency for monitoring stations should be adhered to.

Integral nutrient monitoring network depends on simultaneously involving of adjoining Danube River stretch, inlet/outlet channels, flood area, ponds/pool, drainage canals, ground water table. As essential part of this approach is the balance between five monitoring components: the river, inlet/outlet channels, wetland areas, the groundwater table and drainage/irrigation canals. Therefore, additional operational sampling sites should be established in the most representative wetland habitat types within the Kalimok-Brushlen pilot site. A map is presented in Annex 7 of this report – an example to visualize the monitoring network. The designation of the monitoring network should be finalised after detailed field investigation and assessment of factors such as habitat distribution, hydrological regime, capacity needs of monitoring institutions, training needs, equipment needs, financial resources, etc.

Developing the monitoring network

During the first six-year period, initial collection of detailed baseline monitoring information is envisaged. Historical chemical and biological data for this wetland are scare or completely absent. The first stage will therefore include detailed monitoring of the state of the pilot site before restoration as well as initial monitoring after of flooding and flushing processes restoration works are complete.

At least eight, and preferably fifteen, surface-water sampling sites (surveillance + operational) are recommended with a dense sampling frequency. The number of groundwater monitoring wells will be at least 4 for nutrients and about 10 for ground water level.

After the first six year period, a comprehensive assessment of the monitoring scheme should be undertaken and recommendations made for revision/optimization. Operational monitoring networks should be relatively flexible regarding sampling sites, parameters and frequency. The final monitoring design will depend on the outcome of restoration activities, the state of affected areas and many other factors, which should be identified *in situ*.

A similarly flexible approach should be applied in implementation of the investigative monitoring. At first, investigative monitoring should be undertaken for a limited number of problematic issues. Detailed investigative assessments should then inform the future design of the operational monitoring scheme.

Sampling and nutrient analyses

Sampling design should concentrate in two main periods of the year:

- Flood periods during which hydrological and nutrient dynamics are at a maximum - a dense sampling programme should be followed including corresponding samples from inlets and outlets and assessment of nutrient loads; and
- Low water period during which hydrological and nutrient dynamics are at a minmum and nutrient enrichment may occur due to algae/macrophyte blooms - low sampling frequency is necessary (1-2 times per month, only from permanent ponds within the wetland).
- With regard to analytical monitoring techniques, the use of portable equipment is strongly recommended for measurement on-site of parameters such as nutrients, chlorophyll, turbidity, conductivity, dissolved oxygen, pH, etc.

7.7. What to monitor: suggested quality elements

Monitoring quality elements according to the WFD

Following from the *Wetlands Horizontal Guidance*, Table 7.6 shows the quality elements set out in Annex V of the WFD that are related directly or indirectly to assessment of the status and functions wetlands, with specific regard to nutrient removal capacities.

Table 7.6: Ecological, hydromorphological and physico-chemical quality elements relating to wetlands (from Annex V of the WFD and the *Wetlands Horizontal Guidance*)

Rivers	Lakes (including wetland ponds and pools)
Biological quality elements	
Composition and abundance of aquatic flora Composition and abundance of benthic invertebrate fauna Composition, abundance and age structure of fish fauna	Composition, abundance and biomass of phytoplankton Composition and abundance of other aquatic flora Composition and abundance of benthic invertebrate fauna Composition, abundance and age structure of fish fauna
Hydromorphological quality elements supporting the biological quality elements	
Quantity and dynamics of water flow Connection to groundwater bodies River depth and width variation Structure and substrate of the river bed Structure of the riparian zone	Quantity and dynamics of water flow Residence time Connection to groundwater bodies Pond depth variation Quantity, structure and substrate of the pond bed Structure of the pond shore
Physico-chemical quality elements supporting the biological quality elements	
Thermal conditions Oxygenation conditions Acidification status Nutrient conditions Pollution by all priority substances identified as being discharged into the body of water Pollution of other substances identified as being discharged in significant quantities into the body of water	Transparency Thermal conditions Oxygenation conditions Acidification status Nutrient conditions Pollution by all priority substances identified as being discharged into the body of water Pollution of other substances identified as being discharged in significant quantities into the body of water

From this, Table 7.7 suggests a minimum list of monitoring parameters for the surveillance monitoring and operational monitoring of rivers and lakes/ponds in accordance to the WFD:

Table 7.7: Suggested list of parameters for monitoring the Kalimok-Brushlen pilot site

QUALITY ELEMENTS	PARAMETERS	RIVERS	LAKES/PONDS
		Frequency (per year)	
Biological			
Phytoplankton	Total Abundance (Number of cells/l),	-	7
	Key Groups/Taxa Abundance %	-	7
	Biomass, mg/l	-	7
	Bloom frequency/intensity ha, dominant species	-	Non-flooded period
	Chlorophyll a, µg/l (mg/m^3)	25	25
Other aquatic flora macroalgae/ angiosperms (Phytobenthos)	Composition (Biodiversity)	1	1
	Abundance	1	1
	Presence of indicator taxa	1	1
	Spatial distribution/cover,	1	1
Macro invertebrates	Abundance	1	1
	Composition/Diversity	1	1
	Presence of indicator taxa	1	1
	Biomass g/m^2	1	1
Fish	Abundance	Flood period	1
	Species composition	Flood period	1
	Life cycle/age structure	Flood period	1
	Spawning ground habitats	-	1
	Biomass, kg/ha	-	1
	No outmigrating smolts	Flood period	-
	Bioacumulation/bioassay	3 year	3 year
Hydromorphological			
Quantity and dynamics of water flow	Modeled flows	Flood period	Flood period
	Real time flows	Flood period	Flood period
Connection to groundwater bodies	Water table height	-	4
	Surface water discharge	-	Modeling
Residence time	Inflow/outflow	-	Flood period
Morphology	Depth variation	Continuous	Continuous
	Structure and substrate of bottom	2 years	2 years
	Length of permanent pond shores	2 years	2 years
	Vegetation cover	2 years	2 years
	Bank features	2 years	2 years
	Current velocity	Flood period	-
	Channel patterns	2 year	-
Physico-Chemical			
Thermal conditions	Temperature, ^{0}C	25	25
Oxygenation conditions	Dissolved Oxygen, mg/ l	25	25
	Oxygen Saturation, %	25	25
Other	TDS, mg/l	25	25
	Conductivity, ? S/cm^2	25	25
Nutrient conditions	Total Phosphorus, mg/l	25	25
	Soluble Reactive Phosphorus, mg/l	25	25
	Total Nitrogen, mg/l	25	25
	Phosphate, PO_4-P, mg/l	25	25
	Nitrate, NO_3-N, mg/l	25	25
	Nitrite, NO_2-N, mg/l	25	25
	Ammonium, NH_4-N, mg/l	25	25
Transparency	Suspended solids, mg/l	25	25
	Turbidity, FNU	25	25
	Color	25	25
Other Pollutants *	To be specified	4	4
Priority Substances **	To be specified	1	1

* Other pollutants specified in ANNEX VIII Indicative List of the Main Pollutants of the WFD (see below)
** Priority Substances specified in ANNEX X of the WFD
Mandatory quality elements specified in ANNEX V of the WFD
Recommended quality element

Additional monitoring elements

Many useful additional quality elements and parameters related indirectly to the nutrient issues are not presented in the WFD but should still be monitored. These relate to surface waters (Table 7.8) and groundwater (Table 7.9). Note that Total Nitrogen (TN), Total Phosphorus (TP) and Total Organic Carbon/Dissolved Organic Carbon (TOC/DOC) have been excluded from the suggested additional groundwater quality elements because of the significant expenses.

Table 7.8: Suggested additional surface water quality elements for monitoring in Kalimok-Brushlen pilot site

Element	Parameter	Dimension	Frequency (per year)
Habitat distribution and changes (EUNIS)	Remote sensing/ main vegetation type mapping	ha	1
Nutrients in sediments	Total Nitrogen in sediments	mg/kg	1
	Total Phosphorus in sediments	mg/kg	1
	TOC in sediments	mg/kg	1
Areas of hypoxia/anoxia	Dissolved Oxygen/ Oxygen Saturation	mg/l %	Low water level period
	Hydrogen Sulphide, H_2S	mg/l	Low water level period
	Death Fish cases	Number and distribution of dead fish, species	-
	Macroinvertebrate	Absence or only tolerant taxa	1
Large debris	Amount and size of large woody debris	Number	1
Bank erosion	Bank erosion	m^3	1

Table 7.9: Suggested additional groundwater quality elements for monitoring in Kalimok-Brushlen pilot site

No	Parameter	Dimension	Frequency (per year)
1	Nitrate Nitrogen, NO_3-N	mg/l	4
2	Ammonium Nitrogen, NH_4-N	mg/l	4
3	Phosphates, PO_4-P	mg/l	4
4	Dissolved Oxygen	mg/l	4
5	pH	mg/l	4
6	Conductivity	µS/cm	4
7	Total Dissolved Solids, TDS	mg/l	4
8	Temperature	^{O}C	4

7.8. When to monitor: frequency

Some quality elements will be exhibit variation due to natural and anthropogenic influences. In addition, variability due to sampling error must be guarded against. The confidence and precision achieved by monitoring at any particular monitoring site will depend partly on the variability (both natural and resulting from anthropogenic activities) of the determinand being measured, and the frequency of monitoring.

The following paragraphs summarise recommendations for sampling frequency of individual quality elements.

CONTINUOUS MEASUREMENT

Quality elements:	Water level (during flood period)
Component:	Surface waters
Specifics:	Water level will be measured by automatic limnigraphs with data -loggers.
Comments:	Water level is extremely important for proper flood management of K/B wetland.

ANNUAL FREQUENCY: 25 TIMES

Parameters:	Total Phosphorus (TP), Soluble Reactive Phosphorus (TP filtered), Phosphates (PO_4-P), Total Nitrogen (TN), Nitrate Nitrogen (NO_3-N), Nitrite Nitrogen (NO_2-N), Ammonium Nitrogen (NH_4-N), Temperature, Dissolved Oxygen, Oxygen Saturation, pH, Conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Turbidity, Color, Chlorophyll A.
Component:	Surface waters (all sampling sites)
Specifics:	Irregular sampling – intensive sampling (3-4 times or more per week) during flood period (2-3 months); one per month during non-flood period.
Comments:	These parameters together with water level/water flow are the most important to assess the nutrient load to wetland, nutrient removal/trapping, nutrient status, etc. It needs to sample very intensively during flood period. These parameters will measure with monthly frequency only in permanent ponds and pools in non-flood (dry) period of the year.

SAMPLING DURING A LIMITED PERIOD OF THE YEAR:

Parameters:	Algae Blooms, Fish (abundance, composition, life cycle/age structure, No of out-migrating smolts), Residence Time, Current Velocity, and Areas of hypoxia/anoxia.
Component:	Surface waters
Specifics:	Algae Blooms and Areas of Hypoxia/anoxia will assess during summer period in isolated ponds, while Fish parameters, Residence Time, and Current Velocity will measure in flood period.
Comments:	Algae blooms and fish parameters depend very much on nutrient status.

ANNUAL FREQUENCY: 7 TIMES

Parameters:	Phytoplankton - Total Abundance (Number of cells/l), Key Groups/Taxa Abundance % Biomass, mg/l
Component:	Standing surface waters
Specifics:	Developing of phytoplankton communities are response of nutrient contents.
Comments:	Algae are the key factor, which could compromise the nutrient removal capacity of the Kalimok/Brushlen wetlands.

ANNUAL FREQUENCY: 4 TIMES

Parameters:	Groundwater level, Phosphates (PO4-P), Nitrate Nitrogen (NO3-N), Ammonium Nitrogen (NH4-N), Temperature, Dissolved Oxygen, Oxygen Saturation, pH, Conductivity, Total Dissolved Solids (TDS). Other pollutants specified in ANNEX VIII Indicative List of the Main Pollutants of the WFD 2000/60/EC. (surface waters).

Component: Groundwater table

Specifics: All the groundwater samples will be taken seasonally to assess the water quality.

Comments: This groundwater-monitoring network does not cover the potential affected agricultural areas, where it is necessary to be carried out continuous intensive monitoring of groundwater level during flood period.

ANNUAL FREQUENCY: 1 TIME OR LESS

Parameters: Macrophytes (composition, biodiversity, abundance, presence of indicator taxa, spatial distribution/cover), Macroinvertebrates (abundance, composition/diversity, presence of indicator taxa, biomass), Fish parameters for wetland ponds, Bioaccumulation/bioassay (3 year), Morphological parameters (structure of bottom, bottom substrata, length of permanent pond shores, vegetation cover, bank features, channel pattern) (2 years), Priority Substances specified in ANNEX X of the WFD 2000/60/EC, Habitat distribution and changes (EUNIS), Nutrients in sediments (Total Nitrogen, Total Phosphorus, TOC), Large Debris, Bank Erosion.

Component: Surface waters

Specifics: All of these parameters are typical long-term indicators.

Comments: Most of parameters are costly and slowly changeable.

7.9. Sampling procedures and techniques

General principles and sampling for physico-chemical parameters

The general requirements of sampling are described in international standards[62]. These standards should be followed when establishing and developing the monitoring and assessment scheme at Kalimok-Brushlen pilot site.

Table 7.11 describes the quality elements and parameters to be measured *in situ* without sampling (using special field/portable devices).

Table 7.11: Parameters and quality elements to be measured *in situ* at Kalimok-Brushlen pilot site

Parameter	Analytical Device	Media	Application
Geographic coordinates (location), dd/mm.mmm	GPS with GIS platform	Air, surface area	Mapping, Identification of locations
Pictures	Digital camera	Air, surface area	Documentation of observations, Mapping (satellite images, aerial pictures)
Observations, field protocols	Non or binoculars	Surface area	Registration, mapping, etc.; macrophytes, birds, mammals, tree communities, habitats, etc.
Temperature, ^{0}C	Thermometer	Water, air	Thermal condition in surface waters, groundwater, air, etc.
Dissolved Oxygen, mg/l	Oxygen meter	Water	Oxygen condition in surface waters and groundwater.
Oxygen Saturation, %	Oxygen meter	Water	Oxygen condition in surface waters and groundwater.

[62] See http://www.iso.ch/iso/en

Parameter	Analytical Device	Media	Application
pH	pH meter	Water	Acidification status of surface waters and groundwater.
Conductivity, µS/cm	Conductivity meter	Water	Dissolved Solids (Ions) in water.
TDS, mg/l	Conductivity meter	Water	Dissolved Solids (Ions) in water.
Turbidity, FNU	Turbidimeter, Photometer	Surface water	Depends on suspended solids and phytoplankton contents.
Color, Pt scale	Non	Surface water	Assessment of phytoplankton growth
Chlorophyll A, µg/l	Flurometer	Surface water	Assessment of phytoplankton growth

The surface waters within the Kalimok-Brushlen pilot site area are very shallow (average depth: 0.46 m) thus all surface water samples should be taken from the water surface (0.10-0.20 m). All nutrients should be analyzed using samples without preservation. Transportation time will be up to 2-3 hours to locally installed field photometers equipped with digestion unit (TN, TP, TP filtered). The preservation of nutrient samples should be undertaken only in the case of quality control and analytical quality assurance procedures (intercalibration programs, ring-tests, split samples). Only total suspended solids (TSS) should be analyzed in the laboratory. There are no special requirements for sampling containers, handling, preservation or transportation time.

Sampling procedure for phytoplankton

The sample should be collected directly, without previous filtration, in a glass container, preferably of brown color. For sampling in easily accessible shallow waters like in Kalimok-Brushlen pilot site, the container can be filled directly by dipping the container about 20-25 cm below the water surface. Sample volume should be 0.25-0.5 l or more, depending on trophic conditions. Standard Plankton nets can be used (i.e. *Apstain* type, mesh-size 25-50 µm) for qualitative samples in deeper ponds/canals within the K/B wetland and in the Danube River itself.

Plankton samples can be analyzed alive or after fixing. Live samples are preferable for many cases and the containers should not be completely filled. Part of the container should be left empty to ensure enough oxygen and to prevent the suffocation of plankton microorganisms. Live samples should be refrigerated, preferable left open, in the dark, and immediately sent to the laboratory. For non-living samples, the samples should be fixed using different preservatives depending on the type of the plankton microorganisms (lugol solution or 4% formaldehyde).

Sampling procedure for macrophytes

Manual collection of samples is recommended. Conditions are ideal at Kalimok-Brushlen pilot site for collecting macrophytes by hand because low water depth, transparency, comfortable summer/autumn temperature and the absence of strong flow. Rakes with handles of different lengths and forceps can be useful for collecting macrophytes. Handnets with rectangular frames, a sharp cutting bottom side and large mesh-size (1-8cm) may also be used. When quantitative samples are needed iron frames can be used (i.e. 0.40 x 0.40m) or Surber samplers/Core samplers in flowing waters.

Once samples have been obtained, then should be prepared, mounted and identified. Fresh samples should be used for identification when possible. Immature plants or plants without flowers should be avoided. Aquatic plants contain a high percentage of water (80-95% of weight) so after collection they should be wrapped in several thickness of paper towel and dipped in water. Plants can be kept at 4 ^{0}C for several days. A wet mount should be prepared by introducing the sample in a glass flask with a airtight cap. The preservation medium should be 2.5 - 4% formaldehyde with a small amount of copper powder. After draining excess water, the drained samples should be wrapped in wax paper to keep the plant from adhering to the drying sheets. Then the plant should be pressed for 3-5 days, changing the drying paper every two days until the samples are dry.

Sampling procedure for benthic macroinvertebrates

Sampling techniques, interpretation and presentation of biological data are well developed for macroinvertebrates (including several ISO standards). The most widely used semi-quantitative technique in shallow waters (less than 1 m deep) such as Kalimok-Brushlen pilot site is the handnet (ISO 7828:1985). The handle is 1.5 - 2m long and mesh-size is 300-500μm. Generally, each sampling collection takes about 5 minutes. Before sampling, the different microhabitats present in the sampling site should be identified and described in a field protocol. These microhabitats are defined by water depth (shallow-deep), water velocity rate (fast, medium, slow, still waters, riffle sites, non-riffle sites), bottom substratum (rocks, small stones, gravel, coarse sand, fine sand, mud and silt), and type of weeds (hydrophytes, helophytes, emergent plants). There are three main sampling techniques using handnet: (i) kick sampling; (ii) stone washing; (iii) weed washing. Quantitative macroinvertebrate sampling can be undertaken using a Surber sampler (square rake, 30.5 x 30.5 cm) or core sampler (0.1 m^2 or 0.05 m^2 and cylindrical in shape). Both samplers are suitable for the Kalimok-Brushlen pilot site.

Sampling procedure for fish monitoring

Issues for fish monitoring include:

- Fishway counts;
- Estimation of fish populations;
- Timing of migration between observation points; and
- Fish kills.

With regard to fishway counts, nets can be used as static traps or active scoop and tow devices. Static methods are the most appropriate for the Kalimok-Brushlen pilot site. Fish traps and weirs are used in depths of less than 3 m. These nets are suitable for big fish and live captures. In addition, dumps - stationary traps - could be placed on inlet/outlet structures of the riverine wetlands to guide fish to the place where samples are taken. Active netting may be used in shallow waters for qualitative analyses of fish and catching of small fish and smolts, e.g. trammel nets composed of three net “layers” that are arrayed to entangle the fish. Another approach is to use hydroacoustics (sonars) mounted in standard profile along the inflow/outflow channels of wetlands to count big fish local migration. Electrofishing is particularly useful method for fish monitoring in rivers, channels, canals and some limited shallow standing water bodies. This technique is not selective in terms of the size or type of fish captures.

The methods used for estimation of fish population include redd counts, creel census and direct counts of spawning adults. Key factors for successful estimation/counting are availability of enough trained observers, good coordination, appropriate timing of observations and good field protocols.

Local migrations are extremely important to assess incoming and outgoing fish movements in riparian wetlands and, consequently, to estimating nutrient removal in riverine wetlands through sustainable fisheries. This may be particularly important for phosphorus levels. The best method for observation of local fish migration is tagging. Fish tagging could carry out by pit tags, radio tagging, dyes and other external marks or computer-coded tags (bar-codes). These options should be explored in the Kalimok-Brushlen pilot site but may be expensive and time-consuming.

Large fish kill events within the riverine wetlands are undesirable from the point of view of nutrient removal and nutrient trapping. When the aim of sampling is to analyze fish kills, samples should be made of fish that have recently died or are dying. The number of dead or affected fish should be estimated in relation to numbers of healthy fish.

Habitats and vegetation characteristics

The use of remote sensing (aerial pictures, satellite images) is recommended for assessment of habitats and vegetation type in Kalimok-Brushlen pilot site. Spatial distribution of main vegetation types should be check *in situ* using transects (radial or parallel) and monitoring polygons. Field studies of habitats are important for verification of information obtained by remote sensing methods. The design of a sampling and observation programme, the use of standard field protocols and good identification keys are essential tools.

Water level and flow

Measurements of flow and water levels in wetlands and aquifers are critical for evaluating the ecological quality of wetlands. The continuous control of water level is essential for the management of the pilot site and the determination of flow is needed to assess nutrient input loads.

At each inflow/outflow channel of the Kalimok-Brushlen pilot site, automatic limnimeters (limnigraphs) should be installed. These three limnimeters will be placed in known cross-section profiles for water quantity measurement and equipped with dataloggers. In addition, several limnimetric rules (gauges mounted on a support and fixed to the ground) should be mounted within the flood area. With this simple visual method, the water level can be monitored accurately, usually every week, or more frequently in the case of exceptional events (floods, unusual inflows or outflows) in different parts of the pilot site.

Groundwater measurements are an important element of the pilot site measurements because the surface water level in the wetland depends, *inter alia*, on aquifer input and output processes. As a minimum, ten sites should be equipped with piezometers preferably with a system to enable sampling for water quality. Piezometric level of aquifers should be measure at least four times during sampling procedure for water quality. To prevent surrounding agricultural fields and infrastructure against flooding caused by groundwater level rising, the number of piezometers and monitoring frequency could be exceeded, depending on assessment of the potential risk for neighboring areas.

7.10. Analytical methods and monitoring equipment

The most cost-effective approach for determination of nutrients is to use the field photometers on site. The advantages of field measuring devices are:

- Reduced transportation time;
- Sufficient accuracy;
- Potential for analytical quality control;
- Reduced effort and financial demands for maintenance of expensive analytical laboratory;
- Low price per analysis; and
- Easy operation and user-friendly functions.

Many firms provide such type of field analytical equipment at reasonable prices (e.g. Merck, WTW, Dr Lange, Hach, etc.). In addition, on-site analytical equipment is available for continuous on-line measurement of some nutrient forms. The resolution for nutrients of most of on-line instruments is too high and/or investment and operational costs are significant. These factors may mitigate against their use in Kalimok-Brushlen pilot site.

Table 7.12 provides an indication of analytical methods, monitoring equipment needs and costs for monitoring and assessment of quality elements related to nutrient removal in the Kalimok-Brushlen riverine wetlands.

Table 7.12: Analytical methods, monitoring equipment needs and costs for quality elements related to nutrient removal in riverine wetlands

Parameter	Limit of determination	Method description	Type of measurement/ Equipment	Time for analysis	Price per determination, EUR*
Ammonium (NH_4-**N**)	0,010 mg/l	Ammonium nitrogen NH_4-**N** occurs partly in the form of ammonium ions and partly as ammonia. A pH-dependent equilibrium exists between the two forms. In strongly alkaline solutions NH_4-**N** is present almost entirely as ammonia, which reacts with hypochlorite ions to form monochloramine. This in turn reacts with a substituted phenol to form a blue indophenol, the concentration of which is determined photometrically. The method is analogous to EPA 350.1, US Standard Methods 4500-NH3 D, and ISO 7150/1.	Photometric/ Field research photometer	20 min	0,36
Nitrate (NO_3-N)	0,10 mg/l	In a solution acidified with sulfuric and phosphoric acid, nitrate reacts with 2,6-dimethylphenol to form orange-colored 4-nitro-2,6-dimethylphenol that is determined photometrically. The method is analogous to DIN 38405 D9 and ISO 7890/1.	Photometric/ Field research photometer	20 min	0,94
Nitrite (NO_2-N)	0,005 mg/l	Nitrite ions react with sulfanilic acid in acidic solution to form a diazonium salt, which in turn reacts with N-(1-naphthyl)ethylenediamine dihydrochloride to form a red-violet azo dye. The dye is determined photometrically. The method is analogous to EPA 354.1, US Standard Methods 4500-NO2 – B, EN 26 777, and ISO 6777	Photometric/ Field research photometer	20 min	0,5
Phosphate (PO_4-P)	0,010 mg/l	In a solution acidified with sulfuric acid, orthophosphate ions react with molybdate ions to form molybdophosphoric acid. Ascorbic acid reduces this to phosphomolybdenum blue (PMB), the concentration of which is determined photo-metrically. The method is analogous to EPA 365.2+3, US Standard Methods 4500-P E, EN 1189, and ISO 6878/1.	Photometric/ Field research photometer	10 min	0,38
Total Nitrogen (N total)	0,5 mg/l	Organic and inorganic nitrogen compounds are transformed into nitrate according to Koroleff's method by treatment with an oxidizing agent in a thermoreactor or in a microwave digestion unit. In a solution acidified with sulfuric and phosphoric acid, this nitrate reacts with 2,6-dimethylphenol (DMP) to form orange-coloured 4-nitro-2,6-dimethylphenol that is determined photometrically. The digestion is analogous to EN ISO 11905-1. The determination of nitrate is	Photometric/ Field research photometer + digestion unit (thermoreactor)	96 min	3,12

Parameter	Limit of determination	Method description	Type of measurement/ Equipment	Time for analysis	Price per determination, EUR*
		analogous to ISO 7890/1.			
Total Phosphorus (P total)	0,5 mg/l	In a solution acidified with sulfuric acid, orthophosphate ions react with molybdate ions to form molybdophosphoric acid. Ascorbic acid reduces this to phos-phomolybdenum blue (PMB), which is then determined photometrically. The method is analogous to EPA 365.2+3, US Standard Methods 4500-P E and ISO 6978/1.	Photometric/ Field research photometer + digestion unit (thermoreactor)	57 min	2,68
Chemical Oxygen Demand (COD)	4 mg/l	The water sample is oxidized with a hot sulfuric solution of potassium dichromate, with silver sulfate as catalyst. Chloride is masked with mercury sulfate. The concentration of unconsumed yellow Cr2O7 2- ions is then determined photometrically. The method is analogous to EPA 410.4, US Standard Methods 5220 D, and ISO 6060. The COD (chemical oxygen demand) expresses the amount of oxygen originating from potassium dichromate, that reacts with the oxidizable substances contained in 1 l of water under the working conditions of the specified procedure. 1 mol $K_2Cr_2O_7$ is equivalent to 1.5 mol O_2 Results are expressed as mg/l COD (= mg/l O_2)	Photometric/ Field research photometer + digestion unit (thermoreactor)	152 min	2,40

* The price per determination includes only the price for reagents (consumables)

7.11. Organizational aspects

The institutions framework for monitoring

The complex nature of monitoring nutrient removal in riverine wertlands generally, and in Kalimok-Brushlen pilot site specifically, requires collaboration and coordination efforts between different monitoring institutions. The establishment of a small monitoring unit under the management body of the Kalimok-Brushlen Protected Area will ensure the cost-effective approach for implementing a nutrient removal monitoring. This monitoring unit (2-3 part-time trained technicians) will operate with full set of field monitoring instruments on site (field photometers, oxygen meter, pH meter, conductivity meter, flurometer, GPS, etc.).

Specialists from the Regional Environmental Inspectorate of Ruse will support the monitoring activities of the Kalimok-Brushlen pilot site management body. Laboratory analyses will be undertaken in the laboratories of REI of Ruse. The Project Co-ordination Unit of the World Bank/GEF Wetlands restoration and Pollution Reduction Project together with the Danube River Basin Directorate in Pleven, the Ministry of Environment and Waters and the Executive Environmental Agency of Bulgaria in Sofia will supervise and coordinate the monitoring and report to the Output 4.3 project team. Scientific institutions such as the Bulgarian Academy of Science will monitor some quality elements and undertake some analyses (zoological and botanical investigations, estimation of hydrological parameters).

Table 7.13 summarises the insititutional framework for monitoring in Kalimok-Brushlen pilot site.

Table 7.13: The insititutional framework for monitoring in Kalimok-Brushlen pilot site

Institution	Monitoring responsibilities
Output 4.3 Project Team (Vienna)	Overall steering and assessment of riverine wetlands/nutrient reduction monitoring Liaison with UNDP/GEF Links to, and exchange of experience with, other Output 4.3 pilot sites
Kalimok-Brushlen pilot site management body	Sampling and field investigations of nutrients and general physico-chemical parameters; Observations and field surveys concerning habitat types, etc.; Local coordination of monitoring activities.
Regional Environmental Inspectorate (Ruse)	All the laboratory analyses of waters and sediments; Support the field monitoring activities of KBPS management body.
Danube River Basin Directorate (Pleven)	Supervise the water monitoring activities in K/B wetlands; Collect monitoring information for all water issues, data handling and data analysis.
Project Co-ordination Unit World Bank/GEF Project (Sofia)	Coordination and support during first years.
Scientific organizations (BAS, NIMH, etc.)	Implement or develop specific parts of monitoring program (taxonomic analyses, biological monitoring elements, morphological and hydrological monitoring).
Executive Environmental Agency of Bulgaria (Sofia)	Data collection, assessment and reporting.
Ministry of Environment and Waters (Sofia)	General supervision and coordination.

Reporting

All the monitoring documentation (protocols, data, reports) should be collected in a database held in the Kalimok-Brushlen pilot site management body in Tutrakan, the Regional Environmental

Inspectorate in Ruse and the Danube River Basin Directorate in Pleven. The Project Co-ordination nit of the World Bank/GEF Project should support data management during the next three years especially with respect to the development of GIS tools. Monitoring information should be stored in the Kalimok-Brushlen pilot site management body in GIS format. An annual monitoring report will be prepared by a joint group of experts belonging to different organizations (the Outpüut 4.3 project team, the Kalimok-Brushlen pilot site management body, scientific organizations, MoEW, PCU, DRBD, REI of Ruse, EEAB, etc.).

The outputs of the monitoring activities will include:

- GIS database;
- Annual Monitoring Report with assessment and data analysis;
- Comparison with other pilot site(s) established in Phase 2 of Output 4.3 and with other relevant initiatives such as the DANUBS project; and
- A general report and recommendations for using wetlands as tools for reducing nutrient pollution in the Danube and for achieving the environmental objectives set out in the WFD

7.12. Interpretation and assessment

Recommended long-term assessment indicators for the effectiveness of the Kalimok-Brushlen pilot site in reducing nutrient levels in the Danube include the following:

- Duration of flood period (days y^{-1});
- Nutrient loads and removal (nutrients inflow, t y^{-1}; nutrients outflow, t y^{-1});
- TN inflow, t y^{-1}; TN outflow, t y^{-1};
- TP inflow, t y^{-1}; TP outflow, t y^{-1};
- Average self-purification capacity for TN and TP, % (corresponded samples);
- Sediment budget (TSS inflow, t y^{-1}; TSS outflow, t y^{-1}; turbidity, FNU);
- Areas of hypoxia/anoxia in low water period (DO mg l^{-1}, %; H_2S, lack of macroinvertebrates);
- Algae blooms in low water period (color, chlorophyll A, µg l^{-1}; phytoplankton biomass, mg l^{-1}; abundance number of cells l^{-1});
- Fish kills events in low water period (number; affected areas in ha; biomass of dead fish in kg);
- Habitat type/vegetation type changes (EUNIS) in ha;
- Percentage of reed-beds % or ha;
- Vegetation cover / Open water area, %, ha x ha;
- Anadromous and resident fish species (species composition, abundance);
- Number of outmigrating smolts; and
- Amount and size distribution of large woody debris and bed material load;

Interpretation of monitoring data

Interpretation could focus on nutrient input and output loads. This picture will demonstrate how many tones of N and P come in and out the wetlands for a year and, consequently, how many tones of nutrients are trapped in the wetland for a year.

Another approach is to evaluate the self-purification capacity of the wetland expressed as a proportionate reduction in nitrogen concentrations. The critical point is to analyze corresponding samples from inflow channels and outflow channels in relation to the retention time of the wetland.

Thus, if the retention time at a given water level is 15 days, samples should be taken from the inlets after 15 days.

To estimate the self-purification capacity of the wetlands, we propose to use a very simple formula:

$$\text{SPC} = \frac{(L_1 + G + a) - L_2}{L_2} 100\%$$

Where: SPC – self-purification capacity between point 1 and point 2;

L_1 – nutrient load (concentration x water quantity) in the inflow channel;

L_2 – nutrient load in the outflow channel (corresponding sample);

G – nutrient load of groundwater (average value = concentration x 1.73 $m^3\ l^{-1}$ for the case of Kalimok-Brushlen pilot site);

a – coefficient for atmospheric deposition of N and P for the project area

In the short term it is possible that, from a nutrient removal point of view, negative results could found, i.e. output fluxes are proven to be bigger than input fluxes. In such a case, reasons for this should be examined using other monitoring parameters. For instance, it may be that fish kills, toxic pollution, mass algae blooms within the wetland, significant deposits of organic debris from previous floods, acidification or release of P from sediments, influence results. For this reason, it is important that monitoring and assessment is continued for a significant period, i.e. at least two six-year river basin management planning periods.

8. CONCLUSIONS AND RECOMMENDATIONS FOR PHASE 2 ACTIVITIES

8.1. Key lessons

Surface and groundwater fed wetlands influence the patterns of transport, storage and removal of nutrients along the Danube River and its main tributaries. These influences may be considerable but do not always involve permanently removing nutrients.

The relevance of this nutrient removal in riverine wetlands for the nutrient flows to the Black Sea depend to a high extent on the wetland area and - even more important - on the water volume effected by this area. There is no, or little, relevant influence if only small amounts of river discharges are effected by wetland systems even if they are very effectively treated there. Detailed quantitative assessment of the relevance of this influence is not possible yet.

The principle mechanisms whereby nutrients are removed from the river system by wetlands are through denitrification, harvest or increase of standing stocks of plants, and long-term storage in sediments.

In general for P significant storage mainly occurs during deposition of particulate matter in wetlands and floodplains during high water events. For N and dissolved P, the intake via channels at low and average flow conditions and the retention time in the wetland control the potential for removal in wetlands. Denitrification is the primary process in N transformation and removal.

Increasing the nutrient retention capacity of the riverine landscape in total requires using a broad range of retention areas with different hydrologic exchange patterns such as inshore structures, riparian zones, and side-arms which increase the contact area and the affected water volume during long periods of the year and increase the nutrient retention substantially.

It is clear that the role of wetlands (and other influences on transport, storage and removal of instream nutrients) can never substitute measures to reduce or eliminate (potentially involving wetlands) the inputs of nutrients to the river.

In addition to these general lessons it is apparent from the work conducted under this project that:

- There are only a limited number of larger projects worldwide which have attempted to reduce nutrient loads of a river through wetland restoration.
- The Danube region is a leader in the field of large scale wetland restoration for, *inter alia*, nutrient reduction purposes.
- The primary motivation for undertaking wetland restoration has been related to biodiversity conservation and not nutrient removal or storage but the role of wetlands in influencing the transport, storage and removal of nutrients adds a further incentive to undertaking such projects.
- Nutrient removal is only one possible socio-economic benefit from wetland restoration. Others may include flood mitigation, fishery protection, groundwater recharge and tourism. The emphasis of Output 4.3 has been on nutrient reduction but consideration should be given to optimisation of all socio-economic benefits during the design and implementation of wetland restoration projects.
- Information about nutrient removal of wetlands can be obtained from work evaluating constructed wetlands - but such examples should be used with caution in drawing lessons for riverine and other natural wetlands.

- The information on nutrient removal from existing riverine restoration projects has been limited.
- A large number of smaller scale wetland restoration projects have been undertaken to restore wetland habitat along rivers and in river basins and it may be the case that a coordinated series of such measures can have a significant role in reducing or slowing the input of nutrients to the river. Knowledge of this aspect of wetland management is currently very limited.
- There is a need for further examination and definition of the role of wetlands in nutrient removal and storage and in particular the extent to which wetlands play a role in influencing the timing and magnitude of nutrient releases to the Danube and Black Sea.

The pilot monitoring and assessment programmes proposed as part of Output 4.3 will add further understanding to the issues and help refine conservation and restoration strategies for Danube region wetlands. However, it is apparent that isolated projects focusing on wetland restoration for nutrient removal may not be the most effective way to manage nutrients. Rather, there is a need for overall river basin strategies in which appropriate wetland restoration and management could play an important role in improving water quality and general ecological health. The commitment in the DRB to integrated river basin management as required by the EU Water Framework Directive offers the opportunity to incorporate wetland conservation and restoration strategies into river basin management.

8.2. Recommendations for Phase 2 activities

The following actions are recommended:

1. Implement Phase 2 of the project with assessment of nutrient removal capacities of two selected wetland size based on monitoring principles stated in this report. This will strengthen the leading role of the DRB in the understanding of wetland conservation and restoration and the role of wetlands in influencing transport, storage and removal of nutrients through further funding of projects and ensuring more extensive monitoring and assessment of wetland restoration projects.
2. More specifically, the monitoring and assessment programme suggested in Chapter 7 of this report for Kalimok-Brushlen pilot site should proceed, subject to finalisation of details about precise locations of gauging stations etc.
3. The mechanisms for identifying a second pilot site should be taken forward (i.e. discussions with experts from each potential pilot site early in Phase 2 together with site visits if necessary).
4. At the workshop, build a core team of people to steer the work of Phase 2, drawing on experts from potential pilot sites, the Bulgarian pilot site, the existing Output 4.3 team, the ICPDR nutrient experts (TNMN), IAD representatives, and representatives of potential organizational coordinators for the ongoing work (key large wetland national parks i.e. Donau Auen N.P., the Ecological WG of the ICPDR, WWF, or IAD). The workshop should also serve to finalize the assessment strategies for Phase 2 and should be convened before investments are made in the pilot sites.
5. Establish a mechanism to share the knowledge gained from existing projects examining the influence of wetlands on nutrients with both scientists and wetland managers throughout the Danube region and elsewhere. At the wetland manager workshop held in the course of the project it was apparent that overall interest existed on the part of wetland managers to meet more regularly with one another and to exchange information on the role of wetlands

in nutrient management as well as other aspects of wetland management. Throughout the Danube region there are a number of wetland management activities which are being undertaken with only limited accompanying research activities. Integration and combined management and research projects (including the role of wetlands on nutrients) should be encouraged and the synergy between science and management enhanced. This mechanism should be actively involved in an process of defining a DRB wetlands management strategy (see below).

6. Give greater emphasis in Phase 2 to disseminating the results of Output 4.3 so that a larger audience understands and appreciates the issues and processes involved. Considerable progress has been made in expanding the understanding of the role of wetlands in nutrient removal (critical to remember is that this function of wetlands cannot be isolated from the other functions such as biodiversity conservation or flood protection). It is apparent, however, that if further progress is to be made in phase 2 that a longer-term strategy of linking science of nutrient management and wetland management needs to be followed. There appears to be a large opportunity for the Phase 2 programme to both increase the understanding and science related to these issues but also to strengthen institutional mechanisms for exchange and cooperative research along the Danube.

Finally, it is recommended that the ICPDR might usefully consider how to incorporate the results from Output 4.3 into the river basin management planning process. In addition, knowledge from other initiatives is relevant such as the *Wetlands Horizontal Guidance* that has been prepared under the WFD Common Implementation Strategy and recently approved by Member State and Accession Country Water Directors. It is recommended that consideration is given to the preparation of a DRB wetlands management strategy that builds on the knowledge set out in this report, and that available on the other socio-economic and environmental benefits of wetlands.

GLOSSARY

Nutrient Storage - Storage can be considered as temporary (although often long lasting – i.e. years or decades) retention in the wetland system. Main mechanisms and processes that lead to storage are: sedimentation, precipitation, adsorption and filtration to sediments, algae and plant uptake, as well as heterotrophic growth.

Nutrient Retention – The term nutrient retention is often used as a substitute for storage and has a similar meaning.

Nutrient Removal - In contrast to "storage", "removal" is the final elimination of nutrients out of a river by wetland system in a way that no future release from the wetland system to the river will happen. In this sense only denitrification and harvest can be considered as "removal" out of the river and wetland system. Storage (retention) of nutrients over long periods of time (e.g. decades) may also be considered as removal, depending on the time horizons under consideration.

Nutrient Transformation – Are the processes by which nutrients are altered in their state i.e. denitrification or incorporation into plant matter.

Riverine Wetlands - Riverine wetland are those wetlands situated by channels with moving water, and also near deepwater habitats. In some parts the average depth of the channel is at least 2 meters. Here we concentrate on riverine wetlands with connected (currently or formerly) palustrine and/or lacustrine systems in the whole catchment. In this sense it is including also floodplain, even former. We can call it riverine wetland system sensu lato. * A more detailed description and analysis of wetland types is contained in section 7 and provides further detail about the differentiation between types.

Constructed Wetlands – Constructed wetlands are wetlands specifically built to act as natural pollution control plants and are not directly comparable to natural wetlands.

ANNEXES

ANNEX 1: THE OUTPUT 4.3 TEAM AND ACKNOWLEDGEMENTS

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ANNEX 2: INCEPTION REPORT

UNDP-GEF Danube Regional Project

Inception Report

for

DRP Contract RER/01/G32-UNDP Danube Regional Project

"Monitoring and Assessment of Nutrient Removal Capacities of Riverine Wetlands"

(Project Output 4.3)

Submitted by WWF International

Danube Carpathian Programme

October 10, 2002

OBJECTIVE 4: Reinforcement of Monitoring, Evaluation and Information Systems to Control Transboundary Pollution and to Reduce Nutrients and Harmful Substances

Output 4.3: Monitoring and Assessment of Nutrient Removal Capacities of Riverine Wetlands

A Project Objectives

This project is designed to meet the need for a quantified and consistent approach for the appropriate assessment of nutrient removal capacities of (Danube River Basin) DRB wetlands. This work will demonstrate the possibilities for optimizing such processes via better wetland management while still considering other benefits (biodiversity, water purification etc.) and giving priority to the ecological needs of these ecosystems. The project is intended to considerably improve the knowledge about nutrient removal through wetlands rehabilitation and would define the technical and economic parameters for efficient wetlands management. This is intended to further assist in prioritizing wetland rehabilitation projects based on expected nutrient removal benefits. In a broader context, this would support a larger GEF need in the frame of Targeted Research. Considering this, successful results could be disseminated worldwide.

There are numerous wetland rehabilitation activities being undertaken in the DRB, some as part of the GEF Partnership Programme, in which monitoring has been included or is foreseen as a component. Therefore, before initiating a new observation programme, the DRP should first determine and agree upon a common methodology and approach for monitoring wetlands in the DRB. This involves surveying the current monitoring approaches, bringing together experts to determine a harmonized approach and then working to assure that a consistent methodology for measuring nutrient removal in DRB wetlands is implemented.

It is intended that thereafter, the general methodology can be adapted to site specific conditions based on, where appropriate, accepted wetland classification schemes (Ramsar etc.)

In Phase 1 monitoring programmes and techniques will be reviewed, guidelines will be determined and pilot sites selected and prepared before demonstrating an actual observation programme later in Phase 2. Based on the results of Phase 1 and the monitoring programme, opitimized wetland management strategies will be developed in Phase 2.

B Approach of Work and Activities

Three main purposes that have been identified for the work to be completed under phase 1 of this project. These are:

- to evaluate and identify the most effective monitoring strategies and programmes for assessing nutrient removal capacities of wetlands as a basis for DRB guidelines in relation to wetland classification and;
- to identify and prepare pilot activities that will be carried out in phase 2 of the project;
- to set the basis for identifying management measures to optimize the nutrient removal capacity of wetlands in Phase 2 (leading to a DRB wetland management strategy.)

In order to fulfil the objectives and purposes of the project the following tasks have been identified in the inception phase as being necessary:

- To conduct a review of wetland restoration projects that have addressed nutrient removal capacity of riverine wetlands on a global scale (special focus will be given to the methodology used, the costs and the results).

- To review existing projects related to wetland restoration within the Danube River Basin and define how they could provide guidance and information on nutrient removal capacity in relation to their respective classification (i.e Ramsar Wetland Classification.) This activity will be conducted as a deskwork survey as well as involving direct contact with national experts and the project managers of the relevant projects. Special focus will be given to other World Bank UNDP/GEF projects in the Danube Basin.
- Compare the existing projects related to wetland restoration regarding the consistency of the data as well as regarding what additional monitoring could be undertaken with minimal additional investments.
- Develop draft general guidelines for the assessment and monitoring of the nutrient removal capacity in the Danube Basin.
- Pre-select at least two representative pilot sites (of different wetland types according to the Ramsar classification if possible), where analysis of the nutrient removal capacity can be carried out.
- Develop draft specific guidelines and recommendations for the selected pilot sites. Special focus will be given also to the outcomes 1.4 of the project (Concepts and policies for appropriate integrated land use) to ensure that the results of the projects are consistent.
- Organise a workshop including international as well as national experts and representatives of the possible pilot sites to discuss and review both the general guidelines as well as the recommendations given for the pilot sites. This workshop will include also the relevant experts of the ICPDR as well as members of the related expert groups.
- Based on the outcomes of the workshop, finalise the general as well as the specific guidelines and recommendations for the selected pilot projects, including a work plan and a budget for Phase 2 activities.
- Based on the preceeding activities a synthesis report will be written which will include:
    - information on current knowledge of quantitative as well as qualitative removal of nutrients in riverine wetlands (in relation to classification where appropriate),
    - a description of methodological and monitoring approaches (incl. requirements, benefits, costs, constraints etc.),
    - general guidelines and recommendations for the assessment of nutrient removal in Danube Basin,
    - and specific guidelines and recommendations for the selected pilot sites in the frame of the proposed monitoring programme.
    - Outline for developing the wetland management strategy in Phase 2.

C Duration and Timing

The overall period foreseen for this activity is July 2002 - October 2003. A finalized timetable has been prepared following the Ecological Working Group meeting in September 2002 and the Inception workshop held on October 7-8, 2002.

D Definition of Expected Outputs / Results

The overall output (s) of this assignment will be: i) assessment of approaches for the effective monitoring of nutrient removal in wetlands resulting in guidance for DRB activities and ii) pilot sites selected and prepared for monitoring activities in Phase 2 and iii) the basis for developing a DRB wetland management strategy in Phase 2.

The specific outputs will include the following:

Activity	Outputs	Time Frame for Delivery
4.3	• Inception report	• Draft August 2002 • Final, Oct 10. 2002
4.3.1	• Review of Existing Wetland Projects/Programmes and Respective Monitoring Strategies • General Guidelines on Methodology for Monitoring Nutrient Removal	• December, 2002 • Draft, March, 2003, Final Sept. 2003
4.3.2	• Pre-selection of Pilot Sites • Workshop on Monitoring of Nutrient Removal in Wetlands • Specific Guidelines for Monitoring in Pilot Areas including Pilot Site Monitoring Programme	• March, 2003 • March/April 2003 – Likely date March 20-21 in Budapest. • Draft March, 2003, Final Sept. 2003

E Implementation Arrangements and Roles and Responsibilities

Project Leadership - The Danube Carpathian Programme of WWF International has been awarded this contract and has designated Philip Weller as the Project Leader. The responsibility of the Project leader is to ensure the overall coordination and management of the project and the delivery of project components by the technical experts, national consultants and other experts.

The project leader will all ensure that the project activities are undertaken in close cooperation with the relevant ICPDR expert groups (RBM, MLIM, ECO ESG), the Ramsar Convention Secretariat, and national experts from the chosen areas. The activities should also be coordinated with the DANUBs project. In addition, cooperation with the World Bank/GEF Strategic Partnership Programme will also be developed where appropriate.

The project leader will attend coordination meetings with the ECO EG and if determined to be necessary, the MLIM EG.

The project leader will coordinate closely with the DRP project staff and as well as with other consultants involved in pilot activities to assure a maximum of synergy in the respective activities. The project leader will be assisted by Isabel Wolte, a project administrator employed by the Danube Carpathian Programme. The project leader and assistant will be responsible for the initial collection of data related to wetland restoration projects worldwide and the submission of all reports and documents to the DRP.

Scientific Experts – The project will be supported by three scientific consultants whose major responsibilities will be to assist in the preparation of the assessment of existing wetland restoration projects and the development of a methodology for the monitoring of nutrient removal. The project leader and scientific experts will form the core team for management of the project and have finalized a detailed workplan at the inception meeting.

The following scientific experts have been chosen for this work

- Helmut Kroiss – Technical University Vienna
- Jan Seffer – Daphne Institute of Applied Ecology, Bratislava

- Thomas Hein – University of Vienna
- National consultants – National consultants who will have experience in and knowledge of the Danube River Basin and related nature conservation policy and activities; wetland management, rehabilitation activities and monitoring programmes in their respective countries will be chosen following inputs received from the ECO WG of the Danube River Protection Convention. These consultants will participate in the preparation of the assessment workshop and in the development of local pilot studies.

F Inception Activities and Key Questions and Issues

The following inception activities have occurred and left the following key questions and issues open.

Inception Activities

1. Confirmation of project leader – Philip Weller will act as project leader.
2. Contact with previously named consultants and confirmation of involvement. Changes to the originally perceived project team will be made. The project leader Philip Weller has left his position as Director of the Danube Carpathian Programme Office but will continue to work for WWF as project leader for this project. He will also take over some of the responsibilities anticipated to have been completed by Jasmine Bachmann because of her unavailability to participate in the project because of a job change. Her replacement as Freshwater Team Leader of the Danube Carpathian Programme Office, which will be named by the end of September, will fulfil those functions not fulfilled by the Project leader. It should also be noted that Dr Hein has been added to the project team because of the unavailability of one of the scientific consultants originally chosen for this work.
3. Participation in ECO EG to determine availability of national consultants and to receive inputs from national experts.
4. Meeting with DRP Staff and ECO EG Secretariat
5. Review of Work plan and Project Activities completed.
6. Review of Budget and Timetable completed.
7. Collection of Information on wetland restoration projects in an international context and in the DRB begun.
8. Contact was made with the European Centre for River Restoration for cooperation on data exchange and the project leader met the Board of the organization during their meeting held in Vienna at the end of September.
9. Inception Workshop held October 7 and 8

Key Questions and Issues

1. Confirmation by DRP Project Team of personnel changes.
2. Determination of National consultants following ECO WG meeting.
3. Distribution of Inception Workshop results to participants and interested persons (see attachments).
4. Ongoing Review of Finalized Workplan and Timetable to ensure coordination with ICPDR Work Groups and other DRP activities.

ANNEX 3: REPORT FROM THE WETLAND MANAGERS' WORKSHOP, VIENNA, MARCH 2003

Danube Regional Project

4.3 – Monitoring and Assessment of Nutrient Removal Capacities of Riverine Wetlands

Meeting Report of Workshop on Nutrient Reduction and Monitoring in Wetlands

March 9 and 10, 2003

Vienna, Austria

Introduction: The workshop on Nutrient Reduction and Monitoring in Wetlands involving wetland managers from throughout the Danube Region, 4.3 Project Team members, and other interested parties was held on March 9 and 10 in Vienna, Austria. A total of 24 persons participated in the workshop (a list of participants is attached). The following report summarizes the presentations and discussions held during the workshop, which was principally designed to provide the project team with input on the work completed to date in designing a Monitoring and Assessment Scheme for Nutrient Removal from Riverine Wetlands. In addition to achieving this goal it was clear that the workshop provided wetland managers and other interested and involved persons from throughout the basin with information and contacts regarding various aspects of wetland management and restoration.

Purpose: The primary purpose of the Workshop of Wetland Managers of Danube Floodplains on Restoration and Nutrient Reduction and Monitoring was to provide input from wetland managers throughout the basin to the UNDP/DRP project 4.3 team related to verifying experience with wetland restoration, monitoring of nutrient interaction in wetlands, and expert feedback to the theses and information prepared by the project team related to nutrient reduction from wetland restoration.

Specifically the workshop was meant to:

- Provide response and verification of the work of the project team on the theoretical basis of nutrient reduction from wetlands;
- Provide response to and verification of the wetland classification system used by the project;
- Provide response to the draft criteria for pilot site selection; and
- Provide input to the development of a draft methodology for monitoring of nutrient removal by wetlands.

The workshop included a visit to the Danube National Park to view first hand a wetland restoration project and provide a practical background for the later discussions.

It was intended to have participants from all countries of the Danube River Basin. Regrettably, this was not altogether possible due to some last minute cancellations because of other work commitments or other factors. Nonetheless a very good mix of persons involved in wetland management were brought together for the workshop and communication of the results of the workshop will be undertaken to those not able to attend. A number of helpful inputs to the project team were received and critical questions asked about aspects of the work. It appears based on this input that additional work will be needed and additional consultations with selected persons (scientists dealing with these questions) will need to be made. Although the purpose of the meeting was principally to provide input to the project team, it is clear that the secondary goal of expanding understanding and knowledge of wetland restoration and nutrient reduction by wetlands was achieved. Strong support was communicated for further mechanisms to be established to bring wetland managers together to discuss these and other issues in future.

The Programme: The programme began (see attached agenda) on March 9 with a full day field visit to the Danube National Park to view first hand the wetland restoration work that has been carried out here. Representatives of the National Park and the University of Vienna who are monitoring the restoration efforts were present and provided commentary to the sites observed. A paper outlining the results of the monitoring and additional information about the restoration project is attached.

It was clear that direct observation of such a large scale restoration project was useful to participants and helped orient discussion throughout the workshop.

Following the field trip, a general introduction to GEF/UNDP Danube Regional Project was provided by Andy Garner of UNDP/GEF. This was followed by a general introduction to the purpose and goals of the project 4.3 by Project Manager Philip Weller.

The introductory presentations were followed by presentation of additional selected case studies:

- Babina/Cernovca restoration in Romania (Grigore Baboianu, DDBRA)
- Bulgarian World Bank Project (Marieta Stoimenova, Project PIU)
- Morava River, Slovakia (Jan Seffer, Daphne)

These presentations provided further examples of the work that has been done throughout the Danube Basin to restore wetlands and created a sense of the extent of work that has been undertaken.

The workshop continued on March 10 with presentations of the work products of the project team and feedback and response from participants.

- Presentation and Discussion of Theoretical Paper on Nutrient Reduction (Matthias Zessner, Vienna University of Technology)
- Presentation of Wetland Classification System (Jan Seffer, Daphne)
- Presentation of Review of Technical Literature (Thomas Hein, University of Vienna)
- Presentation and discussion of criteria for selection of pilot sites (Thomas Hein, University of Vienna)
- In addition a presentation of wetland policy developments was made by Dave Tickner, WWF Danube-Carpathian Programme, to ensure that those present were aware of key developments related to wetlands policy (particularly as it relates to the water framework directive).

The above-mentioned presentations are attached to this report. The presentations were followed by a final general discussion on the methodology for monitoring schemes and overall comments by participants on the workshop.

Key points from the discussion

Theoretical Paper on Nutrient Reduction

- agreement with overall presentation
- is there a difference between the upper portion of the river and the lower in the retention and role of wetlands in nutrient reduction
- need to monitor in areas influenced by wetlands
- the theoretical basis of nutrient reduction concentrates itself on the river water and does not account for wetlands role in impacting groundwater nutrient inputs or overall buffering inputs of nutrients
- is there a difference in when nutrients are released to the river and Black Sea?
- should we be focusing on retaining water in the upper catchments to reduce the nutrient loads

Presentation of Wetland Classification System

- concern expressed about the classification system not including floodplains that could be restored (i.e. those areas outside existing dykes)
- suggestion to concentrate on riverine wetlands that will have an influence on the Danube pollution loads.
- what about deepwater habitat
- abiotic factors should be the determining element as opposed to vegetation

Presentation of Review of Technical Literature

- support for the table to be further developed and available
- suggestion for this to be available to the persons present to add information and literature that they are aware of
- how to assure quality control of the data in the database (or in the papers)

Presentation of Wetlands Policy Development

- Horizontal Guidance on Wetlands will be sent to Eco EG of ICPDR for comment

Presentation and discussion of criteria for selection of pilot sites

- Key factor seems to be the relation to ongoing activities (building on existing work)
- Critical element identified is organization who can manage the data collection
- The time frame for monitoring was seen as too short – monitoring must be over 5 years
- Suggestion of Danube Delta, Morava River, Bulgarian Danube wetlands, Gemenc in Hungary as potential sites
- Suggested that sites be representative (include different types of habitats within the one area) and deal with both upstream and downstream areas.

Conclusion

The workshop proved valuable in providing the project team with input to the works in progress. It is clear, however, that the goals of the meeting were not met in their entirety and additional consultations with selected experts will be needed on those questions and issues for which the team requires further technical verification. The participants raised a number of issues, which need to be further examined by the project team, but no complete change of philosophy or approach was suggested. The meeting validated the work done to date and suggested additional directions and avenues that could be pursued. It is apparent though that feedback from people dealing specifically with the scientific aspects of nutrient reduction are going to be needed. The project team will evaluate how all the points can be addressed (or if they can) in the time frame and resources available for this phase of the project.

It is clear that the participants were all very satisfied with the field trip to the Danube National Park and appreciated the opportunity to see this example first hand. It was also clear that a network of wetland managers was desirable and that other mechanisms to bring such a group together to promote and strengthen the interest and understanding of wetlands in water quality were needed.

Evaluation

The workshop evaluation form of UNDP/GEF Danube Regional Project was completed by 13 workshop participants. In general, the response to the workshop was very positive: the large majority of participants saw the objectives of the workshop achieved, complemented the excellent moderation of the workshop and found the results of high quality and applicable to their working context. Recommendations for improvement mention a broader representation (see remarks above), more time and perhaps more detailed preparations so that the “tricky, non-resolved issues” might be “brought to a clear, agreed result”.

Informally, many participants expressed the desire and need for more such meetings with the view to establishing an active network of wetland experts in the region.

Workshop on Nutrient Reduction and Monitoring in Wetlands

March 9 and 10, 2003

Vienna, Austria

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ANNEX 4: DATABASE OF RELEVANT LITERATURE

Aims of the database

The intention of the literature collection was the need to compile available information on the issue of nutrient removal in riverine wetlands. The literature database provides the knowledge base for the scientific work in the DRP 4.3. The following goals have been the motivation for development of a database:

- Gather information on nutrient removal in artificial and existing wetlands.
- Demonstrate information on nutrient removal in current restoration projects.
- Provide a literature analysis to identify papers with original data.

Using the knowledge of the team members, and a literature search, relevant documents "nutrient (phosphorus and nitrogen) retention and removal in wetlands" were collected and stored in a structured form. Additionally, large scale wetland restoration projects with investigations on nutrients and hydrology were incorporated. The main questions are:

- What is known on P and N retention in existing wetlands ?
- What experiments are found in literature which support the nutrient removal ?
- Constructed wetlands: examples for nutrient removal.

In future, the database should have the potential to be used by other projects involved (e.g. DRP 1.4) and can be used by wetland managers as a knowledge base. For all future applications a further development of modules and a "www"- applicability needs to be incorporated. In the present status an internal working area has been developed.

Technical structure of the database

The database was developed in the software program MSAccess 2000 due to the wide distribution of the Office package and the broad range of compatibility with other software.

In table 1 the field names, definition and description for all fields is given.

The first part of fields includes general information on the projects and is especially relevant for large scale restoration work. The second group of fields describe the relevant document (e.g. the location, type of wetland) and the original data presented. A third group of fields analyze how much information on processes controlling nutrient dynamics or measures of nutrient transformation are contained in each document. The third group enables the project team to identify relevant information to answer the questions addressed. All incorporated documents were analysed according to the defined fields. To answer all fields, the abstract, methods, and the conclusion of each document needed to be read. This working step enabled the whole team to exchange the information rapidly and distribute all essential information within the group. This also allows others who will be involved in future work on the issues of the work to examine the literature on nutrient removal. Each member of the working group provided the information on her/his documents to Thomas Hein who incorporated all analyzed literature in the database. All listed documents are available within the working group.

Literature search

Scientific papers were searched in the ASFA index between 1978 and 2002. The key words used were nitrogen or phosphorus or nutrient removal, nitrogen or phosphorus or nutrient retention, river or wetland restoration. In total more than 400 papers were identified and of these 30 papers were incorporated in the database.

Tab. 1: field description.

Fieldname	Datatype	Format/Field Size	guidance
Projecttitle	Text	50	
Funding Agency	Text	50	
Contact Person	Text	50	responsible person with contact address
Project output	Text	50	results of the project: restoration measures,...
Other publications	Text	255	any related output: other monitoring, general project descriptions, homepage,...
Funding	Currency	€uro	
Type of publication	Text	50	S..scientific, R..report, M...monitoring
Citation	Text	50	reference
Title	Text	50	title of the specific paper dealing with nutrient dynamics
Authors	Text	50	
Country	Text	50	place of study
River/Watershed	Text	50	
Wetland type	Text	50	Definitions according to paper of Jan Seffer
Date of publication	number	long integer	year
Duration of investigation	number	long integer	in months
Goal	Text	150	question, hypothesis
Design of study	Text	255	number of stations, frequency of sampling, number of sampling, habitats sampled
Parameter	Text	150	list of parameters presented
Methodology	Text	255	description of methods, standard methods, references
Phosphorus	Yes/No	Yes/No	any measurement available
Description of Phosphorus data	Text	50	what fractions (dissolved, particulate, reactive), habitat (water, sediment, soil, vegetation,..)
Nitrogen	Yes/No	Yes/No	any measurement available
Description of Nitrogen data	Text	50	what fractions (dissolved, particulate, reactive), habitat (water, sediment, soil, vegetation,..)
Data River	Yes/No	Yes/No	chemical measurements in the river

Fieldname	Datatype	Format/Field Size	guidance
Data Wetland	Yes/No	Yes/No	chemical measurements in the wetlands
Data availability	Text	50	data published, data digital available, contact person, costs, data structure
Input/Output	Yes/No	Yes/No	is there a budget approach ?, a massbalance
Hydrological data	Yes/No	Yes/No	are hydrological data (water level, flow,..) presented
Process studies	Yes/No	Yes/No	are there any processes determined (denitrification, nutrient uptake,..) according to the paper of the TU Wien
Biomass estimation	Yes/No	Yes/No	are there any estimations of biological production (plankton, vegetation, bacteria,..)
Methodology of biomass estimation	Text	10	m..measurement, l...literature, o...other
Terrestrial data sets	Yes/No	Yes/No	measurements in the terrestrial part of the wetland
Aquatic data sets	Yes/No	Yes/No	measurements in the aquatic part of the wetland
remarks	Text	150	any additional information
location of publication	Text	50	who of the working group has the paper

Basic characteristics

Currently, 72 documents are incorporated in the database, 12 restoration projects and 60 scientific papers. 10 papers deal with areas located in the Danube River Basin: A total of 46 are from European river systems. Most papers deal with riverine wetlands or with the river and its nutrient dynamics. 8 documents about constructed wetlands have been selected. 3 documents represent literature studies and 4 papers deal with an experimental setting to answer aspects of nutrient removal. 27 documents present original data on nitrogen and phosphorus. These documents can be used in further analyses on the removal capacities in different habitat types and under certain conditions. 32 papers on processes involved in the nutrient cycling have been incorporated, 15 works deal with biomass estimations and 30 documents also analyze hydrological data. Only 7 references deal with all 3 components.

The 12 restoration projects are presented in tab. 2. 10 large scale restoration projects are located in the Danube river basin. One project in the US used restored wetlands to control nutrient input into the Everglades.

Tab. 2:

ID	Projecttitle	Funding Agency	Project output	Title	River/Watershed	Wetland type
4	Functional Analysis of European Wetland Ecosystems (FAEWE) 1991-96	EU DG XII		Effects of the vegetation on Carbon, Nitrogen and phosphorus Dynamics in English and French Riverine Grasslands	Loire, Allier, (F), Torridge, (E)	riverine
10	Gewässervernetzung Orth/Donau	Nationalpark Donauauen Gmbh, WSD, BMLFUW	reports and several publications, pilot study	Bedeutung der hydrologischen Vernetzung für die hydrochemische Situation der Augewässer im Bereich Orth/Donau	Danube, DRB	riverine
11	Martha95	WSD	reports and several publications, pilot study	Generelles flussbaulich-gewaesseroekologisches Gesamtkonzept fuer March und Thaya	March, Thaya, DRB	riverine
28	Gewässervernetzung Regelsbrunn	Wasserstraßendirektion	reports and several publications, pilot study	Hydrochemische Charakterisierung und Sedimentverteilung in einem dynamische	Danube, DRB	riverine
41	Everglades Nutrient Removal Project			Nutrient retention dynamics of the Everglades Nutrient Removal Project	Everglades	?
48	The Morava River at Litovelske Pomoravi	Ministry of Environment from the Programme of Restoration of River Restoration, Czech Republic		Restoration of the Morava River and its Floodplain, Czech Republic	Morawa, DRB	riverine

Tab. 2 Continued:

ID	Projecttitle	Funding Agency	Project output	Title	River/Watershed	Wetland type
49	Kaceni louka	Ministry of Environment; Nature Conservation Foundation for the Management of Reserves, Czech Republic		Restoration of the Morava River and its Floodplain, Czech Republic	Morawa, DRB	small pools
50	Plane loucky	Czech Union of Nature Conservation		Restoration of the Morava River and its Floodplain, Czech Republic	Morawa, DRB	wet grasslands
69	Danube Delta Romania	WWF, DDBRA, DDI	Wetland Restoration and Report	in prep	Danube, DRB	riverine
70	Prut River	PHARE	Reports and vegetation restoration	in prep	Prut River, DRB	riverine
71	Calarasi Floodplain	World Bank	Project Proposal	in prep	Danube, DRB	riverine
72	Development and Implementation of a Management Plan for Srebarna Lake Ramsar Site	Ramsar Small Grants Fund for Wetlands Conservation and Wise Use	Management Plan	Management Plan of the Srebarna Biosphere Reserve	Danube: right hand bank between km 391 and 393, DRB	lacustrine, riverine and palustrine wetlands all present (Ramsar wetland types: O, M, P, Xf, Zk)

ANNEX 5: WETLAND DEFINITIONS AND CLASSIFICATIONS

How to Define a Wetland

Ramsar Convention Article 1

For the purpose of this Convention **wetlands are** areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

Wetlands - areas that are inundated or saturated by surface or ground water at frequency and duration sufficient to support, and that under normal circumstances support a prevalence of vegetation typically adapted for life in saturated soil conditions (Lewis 1990)[63].

Three main conditions for existence of wetland are included in this definition:

- the substrate is flooded or saturated with water during vegetation season
- presence of wetland plants - hydrophytes and hygrophytes
- presence of hydric soils with anaerobic conditions

Reasonable multidisciplinary approach is reflected in functional definition of wetlands, which is defined as:

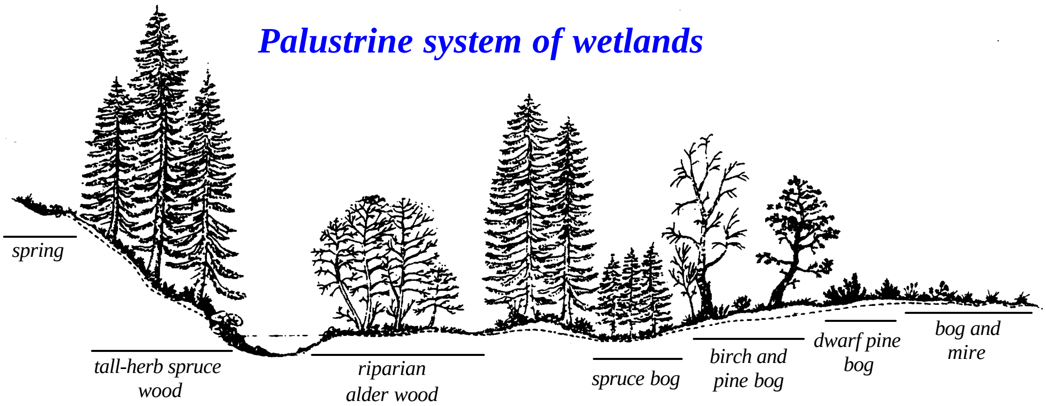
"heterogeneous but distinctive ecosystems in which special ecological, biogeochemical and hydrological functions arise from the dominance and particular sources, chemistry and periodicity of inundation or saturation by water. They occur in a wide range of landscapes and may support permanent shallow (<2m) or temporary standing water. They have soils, substrates and biota adapted to flooding and/or water-logging and associated conditions of restricted aeration'.[64]

This definition is proposed to be used for purpose of this project.

Systems of Wetlands

Inland wetlands are of a palustrine, riverine or lacustrine system type. This division is made according to how the wetland is supplied with water. In the cases of riverine and lacustrine systems, the wetlands are influenced by the water level of rivers and lakes. In the palustrine system of wetlands, water is supplied by groundwater, rain, snow and during periods of floods.

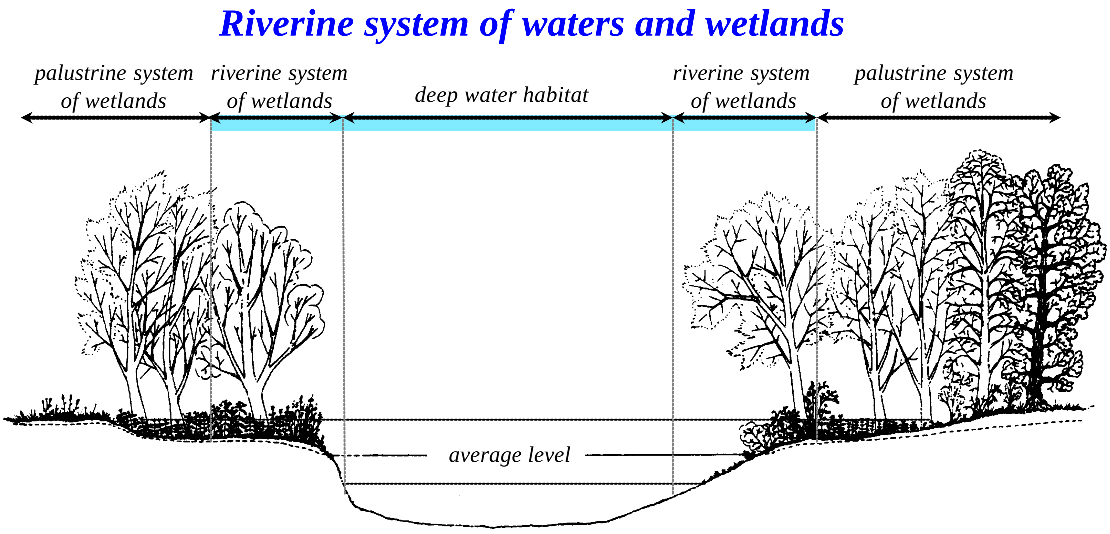
Palustrine system - is not bounded by deepwater habitats. Vegetation covers more than 50% of the area and it has to contain the previously mentioned three characteristics.



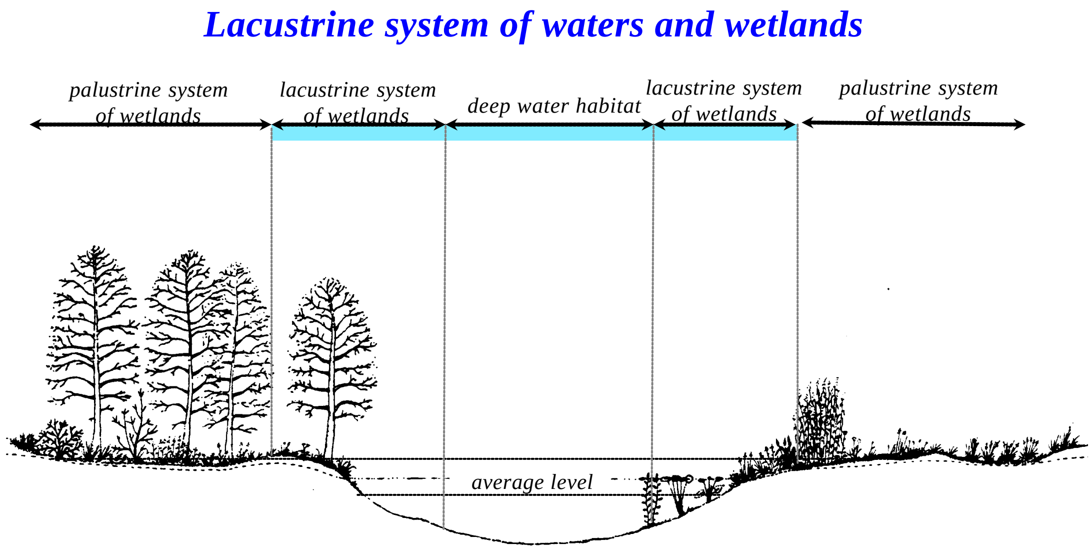
[63] Kusler, J. A. et Kentula, M. E. (eds.), 1990: Wetland Creation and Restoration. The Status of the Science. Washington, D.C., Covelo, California.

[64] Definition provided by Evaluet. Evaluwet - European Valuation and Assessment tooLs supporting Wetland Ecosystem legislaTion - is a research project supported by the European Commission under the Fifth Framework Programme and contributing to the implementation of the Key Action "Sustainable Management and Quality of Water" within the Energy, Environment and Sustainable Development Contract n°: EVK1-CT-2000-00070

Riverine system - is situated by channels with moving water, and also near deepwater habitats. In some parts the average depth of the channel is at least 2 meters. Wetlands of smaller channels, which do not fulfill this condition belong to the palustrine system. Vegetation covers less than 50% of the area.



Lacustrine system - has to have the same conditions as the riverine system. The difference is in the state of water which is stagnant in this case.



It is necessary to distinguish

(Deep)Water system - permanently flooded lands lying below the deepwater boundary of wetlands. Water habitats include environments where surface water is permanent and often deep, so that water rather than air, is the principal medium within which the dominant organisms live. The substrate is considered nonsoil because the water is too deep to support emergent vegetation (Cowardin et al. 1979)[65]. The boundary lies at depth of 2 m below low water because it represents the maximum depth to which emergent plants normally grow.

Classification of Wetlands

[65] Cowardin, L. M., Carter, V., GoletT, F. C., and LaRoe, E. T., 1979: Classification of Wetlands and Deepwater Habitats of the United States. Washington , D.C.

Further classification is according to habitat type (Tab 1). **Formations** are divided according to the form of dominant living plant species (tree, shrub, grasses, herbs and moss). **Habitat types** are according to dominant plant species (spruce - spruce bog, alder - fen alder wood).

Most common are palustrine vegetation types, so we are concentrating on their characteristics. Vegetation types of riverine and lacustrine systems connected with specific palustrine vegetation types are added in the scheme on the inside cover page.

Besides this classification, other types of classification systems also exist. The most well known system of classification is that as described by the Ramsar Convention. Unfortunately, this classification does not contain a very consistent definition of wetlands and its practical use for inventory is very limited.

This classification system also considers wetlands, which contain deepwater habitats. If there are some ponds, reservoirs and canals created by man we did not classify them as a specific category, but we included them in the review if they follow the definition.

Tab 1. Classification of inland wetlands[66] in Danube River Basin with links to Ramsar Classification (Annex 1).

System	Formation	Habitat type	Ramsar Classification
Palustrine	wood	riparian alder wood	M,P,Xf
		fen alder wood	Xf
		spruce bog	Xp
		birch and pine bog	Xp
		tall-herb spruce wood	Xf
		willow-poplar wood	P,Xf
		oak-elm-ash wood	P,Xf
	shrub	willow shrub	M,W
		dwarf pine bog	W
	grass-herb	tall-sedge	Tp,Ts
		wet meadow and pasture	Sp,Ss,Ts,Va,4,9
		tal-herb floodplain	
		reed swamp	Tp,Ts
		aquatic vegetation	9
	moss	bog	U
		fen	U
		spring	Y
	ephemeral	bare bottom growth	Ts
Riverine	tree	with alders	L, M,Xf
		w. willows and poplars	L, M,Xf
	shrub	w. willows	L, M,W
	grass-herb	w. sedges	L, M
		w. grasses and herbs	L, M,4
		w. aquatic plants	L, M
	ephemeral	bare bottom growth	L
Lacustrine	tree	with alders	O,Xf
		w. willows and poplars	O,Xf,1,2,6,7
	shrub	w. willows	O,W,1,2,6,7
		w. dwarf pines	O,W
	grass-herb	w. sedges	O
		w. grasses and herbs	O,Q,R,Sp,Ss,1,2,6,7
		w. aquatic plants	O,1,2,6,7
	ephemeral	bare bottom growth	O,Q,R,Ts,1,2

Ramsar Classification System for Inland and Human Made Wetlands

[66] based on Seffer et al., 1996: Wetlands for life. Daphne, Bratislava, 32p.

The codes are based upon the Ramsar Classification System for Wetland Type as approved by Recommendation 4.7 and amended by Resolution VI.5 of the Conference of the Contracting Parties. The categories listed herein are intended to provide only a very broad framework to aid rapid identification of the main wetland habitats represented at each site.

Inland Wetlands

L -- ***Permanent inland deltas***.

M -- ***Permanent rivers/streams/creeks***; includes waterfalls.

N -- ***Seasonal/intermittent/irregular rivers/streams/creeks***.

O -- ***Permanent freshwater lakes*** (over 8 ha); includes large oxbow lakes.

P -- ***Seasonal/intermittent freshwater lakes*** (over 8 ha); includes floodplain lakes.

Q -- ***Permanent saline/brackish/alkaline lakes***.

R -- ***Seasonal/intermittent saline/brackish/alkaline lakes and flats***.

Sp -- ***Permanent saline/brackish/alkaline marshes/pools***.

Ss -- ***Seasonal/intermittent saline/brackish/alkaline marshes/pools***.

Tp -- ***Permanent freshwater marshes/pools***; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.

Ts -- ***Seasonal/intermittent freshwater marshes/pools*** on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.

U -- ***Non-forested peatlands***; includes shrub or open bogs, swamps, fens.

Va -- ***Alpine wetlands***; includes alpine meadows, temporary waters from snowmelt.

Vt -- ***Tundra wetlands***; includes tundra pools, temporary waters from snowmelt.

W -- ***Shrub-dominated wetlands***; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.

Xf -- ***Freshwater, tree-dominated wetlands***; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.

Xp -- ***Forested peatlands***; peatswamp forests.

Y -- ***Freshwater springs; oases***.

Zg -- ***Geothermal wetlands***

Zk(b) – ***Karst and other subterranean hydrological systems***, inland

Note : "***floodplain***" is a broad term used to refer to one or more wetland types, which may include examples from the R, Ss, Ts, W, Xf, Xp, or other wetland types. Some examples of floodplain wetlands are seasonally inundated grassland (including natural wet meadows), shrublands, woodlands and forests. Floodplain wetlands are not listed as a specific wetland type herein.

Human-made wetlands

1 -- ***Aquaculture*** (e.g., fish/shrimp) ***ponds***

2 -- ***Ponds***; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).

3 -- ***Irrigated land***; includes irrigation channels and rice fields.

4 -- ***Seasonally flooded agricultural land*** (including intensively managed or grazed wet meadow or pasture).

5 -- ***Salt exploitation sites***; salt pans, salines, etc.

6 -- ***Water storage areas***; reservoirs/barrages/dams/impoundments (generally over 8 ha).

7 -- ***Excavations***; gravel/brick/clay pits; borrow pits, mining pools.

8 -- ***Wastewater treatment areas***; sewage farms, settling ponds, oxidation basins, etc.

9 -- ***Canals and drainage channels, ditches***.

Zk(c) – ***Karst and other subterranean hydrological systems***, human-made

Assessment of Vegetation Uptake and Fragility of Wetland Habitats

Plant uptake rate will depend on productivity of different wetland habitats. Crucial is primary production of plants. The vegetation uptake is only a storage process, harvesting of biomass will act as nutrient removal process from the system. Harvesting is the only means of removal of phosphorus pollution in the water. Vegetation uptake of nutrients is closely correlated to wetland habitat productivity. A rough assessment of productivity (prepared by Jan Seffer) is indicative. The productivity has been distinguished into five classes: 1) very high, 2) high, 3) medium, 4) low, and 5) very low (Tab. 1). It is also important to consider the fragility of wetland type in relation to higher loads of nutrients. Well documented is the fact that peatlands impacted by polluted ground and/or surface waters, will be changes into completely different type of wetlands – reed swamp or tall-sedge habitat. Significant decrease of biodiversity follows such changes. Assessment of fragility has been estimated according to sensitivity of habitats to nutrient loads with division into three classes: 1) high, 2) medium, 3) low (Tab. 1).

Tab. 1. Assessment of vegetation uptake and fragility of wetland habitats

Vegetation uptake: ********* very high, ******** high, ******* medium, ****** low, ***** very low
Fragility: ******* high, ****** medium, ***** low

System	Formation	Habitat type	Fragility	Vegetation uptake
Palustrine	wood	riparian alder wood	*	***
		fen alder wood	**	**
		spruce bog	***	**
		birch and pine bog	***	*
		tall-herb spruce wood	**	***
		willow-poplar wood	*	*****
		oak-elm-ash wood	*	****
	shrub	willow shrub	*	***
		dwarf pine bog	***	*
	grass-herb	tall-sedge	*	*****
		wet meadow and pasture	*(*)	***(*)
		tal-herb floodplain	*	*****
		reed swamp	*	*****
		aquatic vegetation	*(**)	**(*)
	moss	bog	***	*
		fen	***	**(*)
		spring	***	*(*)
	ephemeral	bare bottom growth	*	*(**)
Riverine	tree	with alders	**	***
		w. willows and poplars	*	*****
	shrub	w. willows	*	****
	grass-herb	w. sedges	*	*****
		w. grasses and herbs	*	****
		w. aquatic plants	*(*)	**(*)
	ephemeral	bare bottom growth	*	*(**)
Lacustrine	tree	with alders	**	***
		w. willows and poplars	*	*****
	shrub	w. willows	*	****
		w. dwarf pines	***	*
	grass-herb	w. sedges	*	*****
		w. grasses and herbs	*	****
		w. aquatic plants	*(*)	**(*)
	ephemeral	bare bottom growth	*	*(*)

ANNEX 6: REPORT SELECTION OF PILOT SITES

IN ROMANIA AND BULGARIA

2 July 2003 – 4 July 2003

Jan Seffer, Thomas Hein

Purpose of the meetings

The purpose of the trip to Romania and Bulgaria and the meeting with the local persons responsible for various projects was specified in one meeting with the responsible person of the GEF/UNDP and summarized by Phil Weller as follows:

The discussion with Andy Garner and Ivan Zavadsky was very positive and on the basis of the discussion we agreed that the development of pilot site monitoring and assessment would be focused on building a long-term 15-20 year programme of monitoring and assessment of the nutrient reduction capacities of wetlands.

The expected outputs of the visit are as follows:

- To establish whether a monitoring and assessment programme (including one or more pilot projects) for nutrient reduction capacities of riverine wetlands can be developed for the Danube (some part) in Bulgaria and Romania that recognizes and potentially builds upon and compliments the work being undertaken related to the World Bank nutrient reduction projects for Romania and Bulgaria..
- To determine precisely the potential location of such a monitoring and assessment programme (if possible including upstream downstream monitoring i.e. the black box) and potential pilot sites within this area. If local authorities and contacts have alternative suggestions for developing the monitoring and assessment programme on territories not including the World Bank projects to examine and conclude whether such sites could be included or are better suited to the project goals.
- To identify, contract and brief local consultants who will develop further a detailed plan of monitoring and assessment and specifies the monitoring and assessment methods needed.

Meeting preparation and strategy

Within the proposed reach potential pilot sites for assessment of the nutrient reduction by riverine wetlands need to be identified. The potential to implement a long term monitoring program will be evaluated. Basis for the selection are the following questions. Each answer should be in the form of a short statement giving the most important information.

The questioner: Site Selection Criteria for each potential pilot site:

1. Sufficient baseline information level on geomorphology, wetland habitat types, quantity and quality of surface and groundwater water, biomass production in particular habitat types are available for each site?
2. The hydrologic exchange between the wetland and the main channel is defined? The main source of water (groundwater, surface water) and the temporal variability (frequency and duration) of the exchange are known and estimated. An in- and outlet dominated the hydrologic exchange?
3. Is the size of the proposed area large enough and the proportion of discharge draining the wetland significant enough (e.g. at mean discharge > 1%, during flooding > 10 %?)

4. Is there any evidence of a significant point – source pollution (e.g. large municipal area without waste water treatment or industrial waste products) effecting the pilot site?
5. Are there active, credible stakeholders working in the area? Logistic support and the capacity to implement a long term monitoring scheme are necessary.
6. Will the selection of the area somehow contribute to the body of knowledge on land use practices or interact with any other part of the UNDP/GEF project?

Basic features of the proposed monitoring and assessment

Aim of the programmes:

The monitoring and assessment programme should focus on long-term assessment and building of an information base that expands the knowledge and understanding of wetland capacity to influence instream nutrient loads.

The basic question for the long term monitoring is how the discharge (the hydrologic exchange with the main channel) affects the nutrient retention. Restoration practices most often act at the structural level and are expected to ameliorate ecosystem function. The coupling between structure and ecosystem function can be addressed by a long term monitoring (Fig. 1).

For the design of any restoration project one issue could be to optimize nutrient retention in riverine wetlands for each habitat type. Basic reason is to avoid increasing of nutrient removal capacity instead restoration of species and habitat diversity according to potential of the site. The question for the monitoring and assessment to be answered will be to what extent influence hydrologic exchange the retention capacity of nitrogen and phosphorus? A hump shaped relationship is expected.

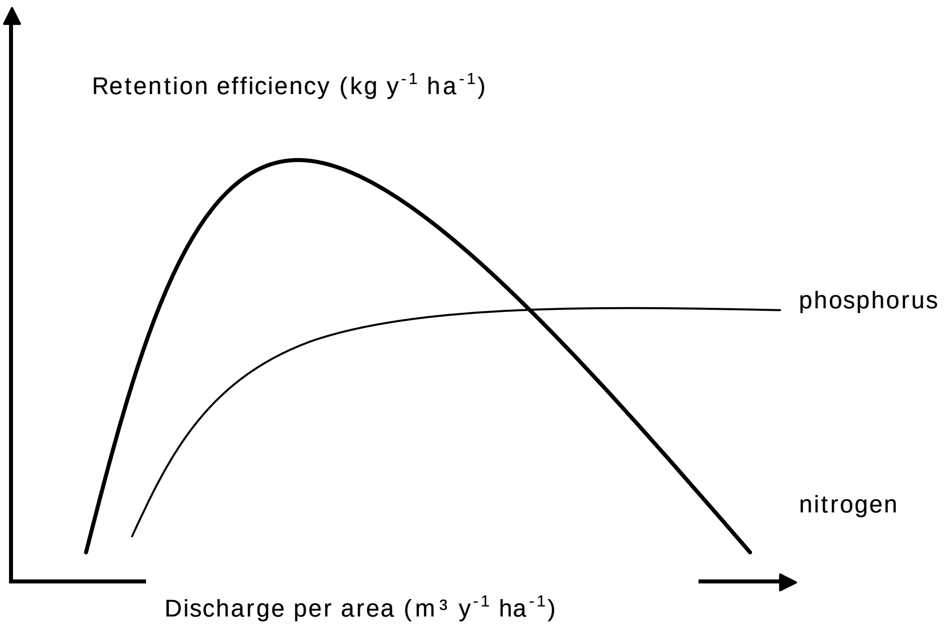


Fig. 1: Conceptual model of the nutrient retention capacity of phosphorus and nitrogen. These function can be applied to different habitat types.

Information on selected pilot sites

For potential pilot site selected based on the criteria stated above following information should be prepared for the meeting:

- What is the size and the type of the selected wetland?
- Is the wetland nearly natural, has a restoration been performed or is a restoration planed for the near future?
- What kind of geographic information on the geomorphology (elevation, channels etc) is available? What format does this information have (analogue, digital)? What resolution?
- What kind of information on habitat types is available?
- Is there any geological information on the wetland available? If yes, please specify.
- The water exchange between main river and wetland happens mainly by surface channels or groundwater?
- How many channels connect the main river with the wetland at low flow, at average flow situations?
- What is the (approximate) discharge from the main river to the wetland by surface water channels at low, average flow and high flow conditions.
- Is the amount of water exchange between the main river and the wetland by groundwater known. What is it approximately?
- Is there any monitoring of discharges from the river to the wetland (groundwater, surface water channels)? If yes, please specify (locations, frequency).
- Do hydrological models for the wetland exist? If yes please specify.
- Is there any monitoring of discharges from the river to the wetland planed for the future (groundwater, surface water channels)? If yes, please specify (locations, frequency).
- Does any water quality monitoring in the wetland exist (groundwater, surface water channels). If yes, please specify (locations, frequency).
- Is there any water quality monitoring in the wetland planed for the future (groundwater, surface water channels). If yes, please specify (locations, frequency).

Basic approach

The main issues discussed in both meetings are the following 3 topics:

- Ecological and socio -economic situation in the potential pilot sites
- Outcomes of the GEF Projects and implementation status
- Information on design of monitoring within this GEF projects

Meeting programme

1st meeting at Environmental Protection Inspectorate (EPI) from Calarasi

List of participants:

Viorica Enache - Head of the Biodiversity Department

Sevastel Mircea

Julian Nichersu

Stefan Nicolau

Results of the 1st meeting

Information related to the area of Calarashi-Raul:

1. Is sufficient baseline information on geomorphology, wetland habitat types, quantity and quality of surface and groundwater water, biomass production in particular habitat types available?
   In the framework of WB/GEF Agricultural Pollution Control Project (APCP) – Ecological Reconstruction component, our Institute (Danube Delta Institute – DDI) carried out last year deeply studies on Calarasi-Raul Precinct concerning geomorphology, habitat types and water quality. No studies about biomass.

   Results of the meeting:

   The habitat map and detailed description of wetland types is missing. According to the assessment of riverine wetland habitats by DDNI and WWF Germany as well as our field trip shows only fragmentary occurrence of natural types of floodplain forest. The majority of forests are composed of Canadian poplar plantation heavily invaded by Amorpha fructicosa. Grassland types consist of dry and ruderal species.

2. Is the hydrologic exchange between the wetland and the main channel defined? Are the main sources of water (groundwater, surface water) and the temporal variability (frequency and duration) of the exchange known and estimated? Does an in- and outlet dominate the hydrological exchange?
   There is a hydrologic exchange between Precinct and the Danube River, in precinct by infiltrations and in the area without dikes through natural small lakes. We have very precise estimations using the hydraulic Dutch model Sobek.

   Results of the meeting:

   No defined in- and outlet for monitoring purposes can be identified. The hydrologic exchange is limited to short periods at the beginning of the vegetation season during flooding and water remain there approximately 1 – 2 months, the rest of the season is dry.

3. Is the size of the proposed area large enough and the proportion of discharge draining the wetland significant enough (e.g. mean discharge > 1%, during flooding > 10 %)?

   In the implementation phase of ecological reconstruction of the area these characteristics will be significantly.

   Results of the meeting:

   The existing area with "close-to-natural" conditions (see 1)is very small in size (675 ha) and have only a little impact on transport of nutrients. The implementation of the wetland restoration alternative is not clear due to limited financial sources.

4. Is there any evidence of a significant point–source pollution (e.g. large municipal area without wastewater treatment or industrial waste products) effecting the pilot site?
   Yes, on one hand the selected site is located at a short distance of the confluence with Arges River, through which the wastewaters of Bucharest City are carried out, and on the other hand there is Calarasi Town with a population of 73,000 inhabitants.

   Results of the meeting:

5. Are there active, credible stakeholders working in the area? Logistic support and the capacity to implement a long term monitoring scheme are necessary.

   Yes, there are, one of them being the WB/GEF APC Project.

   Results of the meeting:

   The EPA and the DDNI have a solid capacity to implement and run the monitoring.

6. Will the selection of the area somehow contribute to the body of knowledge on land use practices or interact with any other part of the UNDP/GEF project?
   The selected area is one of the most adequately for fish species reproduction from the lower part of Danube. That surface of 3,000 hectares can bring a significant contribution to the stock fish conservation from the Danube River, having in the meantime good influences on all water meadows.

   Results of the meeting:

   The outcome of the GEF/APC Project, especially the area 25 km upstream of the selected site, can be expected to contribute to component 1.4 of the DRP as well as to agricultural aspects of the DRP.

2nd meeting 2003-07-03 Bulgaria

List of participants:

Ivan Hristov DCP - WWF International

Sasha Rulinska, Biodiversity expert, Regional Inspectorate of Environment and Water, Russe

Svetlana Ivanova, Biodiversity expert, Regional Inspectorate of Environment and Water, Russe

Reneta Taschkova – Water monitoring expert, Regional Inspectorate of Environment and Water, Russe

Marietta Stoimenova, Project manager, Wetlands Restoration and Pollution Reduction Project GEF TF 050706 BUL

Christina Nikolova, Local liaison officer, Wetlands Restoration and Pollution Reduction Project GEF TF 050706 BUL

Stoyan Mikhov, Local liaison officer, Wetlands Restoration and Pollution Reduction Project GEF TF 050706 BUL

Viktoria Gaydarova, Protected areas management planning coordinator, Wetlands Restoration and Pollution Reduction Project GEF TF 050706 BUL

Valentina Fidanova – NGO Green Balkans

Konstyantin Dichev - NGO Green Balkans

Konstantin Angleov, Game breeding station “Dunav”, Russe

Jordan Kutsarov – Executive director, NGO Kallimok Brushlen Protected Site

Results of the 2nd meeting

Basic information about the area and world bank project (Wetlands Restoration and Pollution Reduction Project, No. P068858) can be found under the following address: http://www4.worldbank.org/sprojects/project.asp?pid=P068858.

The information was provided by Marietta Stoimenova, additional remarks of the 2 team members are marked.

1. What is the size and the type of the selected wetland?

   The wetland is connected via artificial openings and a pumping system and has large permanent water bodies. The size of the Kalimok protected area is approximately 6,000 ha.

2. Is the wetland nearly natural, has a restoration been performed or is a restoration planned for the near future?

   The restoration is planed for the near future. The detailed design for the restoration will be ready at the end of March 2004, and the construction works will be completed at the end of April 2005. First flooding is planed to be after the completion of the construction works.

3. What kind of geographic information on the geomorphology (elevation, channels etc) is available? What format does this information have (analog, digital)? What resolution?

   All information pointed above is available in digital format as a layers of GIS.

4. What kind of information on habitat types is available?

   The available information on habitat types was gather by WWF Germany during the preparatory phase, and the report is available in the PCU.

5. Is there any geological information on the wetland available? If yes, please specify.

   The geological information is available in the PCU. The baseline surveys on the both project sites were just completed.

6. Does the water exchange between the main river and the wetland happen mainly by surface channels or through groundwater?

   The water exchange between the Danube River and the wetlands will happen mainly by surface channels, and to some extend through groundwater. The hydrological and hydrogeological water balance was done during the preparatory phase, and is available in the PCU.

7. How many channels connect the main river with the wetland at low flow, at average flow situations?

   Will be determined by the consultants.

8. What is the (approximate) discharge from the main river to the wetland by surface water channels at low, average flow and high flow conditions?

   Will be determined by the consultants.

9. Is the amount of water exchange between the main river and the wetland by groundwater known? What is it approximately?

   Will be determined by the consultants.

10. Is there any monitoring of discharges from the river to the wetland (groundwater, surface water channels)? If yes, please specify (locations, frequency).

    There is not monitoring of discharges.

11. Do hydrological models for the wetland exist? If yes, please specify.

    Yes.

12. Is there any monitoring of discharges from the river to the wetland planned for the future (groundwater, surface water channels)? If yes, please specify (locations, frequency).

    The monitoring of discharges from the river to the wetland is planned for the future (groundwater, surface water channels). The locations, and the frequency will be determined. Under the PHARE funded subcomponent Monitoring programme of the Component 2 of the Wetlands restoration and pollution reduction project.

13. Does any water quality monitoring in the wetland exist (groundwater, surface water channels). If yes, please specify (locations, frequency).

    The water quality monitoring in the wetland does not exist (groundwater, surface water channels). There is an urgent need of the conduction of the baseline monitoring, but this is not included in the project budget.

14. Is there any water quality monitoring in the wetland planned for the future (groundwater, surface water channels). If yes, please specify (locations, frequency).

    Yes. The consultant, who will do the design of the monitoring system, will specify locations, frequency.

3rd meeting 2003-07-04 Romania

List of participants:

Dr Liviu Popescu

Sevastel Mircea

The main topics of the meeting has been the methodology and the logistic of nutrient monitoring in wetlands. Generally, the experience with long term programmes dealing with monitoring of nutrient concentration along the lower Danube was discussed. Although a transnational monitoring network was successfully established, still especially in terms of quality control some efforts are needed in the near future.

For an implementation of a special task like the capacity of wetlands for nutrient removal, a quality control seems to be necessary, because the mass balance of nutrients will show only slight differences.

The recommendation of Dr. Popescu are to involve laboratories which are close to the investigation area to minimize logistic difficulties.

Recommendations

We cannot recommend the pre-selected site at Calarasi-Raul for monitoring and assessment of nutrient removal capacities of riverine wetlands in the present situation. The hydrologic exchange with the main channel is very limited (less than 2 months) and the existing wetland habitats are degraded and the majority of the area is characterized by intensive agricultural land and drylands. In case that the implementation of the restoration start within the next 12 months the potential for a monitoring and assessment programme significantly increase, but according to the information of the local project team the step remain unclear.

The possibilities of local cooperation with the EPI and the DDNI still are very high and we asked for alternative sites along the Romanian Danube.

The wetland restoration at the Kalimok marshes (Danube river km 460 – 432) offer the possibility to implement a monitoring on nutrient removal. Although in the present condition the area will be of limited value in terms of nutrient removal of riverine nutrient loads, after the final construction works scheduled March 2005 this area meets most of the requirements. One important fact missing are baseline information before restoration. A first assessment would be necessary. The local cooperation with the project management of the GEF project Wetlands Restoration and Pollution Reduction, project manager: Marietta Stoimenova, would fulfil the requirements and our time schedule for the work of the national consultant. A contract and the terms of references need to be fixed her. Special attention should be given to the laboratories involved in nutrient analyses to ensure the needed quality standard for the monitoring. An evaluation of methods and quality standards of all possible laboratories is suggested.

Finally, in the present situation we only could recommend 1 site of the pre-selected along the Lower Danube, but identified in both countries local consultants who could provide all necessary information in case. An alternative pilot site could be located in a large existing wetland, e.g. Gemenc, Kopacki Rit. An integration in the TNMN was discussed with Dr. Liviu Popescu and according to his opinion there are still open questions and significant improvements in the quality management needed before any other program could be implemented in this network..

ANNEX 7: MAP OF KALIMOK/BRUSHLEN MARSHES

MAP OF KALIMOK / BRUSHLEN MARSHES