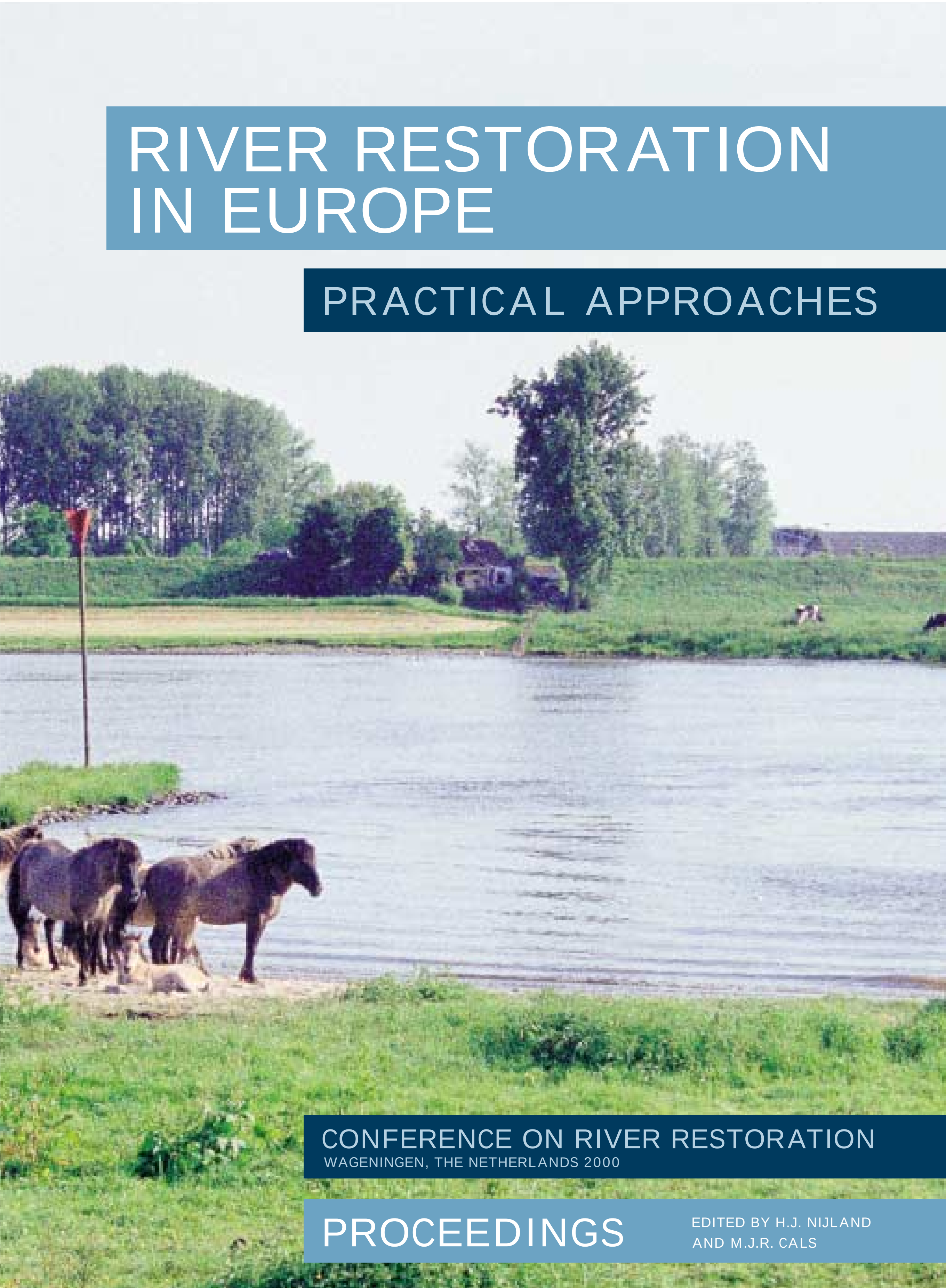
RIVER RESTORATION IN EUROPE

PRACTICAL APPROACHES



CONFERENCE ON RIVER RESTORATION
WAGENINGEN, THE NETHERLANDS 2000

PROCEEDINGS

EDITED BY H.J. NIJLAND
AND M.J.R. CALS

River restoration in Europe

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European Centre for River Restoration
ECRR

Ministry of Transport, Public Works and Water Management
Directorate-General of Public Works and Water Management
Institute for Inland Water Management and Waste Water Treatment RIZA

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PREFACE

Rivers are lifelines in all kind of aspects. They are dynamic, diverse and complex ecosystems and they always have been a focus for many human activities. Rapidly increasing populations and growing demands for water and land have led to the degradation of many river systems.
Currently many river restoration projects are being implemented. Rivers in Europe show many similarities on one hand and important differences on the other hand. This is also reflected in the restoration approaches. The experiences gained can be used in future river restoration projects.
River restoration will even get a higher attention within the framework of the implementation of the European Water Framework Directive.

The international conference 'River Restoration 2000 - Practical Approaches' focused on practical approaches in river restoration throughout Europe. It was a unique experience to have representatives from all European regions present at this conference, discussing the current issues on river restoration. During an inspiring week, highlights as well as failures in approaches on river restoration were discussed freely. It appeared that, successful projects always are characterised by partnership and co-operation. Stimulating the sharing of knowledge on river restoration was an important part of these projects.

This justifies the existence of the European Centre for River Restoration. The establishment of networks of practitioners of river restoration and the wise use of these networks is important to both the ecological and economical values of the rivers of all the European countries. I am convinced that the conference and this proceedings will contribute to intensified networking, extending co-operation and new partnerships in the field of river restoration to the over all benefit of the European society.

Bart Fokkens
Director Wetland Development and Restoration Department, *RIZA*

EDITOR'S CONTRIBUTION

The European Centre for River Restoration/ECRR took the initiative to organise the Conference on River Restoration 2000. The conference on River Restoration 2000 was hosted by the Institute for Inland Water Management and Waste Water Treatment/*RIZA*, and held in Wageningen, The Netherlands from 15-19 May 2000. Project leader was M. Cals. For the organisation of the Conference three committees were nominated.

Programme Committee:

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Organising Committee:

H. Bos (*RIZA*)
M. Cals (*RIZA*)
M. Stoffer (*RIZA*)
S. Vos (*RIZA*)

The conference focused on practical approaches in river restoration throughout Europe, and brought together all those involved in the fields of management, research and communication of river restoration in Europe. In other parts of the world, opinions and perspectives about river restoration may be different from the ones in Europe, and therefore, also a few participants from outside Europe were invited. The organisers regarded it important to give the participants optimal opportunities to communicate intensively and to have representatives from all over Europe. Therefor it was decided to have a conference on invitation and to limit the number of participants to approximately 100. In total 103 participants from Europe and 3 from abroad responded to the invitation to attend the Conference and to provide discussion papers or present posters.

Participants have presented papers on various subjects and representing different backgrounds around the central theme of river restoration. The conference generated 61 papers and abstracts.

The papers and abstracts in this proceedings are grouped as follows:

General:	Conference Considerations, Opening Address and Welcome address.
Key-note papers:	Papers covering characteristics and functions of the rivers in Europe as well as their geo-ecological perspectives, water quality, and status.
Eastern Europe:	Papers dealing with the Rivers Danube, Volga, Tisza (Hungary), Sava (Croatia), Hornad (Slovakia), and Lithuanian rivers. Water quality aspects are presented in papers from Poland, Ukraine, Russia.
Western Europe:	Papers dealing with the River Rhine, and rivers in Belgium, Denmark, France, Germany, Ireland, Switzerland and the UK.
Southern Europe:	Papers from Spain, Portugal, Greece and Italy.
Northern Europe:	Papers from Norway and Finland.
Outside Europe:	Papers from Australia and America.

By nature of the Conference the diversity of the papers is large. To retain the opinions of the individual writers, as little as possible has been changed in the text, the contents of which remain the full responsibility of the authors. The reader will notice the variation in style in the papers presented.
The editors, however, did not feel that it was their task to superimpose uniformity.
The editors are grateful to all participants for their contribution.

It is hoped that the proceedings will find its way, not only among those who participated in the Conference, but also among the numerous people in the world who are interested in the problems of river restoration.

H.J. Nijland
M.J.R. Cals

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1. Introduction

Degradation of rivers in Europe
European rivers and their flood plains are used by man for many purposes. Many modifications have been made in the European rivers to adapt them to human needs. So the water quality, the discharge characteristics and the habitats in river courses and in floodplains have been seriously modified by man in this century. Many of these modifications, related with one function, degraded the potential of the river to support its different functions. Sometimes, such degradation had been foreseen and taken into account before the implementation of modifications. But in most cases, degradation arose unintentionally and unexpectedly. Degradation of rivers is a general phenomenon in Europe. Different parts of Europe, however, each have specific degradation problems. Habitat degradation is characteristic for rivers in Western Europe; water pollution for rivers in Central & Eastern Europe; water shortage and the modification of seasonal discharge patterns for rivers in Southern Europe.

What is river restoration?
River restoration embraces a great variety of measures that have in common, that they restore natural functions of rivers, that were lost or degraded by human intervention. Disposal of waste water into the river, for example, has negative effects upon many different functions, like drink water supply, irrigation water supply, maintenance of fisheries and maintenance of biodiversity. Dams for the generation of hydropower, as another example, interrupt the migration routes for migratory fish and by doing so, have a negative impact upon the income from fisheries. River restoration usually aims at restoring a multifunctional use of rivers, often by restoring more natural conditions in the river system. It is becoming increasingly clear that future river management should not focus upon adjusting the river system to human needs, but upon adjusting the human use to the natural river system.

Why do river restoration?
Many European rivers have often been modified in the past decades to serve only one dominant function. With some exaggeration we may say that some rivers were cut by dams into a chain of basins for the production of hydropower, some rivers were transformed into an open sewage discharge system, some rivers transformed into highways for shipping. All over Europe, however, changing environmental, economic and social preferences exert influence on river management.
One-sided use with disregard of different functions is no longer considered optimal. As every function influences the different functions, an integrated approach of river restoration is prerequisite for success. With additional attention, and often additional investments, a more multi-functional river system can be created. Such 'cleaner, more complete and healthier rivers' produce more benefits for society.

How to achieve river restoration?
Decision making in the European societies is becoming ever more complex. Concerning rivers, water managers no longer dominate the decision making process. Negotiated agreement, interactive

planning and the involvement of the public opinion and various stake holders are the promising ways to reconcile conflicting interests. This implies that the technical and ecological considerations are only part of the game. Raising support and the promotion of public awareness are just as essential to obtain results.

Conferences

The first international conference on River Restoration was held in Denmark in 1996. The conference was organised by the European Centre for River Restoration/ECRR. The conference was hosted by the National Environmental Research Institute/NERI in Denmark.
The main theme of the first conference was the physical aspects of restoration of rivers and their riparian zones, reflecting the increasing attention being focused on this dimension of river quality in many parts of the world.
Most contributions at the conference came from Denmark, United Kingdom, The Netherlands and Germany. So, it was quite logic that institutes from these countries were among the first to participate in the development of a network on river restoration. These countries, however, cover only a part of Europe.

Since the first conference the European Centre for River Restoration has developed a denser network of relevant national institutions, and the ECRR was officially established in 1999. Detailed information on ECRR is presented in Appendix 1.
The 2nd Conference on river restoration was arranged by ECRR in 2000.

2. Conference Objectives and Programme

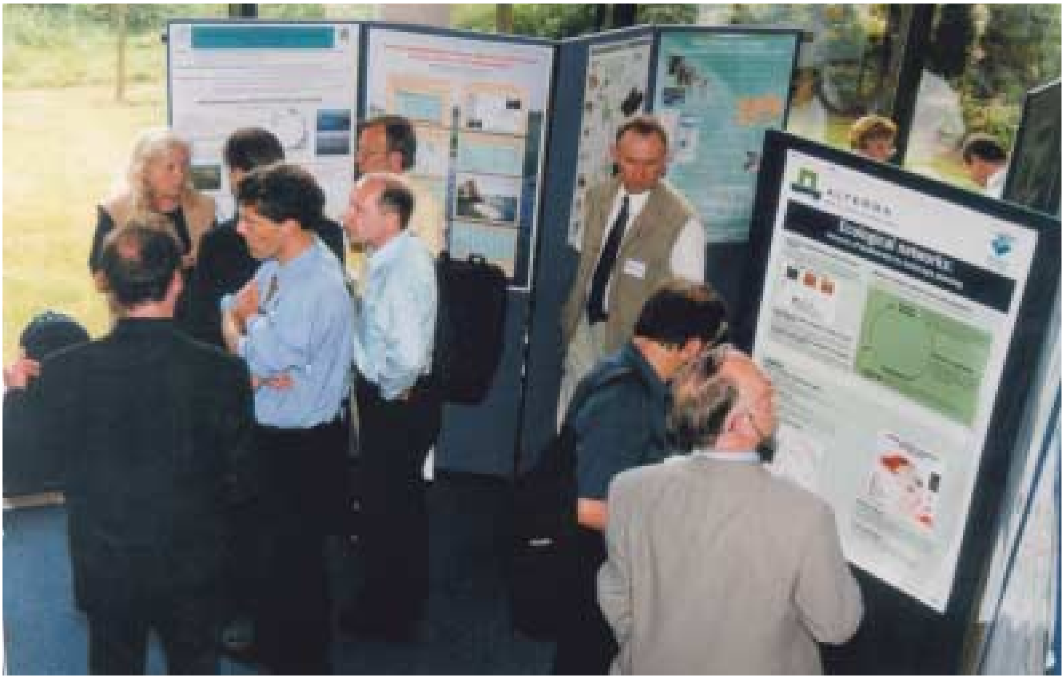
The main goal of the conference was to contribute to the further development of a Pan European network on river restoration, which is to implement its activities under the umbrella of the European Centre for River Restoration.
During the Conference on River Restoration 2000 efforts were made to answer questions like:

- How can river restoration be integrated in river basin management?
- What technical solutions reconcile potentially conflicting river functions?
- How to raise public awareness and support for river restoration and how involve stake holders?
- What are the common features in river restoration all over Europe, and what items are specific for different parts of the continent?

In his welcome address, Mr. Iversen, Chairman of the management board of ECRR, mentioned the immense interest for river restoration presently found throughout Europe. He, further, highlighted the role of ECRR in the process of river restoration.

Mrs. De Vries, the Vice-Minister of Transport, Public Works and Water Management in her opening address to the conference participants, mentioned that the Dutch Government considers issues on river restoration issues very important.

Keynote lectures, oral presentations, workshops, poster sessions, information and demonstration market, and discussions provided an excellent overview of the many aspects of river restoration in the different European regions and other continents. In addition, the excursions gave the opportunity to visit a number of Dutch restoration sites, like, '*De Blauwe Kamer*', '*Millingerwaard*', the River Niers, and '*Biesbosch*'.



Poster session.

For preparing the programme and as input for the discussions during the conference, the participants were asked to provide some information beforehand. The participants answered some questions concerning their experiences with river restoration and their expectations of the conference. The results of the questionnaires filled in by the participants is presented in Chapter 3.

The participants expressed their opinions on a number of issues in the thematic workshops. Regional workshops had drawn up a number of special considerations reflecting different trends, problems and solution options regarding river restoration in different European regions: the Southern, Eastern and Western regions of Europe. These thematic and regional workshops generated additional reports, which are summarised in Chapter 4.

At the end of the conference a number of general key messages on the way ahead in river restoration could be concluded, and some present strengths, weaknesses, opportunities and threats could be identified. A set of priorities on how to enhance river restoration on a national and EU level was worked out. Likewise, a number of priorities for the future work of the ECRR were outlined. These key conclusions and recommendations, and the priorities for actions are presented in Chapter 5.

3. Conference Questionnaire

Introduction

Europe consists of many countries that differ strongly in climate, geomorphology, population density, culture, economical development and history regarding river restoration. One might expect that different parts of Europe have different problems in their river systems and/or have a different

approach to cope with or solve them. And: do these differences also result in differences in expectations of the participants of the ECRR and this conference?
Therefor, prior to the conference, the participants were invited to fill in a questionnaire on features of their organisation and river systems that they manage or research. To analyse the questionnaires Europe was divided into 4 regions:

Eastern Europe:	Bulgaria, Hungary, Poland, Romania, Russia, Slovakia, Turkmenistan, Ukraine, Croatia, Lithuania;
Western Europe:	Belgium, Denmark, France, Germany, Ireland, The Netherlands, Switzerland, United Kingdom, Austria;
Northern Europe:	Finland, Norway;
Southern Europe:	Greece, Italy, Portugal, Spain.

Note: the analysis is not scientific accounted for, but reflects participants' view.

The results of the analyses

Functions of the river system
The participants of different regions in Europe have listed the most important functions of their river system(s). An overview of the frequency (in %) of the listed functions of the participants in the 4 regions in Europe is presented in the table below. Rivers in Europe fulfil a broad range of functions, important for economy and the common good. Most important functions mentioned are: nature (22%), safety (17%), hydropower (16%) and fishery (15%). Other, but less important functions are, shipping (10%), drinking water and irrigation (11%).
On average throughout Europe, nature is regarded the most important function. In Northern Europe hydropower and fishery are considered the most important ones. The figures of the most important functions are displayed bold.

	Hydro-power	Drinking water	Irrigation water	Water supply	Shipping	Safety against flooding	Fishery	Nature	Total
Eastern	10	14	10	3	6	**16**	**16**	**25**	100
Western	2	8	6	4	**17**	**23**	15	**25**	100
Northern	**31**	8	0	0	15	15	23	8	100
Southern	**21**	7	**21**	0	0	14	7	**29**	100
Average	**16**	9.25	9.25	1.75	9.5	**17**	**15.25**	**21.75**	

Also in the Southern Europe hydropower is an important function, as is water supply for irrigation.
In Eastern Europe safety against flooding and fishery are regarded as most important items. In Western Europe also safety is one of the most important items, directly followed by shipping.

Problems met in the river system and objectives for river restoration
There is a great similarity in problems that are met in European rivers. Most mentioned are problems with safety, water availability, water quality and the degradation of fishery and nature. Differences in

problems in different watersheds appear, due to differences in the nature of the rivers, dominant functions, culture and focus of research and river restoration.
Participants of all parts of Europe underline the importance of creating public or administrative support for working on solutions. The participants indicated that all over Europe a lot of attention is paid to create public awareness and support.

All participants consider changes that have occurred in the river morphology (for safety, hydropower, land reclamation, intensive forms of land use) as a source of problems in the river. In all parts of Europe nature has degraded due to these changes. Many participants mention the (partly) restoration of the original morphology of the river as an objective for river restoration. Participants of Western Europe stress also the importance of restoring the natural processes in the river bed and the floodplains.

Participants of Eastern and Northern Europe consider water quality and loss of habitat as the most important problems. In Northern Europe, especially the loss of fish habitat is considered a major problem. Both Southern and Eastern Europe encounter problems with water availability; due to their climate (high temperatures and low precipitation in summer). Further in the Western and Southern part of Europe safety is considered to be a main problem. The participants from these regions also consider the loss of identity and beauty of river landscape as a problem. River areas in these parts of Europe are often densely occupied and have a high recreation pressure. The original beauty and scenery of a river landscapes, which are often habituated for many centuries, is highly valued from cultural, ecological, and aesthetic point of view. None of the participants in Northern and Eastern Europe had explicitly mentioned this aspect.

The various functions of the different rivers show a similarity which implies that the possible conflicts between these functions also show a similarity. However, in Eastern European countries possible conflicts are seen as a local problem related to one sector. The objectives for river restoration are beside source-oriented often *result-oriented*, e.g. the use of macrophyte filters or aeration techniques to improve water quality or the construction of a waste removal infrastructure to mitigate silting effects of a constructed dam.

In Western Europe the mentioned cases are more *source-oriented*. Conflicts are mainly defined as an integrated problem of the whole river basin. River restoration objectives focus on hydro- and morphodynamics in order to restore ecological functioning. The difference observed might be related to the difference in implementation stage of integrated concepts at policy levels.

Conflicts between and compatibility of functions, as well as a certain similarity and a great variety in conflicting functions was mentioned. Conflicts and compatibility seems to be related to the scale and discharge capacity on the one hand and the climate and geographical characteristics on the other, i.e. the large rivers in Western and Eastern Europe have important economic functions, like shipping, agriculture, safety and water supply that conflict with nature, fisheries and water quality. In smaller streams, nature conflicts with either water supply and irrigation (Southern Europe) or hydropower, and several ways of land use (Northern Europe).
Functions that are seen as most compatible are:
- Nature and fishery;
- Hydropower and water supply, irrigation, drinking water, safety, shipping;
- Nature and water supply, drinking water.

Expectations of the participants

With respect to ECRR
Participants of whole Europe see the ECCR as an opportunity to create a *powerful network* to exchange knowledge and experiences. Participants of South and West Europe stress the role that ECCR can play in *enhancing international cooperation* (catchment area approach). Many East European participant stress the role that ECCR can play to *increase* administrative (both national and international) and public *support* for river restoration.

With respect to the conference
Participants of Eastern Europe focus on the exchange of *knowledge* between specialists, while participants of the rest of Europe emphasise the exchange of *experiences* in the practice of river restoration.

With respect to international co-operation
Many participants stress the importance of international co-operation and of a catchment area approach (West European participants). This approach is widely adopted in Western Europe. In Eastern and Southern Europe this approach seems less common (or in some cases less relevant). In these parts a more sectoral approach is applied. However, participants from these parts (especially from Eastern Europe) stress the importance of international exchange of knowledge and co-operation and also some participants stress the importance of cross sectoral co-operation.

Its remarkable that a number of participants from Eastern Europe find their task in ‘to put a problem on the map’. The magnitude and nature of problems in riverbed have still to be researched and then to be put under the attention of relevant administrative organisations and the public to create support for solving the problem.

Participants at the River Niers.

4. Workshops Reports

Thematic and regional workshops were part of the conference. At these workshops papers on integral river restoration with accents on ecological restoration (nature), physical adaptation to human use, and water quality, and papers concerning issues in the regions, were presented. The results of the whole week of presentations and discussions, reflecting different trends, problems and solution options regarding river restoration in different European regions: the Southern, Eastern and Western regions of Europe have been summarised.

Southern Europe

Key issues

- Climatic and hydrological variability leading to low flows and flash floods, high sedimentation. This is accentuated by land-uses such as irrigated agriculture or the cultivation of slopes;
- Modulation of flow regimes by dams is usual, leading to altered geomorphology and habitat/species changes;
- Restoration can only be partial due to the strong influence of dams which have 'tamed' the rivers, so you cannot restore pre-dam flow regimes and the associated river features;
- Continuing major funding of river infrastructure projects;
- Very high value of the remaining 'unspoiled' rivers, with special characteristics - but these are poorly protected and their special nature is not recognised by the EU or other international institutions;
- Strong dominance of engineering philosophy is preventing more ecological alternatives from becoming reality; there is a lack of inter-disciplinary approaches;
- Riparian forests are left 'high and dry' due to channelisation, the influence of dams and river deepening;
- Native fish species are very specialised and with river alterations, exotic fish species quickly take over.

Priority objectives

1. Ring the alarm bells on losses of species and habitats of Mediterranean region in key institutions, such as the EU;
2. Conservation of important rivers and river stretches and areas which influence the river processes;
3. Prevent more major channelisation and infrastructure development schemes e.g. those funded from EU;
4. Remove subsidies and incentives which result in land and water uses that have severe impacts in southern Europe -and promote positive use of these funds for integrated river management schemes that include river restoration measures;
5. Identify and promote options that would partially restore the river dynamics by altering the flow regimes of dams;
6. Ensure that river management schemes take full account of the natural values of the rivers;
7. Improve the use of Environmental Impact Assessments and monitoring of river engineering schemes - and use case studies to inform funding bodies;
8. Develop tailor-made (for Southern Europe) public awareness and formal education and capacity building programmes for all those involved in designing and implementing river management and restoration projects;
9. Improve the communication and working relationships between environmental and water managers.

Recommendations to ECRR

1. Consolidate the experience (from the World Commission on Dams reviews, from ICOLD, ECRR networks and from other areas with similar climatic conditions, such as California and Colorado), on river restoration projects, with a special emphasis on dam management that has relevance to southern Europe;
2. Develop a public awareness campaign for the benefits of river restoration in Southern Europe;
3. Provide case study examples of the negative effects of subsidies and the possible alternative use of these funds on Southern European rivers - for MEP's, NGOs and others that can influence finance institutions.

Western Europe

1. Is there an European river restoration philosophy?

The opinion of the participants was that one could say so 'more or less'.

- The ecological functions are the basics for river restoration (EU-Water Framework Directive);
- For the practical work there is a framework of legal conventions and knowledge. Within these frameworks the acceptance of the people should be obtained.

2. Objectives of river restoration

Technical Objectives

There is a lot of knowledge, but there are:

- Language problems;
- Information deficits (how to find access to existing knowledge).

River restoration works includes to see what is going on in the watershed.

Sustainable developments of river systems means:

- The objectives for a river channelisation in the past have changed. There is no need anymore to maintain this system in the traditional way. Restore it, but don't subsidise the old way.

Psychological objectives

To find acceptance for river restoration you have to:

- Show the social benefits;
- Inform stakeholders and the public at the right time (long-term projects);
- Find solutions for the problems the stakeholders may have by the project;
- Combining the interest of stakeholders can open the way for an advanced river restoration project.

3. Information Links

There is a lack of information on river restoration experiences.

Links are needed to:

- Cost management;
- Psychological experts;
- Related organisations.

These links could be established through journals. Everybody is asked to submit articles and information for the web site.

Eastern Europe

General

- Pressure on nature and rivers due to economical development. The good news is the construction of sewage treatment plants, the bad news is uncontrolled development;
- EU subsidies for infrastructure projects may have negative effect.

Solutions typical for Eastern Europe

- Adapt a small scale, integrated approach;
- Prioritise conservation of the many positive/valuable rivers; stop further degradation. First focus on natural rivers: protect these rivers; designate them as nature reserve. Restoration of degraded sites will cost large amounts of money;
- Create Public Awareness: dissemination on all levels, to counter balance the engineering approach;
- Develop the hydro-ecological knowledge, like the role of small streams on flood retention, instead of looking only for engineering solutions;
- Stakeholder involvement is growing and has perspectives.

Tasks for ECRR

- Promote an integrated approach for land use planning;
- Provide an inventory of valuable rivers and potential sites. We know where to build dams, but not where the potentials are for nature. We need maps for that;
- Provide a manual of best practices;
- Start/promote pilot projects in Eastern Europe.

Workshop session.

5. Conclusions and Recommendations

Conclusions

Key Messages

- There should be No Regrets and No Recriminations - One should act now if a 'win win'-situation is to be achieved;
- Provide 'Space for the river' - Recognise the need and share it;
- Integration of interests should be eased - Find alliances - at operational, functional and community levels;
- Understanding the benefits - Nature/biodiversity; Water quality and purification; Flood defence; Water resources; Fisheries/angling; Forestry; Agriculture; Hunting; Recreation; Economics (local, regional, national, international);
- There is a need to get the 'benefit' message across - We all have a role to play;
- Sustainability and processes - Solutions *must* be sustainable and restore elements of 'function';
- Avoid disasters - Value more what we have, protect the best and do not wait for disasters to trigger projects
- Commonality - ALL the above apply to all European regions, but….
- Priorities and needs do vary - Recognise this and help each other.

Strengths, Weaknesses, Opportunities and Threats

Strengths

- Peoples enthusiasm;
- External support – collaboration, people and legislation;
- Funds (internal and external).

Weaknesses

- Aspirations often too modest;
- Insufficient analysis and understanding of constraints;
- Understanding scale of cost/benefit linked to objectives.

Opportunities

- Harnessing of energy and enthusiasm;
- Linkage of benefits for all through river restoration;
- Multi-functional involvement.

Threats

- Need for space and lack of recognition;
- Short-term focus or public rejection;
- Costly delivery of promises by not sharing.

Special Considerations - Southern Europe

Climate	Leads to dry rivers and flash floods. Land-use: irrigated agriculture and cultivation of slopes.
Dams	Too common – Destroyed geomorphology/hydrological regime - restoration can only be partial. Destruction of riparian forest.
Approaches	Philosophy is traditional 'engineering' - constraint to ecological alternatives.

Assets	Few unspoiled rivers and specialised species left. Pressures are great and protection is poor.
Priorities	Ring the alarm bells - Prevent further destruction. Promote positive use of funds. Promote restoration of dynamics. Use EIA and public awareness to save and restore natural values.

Special Considerations - Eastern Europe

Unique Pressures	Due to rapid economic adjustments and pressures.
Actions	Need small-scale approaches to foster wider adoption.
Priorities	Still retains good/pristine examples on what most of Europe has destroyed - priority is protection in combination with socio-economic development.
Awareness	Stakeholder interest is growing and they are developing their own perspective. There is a need of demonstration projects to kick-start internal development of concepts and benefits.
Quality	Special need for co-ordination of European Water Quality Standards.

Special Considerations - Western Europe

Understanding	Need to improve measurement of effects of activities – ecological, hydrological/geomorphic processes, economic etc.
Language	Much activity - but lack of common terms hinders understanding and sharing.
Information	Much information - but still poor exchange within same countries and across boundaries. Have better co-operation between organisations, publish more and then put theory into more practice.
Links	River restoration needs better funding and operational links to economics and water management.

Recommendations

Priorities at National and EU Level

Recognition	Get principles of river restoration officially adopted as an integral part of NATIONAL water management.
Sustainable Actions	CAP and other EU funding rarely delivers sustainable solutions and destroys cultural and historic practices that evolved in harmony with nature.
Frameworks	Influence and use directives - e.g. Water Framework - Physical quality objectives as well as water quality.
Awareness	Ring alarm bells on losses; develop awareness and training to deliver integrated, sustainable and multi-use management practices and projects.
Transboundary	Further co-operation of national centres and transboundary initiatives important for whole of Europe.

Priorities for ECRR

Networks	Help existing Centres to operate more effectively and help new ones develop. Encourage individuals and organisations.
Demonstration sites	Promote more sites to raise awareness and learning. Facilitate better value for money from investments.
Facilitate	Regional needs, e.g. dam management options for Southern Europe. Encourage adoption of water quality standards across Europe.

	Promote pilots in Eastern Europe.
Promote	Integrated catchment approaches to problems and understanding of land-use influences.
	Public awareness of *Benefits* at local, national and eco-regional scales.
	Public awareness of *Problems* of dis-functioning systems.
Inventories	Of valuable rivers and floodplains requiring protection and priorities for rehabilitation.
Documentation	Facilitate access to 'solutions', manuals of techniques, case studies (of negative and positive actions and pressures), reference conditions etc.

Participants of the Conference on River Restoration 2000.

APPENDIX 1.

EUROPEAN CENTRE FOR RIVER RESTORATION: CONNECTING PEOPLE IN RIVER RESTORATION

The European Centre for River Restoration/ECRR was established in 1995 as part of a joint demonstration project between Denmark and the United Kingdom. To involve more European countries in the European Centre for River Restoration, in 1998 an enquiry was forwarded to potential practitioners of the Centre. The answers from the questionnaire were convincing and supported the idea of establishing the ECRR. In March 1999 the official constituting meeting for the ECRR was held in Silkeborg, Denmark.

Waters are under increasing pressure from the continuous growth in demand for sufficient quantities of good quality water for all purposes. Also climate change and focus on biodiversity has enhanced the necessity for sustainable and integrated water management. These developments and in result the Water Framework Directive/WFD have gained momentum for the European Centre for River Restoration and the role it aims to play. The need for exchange of information and learning from each other exists on Pan European scale. The importance for Central and Eastern European countries is recognised because they have to implement the Water Framework Directive as part of the enlargement or approximation process.

Vision

ECRR supports the development of river restoration as an integral part of sustainable water management throughout Europe, by connecting people and organisations working on river restoration.

ECRR strategy

- ECRR will facilitate access to any type of practitioners of the network through a web based matching service to allow and encourage the sharing of experience on river restoration and building of ideas;

- ECRR will reinforce the development of this learning community through the organisation of conferences, workshops, seminars etc., and the delivery of newsletters;

- ECRR will facilitate access to information on research, planning, implementation and monitoring on river restoration through the development of a website;

- ECRR will facilitate establishment of national networks on river restoration;

- ECRR will frequently poll the users to identify how the network can be improved.

ECRR and the Water Framework Directive/WFD

The WFD provides new tools into European water policy, covering the whole water cycle, attending a holistic approach to water status assessment and passing across all administrative borders. In order to achieve this, the WFD puts forward the following main principles:

- Freshwater management must be carried out on the basis of River Basin Management Plans;
- In order to define objectives the concept of ‘Good Water Status’ is defined at the level of biological, hydrological and chemical quality that has to be reached in a catchment area.

In addition the WFD puts great emphasis on economic instruments to help meet environmental objectives and on public participation in local water policies and planning. Integration with other policies and Directives, especially the Convention on Biodiversity, is important.

Ideas on the strategy for implementation of the WFD can be summarised as follows:

- Implementation should be based on trust and confidence, not infringement: challenge is to stimulate stakeholders to act in the spirit of the WFD;
- To meet the need for common understanding on scientific techniques, directive instruments and capacity building;
- Idea is to stay away as much as possible from the pitfall of large administrative concerns and to learn from good practices, efficient reporting and experiences with integration of tools and approaches.

With the aim to enhance sustainable integrated water management, based upon river basin plans, in all European countries, capacity building and exchange of information should occur at all levels. ECRR can play an important role in networking and facilitating. ECRR focuses on scientific, technical and practical questions related to the WFD, not institutional aspects.

Organisational structure

The ECRR is a network, in which all practitioners have the opportunity and responsibility to make the centre work. A close contact between practitioners, both nationally as internationally, should be established for the exchange of information through newsletters, home pages and meetings. The ECRR facilitates and encourages the establishment of national networks, especially in Eastern European countries. The main function of national networks is the establishment and maintenance of a national network of individuals and organisations working on river restoration. The (international) ECRR and the national networks work complementary and support each other.

A Management Board, with seven representatives, is responsible for general management and organisation of ECRR. The management board activities consider organisational and co-ordinating aspects, e.g. proposing structure and working practices, organising meetings and conferences etc. The Board includes equal distribution of institutions from countries all over the EU with at least one representative from TACIS countries, one from PHARE countries and one from southern Europe.

The Management Board meets twice a year. Meetings are held in different countries to provide information on a wide range of geographical differences.
A secretariat elected by the management board for a period of 3-5 years will represent ECRR externally and function as the contact centre.

With this structure the ECRR can create a platform, covering the activities and projects of individual practitioners. Therefor, it is important that ECRR supports the development and implementation of concepts on river restoration into integrated river basin management within the European framework. Subgroups with certain common interests will be stimulated to organise meetings, workshops or study tours to further develop their topics and ideas. In such cases ECRR can play a facilitating role and feedback information to others within the network.

ECRR funding

The operational development of ECRR requires external funding. Support from EU LIFE and COST programmes have been sought.
Practitioners should seek national funding for their own internal activities as the ECRR cannot provide grants or fund them.

OPENING ADDRESS

J.M. de Vries
Vice-Minister for Transport, Public Works and Water Management

Ladies and gentlemen,

This symposium on river restoration could not have come at a better time.
In the next few months, I have to make some major decisions about The Netherlands' rivers.
By exchanging your knowledge and ideas about European rivers this week, you will contribute to the debate on this subject.

The main objective of Dutch water management policy is to keep our country safe and habitable and our water systems healthy and resilient. Three values are central to these water systems: safety, ecological restoration, and sustainable use. And as far as I can see, these are also the main ingredients of river restoration.
Two fairly recent floods have put flood protection high on our social and political agendas.
In 1993 and 1995, this country was struck twice in short succession when two of our widest rivers, the *Maas* and the *Waal*, burst their banks. Two hundred thousand people had to be evacuated, with considerable human suffering and financial loss. It was another reminder of the vulnerability of our low-lying country. And of our need to protect ourselves better against water.

I know that some of you come from Poland, Romania, and Hungary, countries struck very recently by raging floods and serious water pollution. Some of you will have witnessed even more starkly than we have, how vulnerable people are who live near major rivers. The floods even cost human lives, a trauma that we in The Netherlands have fortunately not experienced since 1953.

The fact remains that we Dutch live in a low-lying river delta several metres below sea level. If we had no form of protection against the sea and rivers, three quarters of this country would be under water. For us, flood protection is a question of survival. Literally *to be or not to be*.

We responded fast and effectively to the recent floods with a comprehensive project to strengthen our dikes: the Delta Project for the Major Rivers. We spent one billion guilders (or more than 450 million euros) to strengthen 750 kilometres of dikes and banks along the Rhine, *Maas* and *Waal*, making The Netherlands safer than it has ever been before.

But ‘foresight is the essence of government’, as a well-known Dutch saying goes. And our rising river levels give us cause to worry about the future. Climate change, sea level rise and subsidence are expected to increase the likelihood of floods like those in 1993 and 1995. To control high water levels, we need more than just higher dikes. We need a new strategy: Space for Rivers.

Over the years, we have clearly taken too much space away from our rivers. We kept on pushing them back, forcing them to run through narrower and narrower channels. And we built houses and factories near rivers, where we obviously should not have done. All in all, water management has been subordinated for too long. Serious flooding is the price we have paid for that ignorance of the past.

So it's time for a new, less arrogant attitude. Under the new Space for Rivers strategy, the Dutch government is carrying out an extensive programme of measures. Instead of raising dikes, we aim to lower water levels. We no longer seek to drain river water as fast as possible into the sea, but to give the rivers the space that they demand. We can't always impose our will on water; we have to accept some give and take.

In the Fifth Town and Country Planning Document, now being prepared, I want water to be treated as a stakeholder - to show that we have learned from our mistakes. When interests conflict, the water manager has to be firm and sometimes say ‘no’:

- No to large suburban housing developments in places where the river needs to run free;
- No to heavy industry in areas needed for the retention of very high waters.

The rivers have to regain the space they need so that heavy rain will no longer cause catastrophes or near-catastrophes.

Safety and nature are a powerful combination in The Netherlands' river region. One of the principles of Space for Rivers is that rivers should be respected as a fact of nature with their own natural environment.

The Netherlands has been restoring the ecology of its water systems for a long time. This is important for water management because nature-centred restoration and planning measures demand less effort and maintenance.

As you may know, only two months ago The Netherlands hosted the World Water Forum, where global and regional visions on water management were formulated and supplemented by action programmes. Ministers from 80 countries concluded that water management partnerships and final resources are needed to implement these action programmes.

Occasions like this conference are most useful for the further identification of common areas of interest, management constraints, and exchange of experience. With respect to The Netherlands, I can say that we are enhancing our international efforts in the field of water. We recently formulated the *Partners for Water* programme for Dutch involvement in the water sector outside The Netherlands.

We have our reasons for being so active abroad. The first is a matter of policy interests. We share water with our neighbouring countries, and international co-operation is a prerequisite for improving water quality and ensuring the sustainable development of our river basins. We have many years’ experience of international co-operation in managing the rivers Rhine, *Maas*, and Scheldt, and the North Sea and *Waddenzee*. And the results have been good, for instance where the quality of the Rhine is concerned.

Secondly, I regard the exchange of knowledge as a responsibility of my Ministry. In The Netherlands, we have gained a wealth of experience in water management, because of our long history of working with water systems. *Rijkswaterstaat* has been working with Dutch consultants and companies to lessen the potential conflict between flood protection, nature conservation in water management, and economic development. A potential conflict that is an important theme for this conference.

The exchange of knowledge and international co-operation give us the opportunity to achieve synergy in our responsibility for helping sustain river systems.

European water policy has become more and more important in the past few years, nationally and internationally, not least in river restoration. So this conference has been held at the right moment. The co-operative ventures that already exist in Europe should be intensified and developed into sustainable relationships.

The forthcoming EU Water Framework Directive will oblige member state governments to establish river basin management programmes and set standards for both quality and quantity. To do so, they will need knowledge and co-operation across all the borders. That’s why the specific objectives of this conference were: to exchange knowledge about rivers and river restoration in Europe; and to identify useful partners in Europe.

I regard the European Centre for River Restoration, which now has representatives from almost all of Europe's countries, as the ideal base from which to build capacity in river restoration. Not surprisingly, the ECRR is one of the organisers of this conference.

Ladies and gentlemen,
This conference provides excellent opportunities to exchange experiences on river restoration in Europe and the constraints encountered. The river systems presented in the coming week may vary, but there are two questions that we all want answered:

- How can we combine different river functions in an integrated and sustainable way?
- How can we put our plans to do so into practice?

I thank you all for your willingness to open your minds to each other's experiences and opinions, to learn from each other, and to continue to work together in order to answer these two questions. In result, this conference will help to build capacity and will lead to a more integrated, sustainable river restoration throughout Europe.

Thank you.

WELCOME ADDRESS

T.M. Iversen
Chairman of the Management Board of the European Centre for River Restoration

Ladies and gentlemen,

It is a great pleasure to welcome you to the second international conference on river restoration arranged by the European Centre for River Restoration/ECRR.

The conference is kindly hosted by the Dutch Institute for Inland Water Management and Waste Water Treatment/*RIZA*, and we owe great thanks to the institutions and organisations who financially supported this conference. The Ministry of Transport, Public Works and Water management in The Netherlands delivered an important contribution by giving *RIZA* and the Regional Directorates of South Holland and of Eastern Netherlands the opportunity to contribute from their budgets. Also WWF - The Netherlands and EU-LIFE programme have substantially supported the conference.

To me the attendance of more than one hundred participants from 28 countries shows the immense interest for river restoration presently found throughout Europe.

A conference on river restoration was held in Lund in Sweden in 1991, when stream restoration was in its infancy. Only a limited number of projects were carried out, and there was a sincere lack of documentation of the ecological effects of restoration. To get the process started a main conclusions from the Lund conference was: ‘Don’t hesitate and think too much – go do it!’

Following the Lund conference the Danish County of Southern Jutland and the English River Restoration Project initiated a joint EU LIFE demonstration project re-meandering three rivers in the two countries. The project included an information centre on river restoration. The European Centre for River Restoration was subsequently established at the National Environmental Research Institute in Denmark in 1995 in connection with the project.

In late 1997 five institutions met to bring the Centre forward to become a true European Centre, and in March 1999 the Centre was officially established at a constituting meeting in Silkeborg.

At the meeting a network of institutions and persons working with restoration of rivers was set up and the managing board appointed. The Members of the ECRR management board are:

- Torben Moth Iversen – Chairman of the Board
  National Environmental Research Institute/NERI, Denmark
- Bart Fokkens
  Institute for Inland Water Management and Waste Water Treatment/*RIZA*, The Netherlands
- Nigel T.H. Holmes
  The River Restoration Centre/RRC, United Kingdom
- Petru Serban
  ‘Romanian Waters’ National Company, Romania
- Nadezhda Prokhorova
  Russian Research Institute for Integrated Water Management and Protection/*RosNIIVKh*, Russia

- Javier Cachón de Mesa
  Centro de Estudios y Experimentacion de Obras Públicas/*CEDEX*, Spain
- Jane Madgwick
  World Wide Fund for Nature - International
- Henk Zingstra
  Wetlands International

The overall objective of the Centre is to support the development of river restoration as an integral part of sustainable water management throughout Europe. That and other objectives will be achieved through the development of a European network of relevant national institutions and persons working with river restoration.

The goals for the Centre are to:
- Exchange information on river restoration;
- Gain greater benefits from river restoration projects;
- Increase the cost-benefit of river restoration works;
- Obtain greater biodiversity, and better water quality and flood management;
- Improve confidence in promoting and implementing river restoration;
- Bring about changes in policy and practice on river restoration;
- Improve European access to world-wide experience.

To exchange information also means arranging workshops and conferences as the one we are attending right now.

The first International conference on river restoration arranged by the Centre was held in Silkeborg in September 1996. The focus was on the ecological effects of various restoration measures in small lowland rivers, especially physical modification of watercourses and the consequent effects this has on habitats and biota.

The conference here in Wageningen is the second conference arranged by the ECRR. It is part of the process and one of the main goals of the conference is to contribute to the development of this Pan European network. The ECRR is an organisation dependent on the inputs and active work of its participants. Therefore, the immediate future tasks for the Centre will be to develop the network and to commit people to actively take part in the ideas behind the centre.

At the end of this conference we hope to have a number of technical recommendations on river restoration as well as a clear view of what you, as being the network, expect and need the ECRR to be and work for. I therefore sincerely hope you will all actively participate in the discussions and workshops and I invite you to consider and express your opinions during discussions and workshops.

Besides the discussions concerning the ECRR network this conference will also bring information on many aspects on river restoration, through presentations, workshops and discussions, keynote lectures and poster sessions. On the excursion Wednesday we will have the opportunity to visit a number of Dutch restoration sites.

We have come a long way with river restoration and restoration of rivers and their floodplains has been acknowledged by the EU as an essential tool for future improvements of degraded riverine ecosystems, and restoration is about to become an integrated part of European water management.

Many river restoration projects have been carried out throughout Europe since 1991 and numerous experiences have been gained. Considerable sums of money are now being spent on restoring our rivers. For instance, last year the largest European re-meandering project till date was initiated in the Danish River Skjernå re-meandering the 19 km channelised river into a 26 km meandering river.
The costs of this project alone amounts to more than 35 million Euro.

Although river restoration has made considerable progress, it still faces many problems, technical as well as administrative. It is my hope that the European Centre for River Restoration will help overcome some of these problems.

The conference we will be attending for the next 5 days will undoubtedly be an important step.

With the ambitious and exciting programme I am sure this conference will bring inspiration, motivation and innovation to you all, and further lead to rivers that may once again hold natural qualities!

Let me finish by using this opportunity to present the official logo of the European Centre for River Restoration that will be used in future communications from the Centre.

With this I once again welcome you and hope for a fruitful and inspiring conference.

Thank you.

KEYNOTE PAPERS

EVOLUTION OF EUROPEAN RIVER BASIN MANAGEMENT

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Abstract
Although the Rhine basin takes a modest fourth place in the ranking of large European rivers, from an economic point of view this river basin is most important. In the course of time, many water and river management measures have been implemented in the Rhine River basin. Many of these measures were also applied in other European river systems and wetlands. These measures were conducted to meet both economic and flood protection goals. However, they also evoked unexpected hydromorphological responses, which affected the natural water system. Eventually, this resulted in a great loss of riverine habitats and a reduced hydrological resilience of the river basin. In contrast to the past, periods with high or low precipitation are now almost immediately reflected in extreme high or low water levels in the Rhine river. In this paper, the reasons underlying the major interventions in Rhine River basin are described. A new approach of water and river management is needed to achieve sustainable use and management of this river basin. This new approach comprises both preventive and recovery measures, which are also suitable for other European river systems.

1. Introduction

Nature restoration of river basins has been an intriguing issue for water and river authorities for at least some decades. At the beginning environmental organisations and ecologists stressed the importance of pristine, natural water systems. Hence, the conservation of natural values was generally expressed in loss of biodiversity and of aesthetic values such as small-scale agricultural landscapes. In general, ecological rehabilitation of stream corridors is still considered as a luxurious improvement of the landscape. Nature is ‘tolerated’, and not considered as an indispensable part of sustainable water and river management. Therefore, nature conservation is often the last item in the water authority’s bookkeeping. Only if we are able to ‘prove’ that nature is a building stone for flood protection, water quality and economic development the ambitious goals of nature conservation and restoration will be feasible. Based on historical events and present experiences in European river basins this paper focuses on this aspect. The developments in the Rhine River basin will serve as a guideline. Additionally, some references will be made to some other European river basins in order to illustrate the similarities of river management approach in Europe.

2. Major Interventions and Developments in the Rhine River Basin

The basin area of the Rhine River comprises approximately 185 000 km^2 and the river has a length of 1320 km (Figure 1). After the Volga, the Danube and the Wisla, the Rhine River takes a fourth place in the European top-ten of river basins (Middelkoop and Van Haselen 1999). The Rhine has been, and

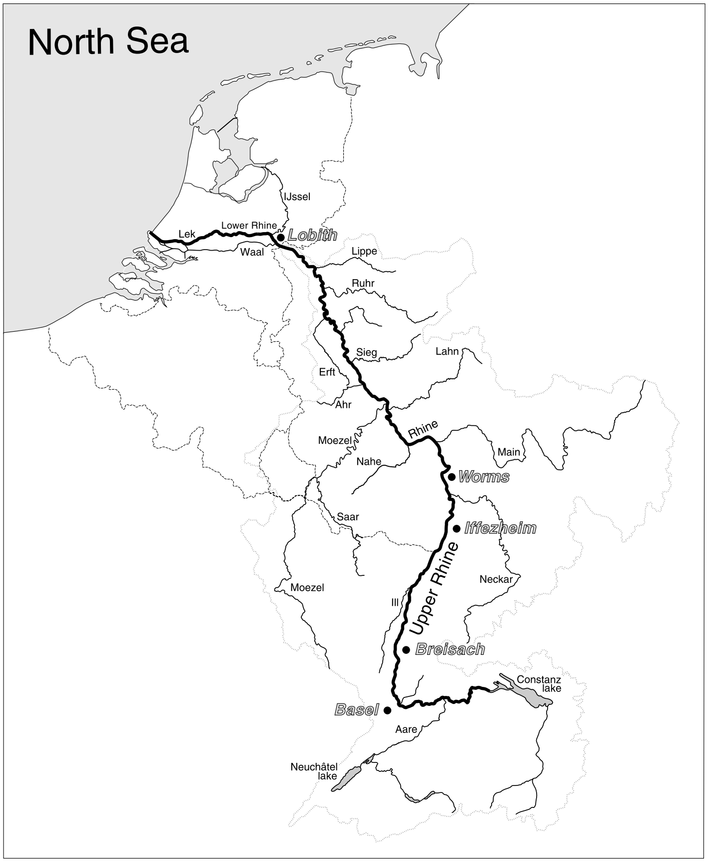

Figure 1. The length of the Rhine River is 1320 km and its basin area comprises 185 000 km^2.

still is, of major importance for the economic development of many European countries. Per year 150 million tonnes are transported across the Dutch-German border and it is expected that this quantity will increase the following years. A number of major interventions and spatial developments have transformed the original Rhine into the Europe's most important waterway. However, this resulted also in some undesirable side-effects.

1) Land reclamation and flood protection

The earliest water management intervention in the Rhine River basin was the digging of ditches in the delta (Huisman *et al*. 1999). By draining the peat-containing soil better growth conditions were obtained for agricultural products. With the aid of the windmills and a complex system of canals and reservoirs the wetlands were effectively drained. Actually, it was so successful that the Dutch 'exported' this drainage technology (e.g. Purseglove 1988). After these land reclamation projects many water management measures would follow eventually resulting in the globally well-known land under sea-level. The subsidence of the soil elicited another water management measure; the construction of dikes. In medieval times almost all river sections in the lowlands of the Rhine River basin were embanked. From that time the floodplains started to rise because the river could only deposit the sand and the silt between the dikes (Middelkoop 1998). In contrast, the drained soil of the embanked areas (polders) continued to subside. Up to now the standard solution to this problem is the

construction of even higher dikes and more powerful drainage pumps.
The process and methodology of land reclamation and flood protection along the Rhine has been applied in many other European river basins. However, time, place and scale may differ considerable.

2) River regulations, navigation and hydropower
Also along the upper Rhine River dikes were constructed close to the river bed (Dister *et al*. 1990; IKSR 1993) especially after the so-called river regulations carried out by Tulla (Monsoni 1970). Figure 2 depicts the total effect of many of these regulations along the upper section of the Rhine River.
The exploitation of hydropower on the Rhine River is mainly concentrated along the upstream section. Various hydropower dams combined with navigation channels were constructed. These navigation channels withdraw almost all the water from the river becoming to a large extent unavailable for biota and causing a severe lowering of the groundwater levels (Dister 1990). Similar ecohydrological effects due to hydropower dam construction can be observed near the Gabcikovo-Nagymaros hydropower dams in the Danube between Slovakia and Hungary (Leentvaar and Glas 2000). Moreover, the hydropower dams are blocking the sediment transport of the river and as a consequence erosion of the Rhine riverbed occurs after the last dam at Iffezheim. To compensate this effect, the riverbed must

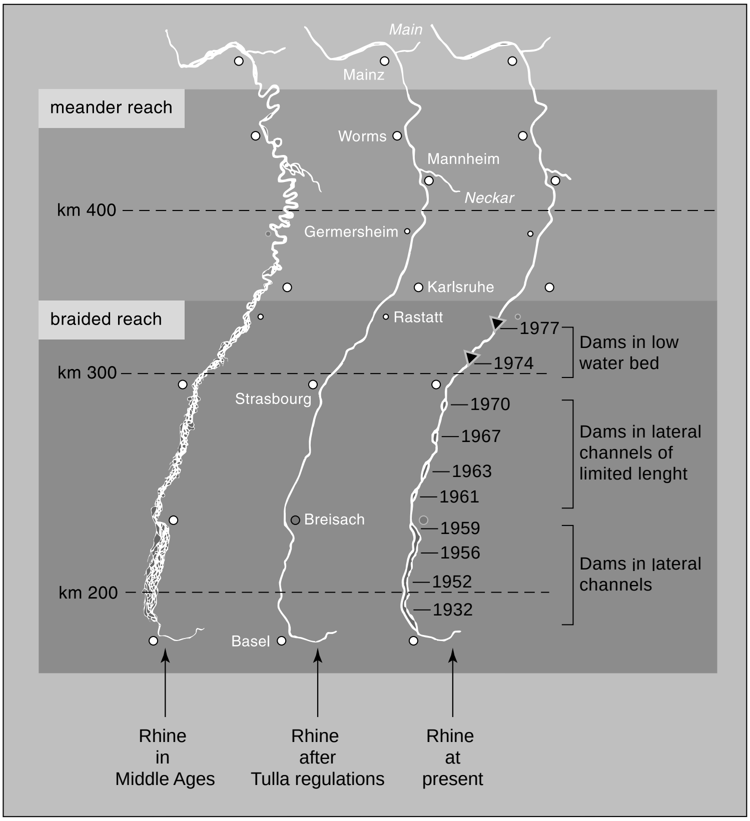

Figure 2. Three historical stages of the Upper Rhine. The original Rhine River was a hydromorphological complex system with braided and meandering river sections (left). After the Tulla regulations a simplified and low water bed remained (middle). At present the Upper Rhine is provided with several hydropower dams and navigation channels constructed to various strategies (Source: Dister 1985).

be yearly re-supplied with additional sediment (IKSR 1993).
During the last years in many European countries dams are constructed. Especially the Scandinavian countries and Spain are building dams in a fast pace. It is obvious that the construction of hydropower dams have advantages when all aspects of water supply are considered (e.g. 'clean' energy, water reservoir for irrigation, flood protection etc). Unfortunately, history teaches us that many dam projects are not well considered and often result from short-term strategies and the prospect of big profits. Within this context Goodland (2000) has excellently summarised guidelines, which can lead to a justified and sound decision process related to hydropower dam construction.

3) Water quality
One of the main problems realising nature restoration is pollution. Recently, Europe was startled by the pollution disaster along the Tisza River in Rumania. Also the Rhine River has a long history of pollution and environmental disasters. Eventually though, due to the efforts of all Rhine River border states, water quality has considerably improved (IKSR 1993; Middelkoop and Van Haselen 1999).
Since the international agreements related to the emission of pollutants at the Rhine River basin level and the construction of purification plants, the dissolved oxygen content has increased enormously. The concentration of many organic and inorganic pollutants has been reduced to a very low level. However, due to the massive use of fertilisers in the Rhine basin it is still difficult to reduce the amount of nitrogen in the river.

4) Water quantity (shortage)
It is well known that the East and South European countries suffer from water shortage. This water shortage is mainly the result of the climate but unfortunately also some man-made environmental disasters caused by large-scale irrigation are known (e.g. Aral Lake). In West European countries ecohydrological damage is mainly caused by inefficient use of rainwater and ground water consumption. Even in the delta of the Rhine and Meuse ecohydrological damage due to water shortage can be considerable (Veel 1999). The increasing rates of ground water consumption by industry and agriculture underlie this effect.

5) Cultural and natural values
Although the people living along the Rhine River must have appreciated their landscape they accepted the changes that have been implemented during the centuries. However, in The Netherlands this came to an end when the estuaria were closed with dams and during the large-scale dike improvements along the Rhine tributaries and the Meuse River. It can not be denied that public involvement in the large-scale interventions has increased enormously over the years. Politicians and administrators of all democratic countries are well aware of this effect and now involve the public opinion in their decisions.

3. Lessons Learnt

What can we conclude from the water and river management evolution in Europe?
1) We have learned that safety and economy are the driving forces of water and river management. The valuation of nature and aesthetic aspects of the river landscape is considered only important after the first two requirements are met;
2) We also have learned that far-reaching interventions in the natural water system generally lead to unexpected side effects that have to be compensated by expensive, management measures. In this paper, some cases are presented concerning the drainage of wetlands, the rising of floodplains and the construction hydropower dams;

3) We also have learned that when it comes to flood protection and water pollution control only a river basin approach can offer relief. This requires international co-operation in those river basins that are shared by a number of countries and a multisectoral approach;
4) Additionally, the influence of public support on the decision making process has increased enormously over the last decades in all European countries and is considered of great importance for the support of management measures on the long term.

4. Future Research Topics for Strengthening Nature Conservation and Restoration

If we want to restore nature effectively we have to make use of these lessons and identify mechanisms in which the interests of nature and the driving forces of water and river management reinforce each other. Research questions that proceed from this analysis must be preferred above others. From this point of view, two research topics with priority are:

Research topic I. Adapting user functions
What we have learned from the past is that far-reaching interventions in the natural water system generally provoke unexpected side effects. These side effects generally have to be mitigated or compensated by (often) new and expensive measures. It appears to be the best advice to leave the system unaffected as long as possible without hindering further economic development.
For that reason (technological) innovations are needed that focus on adapting user functions such as agriculture, housing and navigation to the natural water system. These innovations will preserve the natural system and are in that way more important than any ecological restoration methodology whatsoever (Smits *et al*. 2000).

Research topic II. Flood protection measures; Room for the river
Adapting user functions to the natural water system is very effective in achieving nature conservation. Unfortunately, it will take some time before this will be realised on a river basin level. Thus, in many river systems that suffer from floods other supplemental measures are needed. Also here, some opportunities appear where both flood protection, ecological as well as economic goals can be served. At present, this is a topical event in many European river basins and therefore will be discussed in more detail here.

Planning of nature restoration along tributaries
Riparian vegetation increases the hydraulic roughness of the floodplains. Therefore, the river authorities perceive this as contra-productive with flood protection measures. Indeed, their opinion is justified if along the upstream parts of a river system only measures are taken that will increase the water discharge capacity. At the river basin level this would have a similar effect as a choked rain pipe. On the other hand, the hydraulic roughness caused by the riparian vegetation can also be used to regulate the water discharge of the river system. However, this would imply that the planning of nature restoration projects should be done at the river basin level. This would give floodplain restoration a major added value. Computational models at the river basin level that are based on both hydraulic as well as ecological data sets are needed for this purpose.

Management of retention polders
In Germany and in The Netherlands plans are made that involve the setting back dikes, the creation of retention polders and spill-overs (IKSR 1997; Hendriksen 1999). A proper operation of these retention polders is not a simple task, but this aspect will not be discussed here. However, some have stressed

that if these retention polders are managed as if they were agricultural grounds this would be disastrous for both agriculture as well as for the present biota (Dister 1986). Both flora and fauna are not able to cope with the unexpected inundation that would occur during operation of these retention polders. However, if these retention polders are managed as wetlands we may be able to avoid this problem. In contrast to terrestrial ecosystems, the biota of wetlands are able to cope with a sudden inundation during the winter period. Management experiences with for example the Oostvaardersplassen, a well-known site for bird watchers all over Europe in the province of Flevoland, The Netherlands, could be very useful in defining a managing strategy of these retention polders.

Spill-ways or by-passes

In Europe we became aware that generally we have constructed our dikes far too close to the main riverbed. Behind these dikes, cities were built. At present these cities are now hydraulic bottlenecks. Also here, the combination of flood protection by constructing by-passes or spill-ways and nature restoration could offer relief.

Despite all the efforts that have been made to restore the riparian habitats in the floodplains, it has been almost impossible to reintroduce side channels; i.e. aquatic habitats characterised by slow flowing water and which occasionally dries up. These habitats are extremely important for many amphibian species and aquatic plants, which are not able to cope with the extreme hydrodynamics of the narrow floodplain area that remained after the dike construction. New opportunities appear when we try to combine these ecological interests with flood protection measures. At present, in The Netherlands some have suggested that the construction of by-passes around these cities could serve both the flood protection goals and simultaneously provide new ecotopes. To reduce the costs of such projects sand excavation and the building of luxurious apartments in a 'park-like' environment could be considered.

Floodplain lowering

Restoring the hydromorphological dynamics is most important in the restoration process of riverine nature. In some cases realising this goal could be combined with flood protection and economic interests. As a flood protection measure the lowering of floodplains (that have been raised due to increased sedimentation in the past), can be important. The lowering of these floodplains can be combined with the excavation of gravel or sand. Modified sand and gravel excavations even may

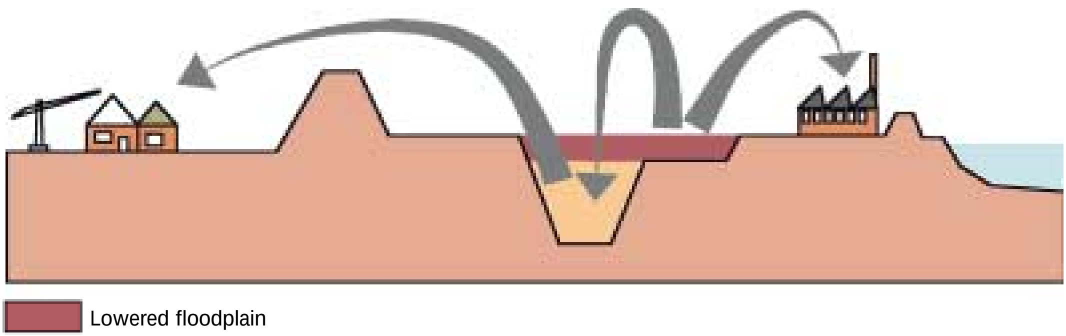

Figure 3. Combining ecological, economic and flood protection goals; modified sand mining.
By lowering the floodplains more room is made for the river. 1) Firstly, the clay layer is removed and transported to the brick industry. 2) Secondly, sand is dredged resulting in a (temporary) sandpit. 3) Thirdly, the polluted upper layer of the floodplain is concentrated in to the sandpit resulting in a lowered floodplain. The lowered floodplain is the start of a nature restoration project.

result in a reduced risk of assimilating pollutants by biota present in the top layer of the floodplains (Figure 3).
Along the River Meuse some projects are already carried out in which gravel extraction, increase of the water discharge capacity and ecological rehabilitation are combined. Apparently, there are some possibilities that these flood protection measures can be matched with both economic and ecological goals.

5. Concluding Words

We realise that it is easy to criticise the past. Considering the specific historical circumstances and the available knowledge the management decisions that have been made can be justified. However, copying these interventions at present to other river systems without a critical analysis of present knowledge and experience bears testimony to the lack of vision and responsibility for future generations. Governments must stimulate their river managers to explore new venues, which are based on river catchment dimensions rather than on regional or national boundaries. While doing this the management of water systems must be approached from the concept that first user functions must be adapted to the natural water system before we start to intervene with the water or river system. This requires an intense interaction between environmentalists and civil engineers. We hope that this paper contributes to this interaction.

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GEO-ECOLOGICAL PERSPECTIVES FOR THE MULTIPLE USE OF EUROPEAN RIVER SYSTEMS

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1. Introduction

In all long-settled regions of the world subject to large-scale administration, development has involved mega-projects of land and water management designed to extract wealth from rural areas for dispersal through cities. The 1990s saw a major change in social philosophy, with global recognition of the need for *sustainable* environmental management and the protection of biodiversity. In developed countries, attention has turned to environmental restoration. Traditionally, rivers were used for water supply, the dispersion and disposal of wastes, navigation, flood control and land drainage and fisheries. Today, the incorporation of river conservation into multiple use strategies for river systems is a new priority (see Boon, Davies and Petts 2000). This priority focuses on enhancing the quality of life, landscape restoration and the protection of biodiversity.

2. The Analysis of Fluvial Hydrosystems

Rivers are three-dimensional systems. Longitudinally, river systems extend from a network of small headwater streams to a single, large lowland river ending in either an estuary or a delta. They are usually considered to be unidirectional but, laterally, river systems comprise the channel(s) and the adjacent riparian and floodplain zones which are connected to the channel during high flows (Junk *et al*. 1989). Vertically, they include the alluvial aquifers with which surface-waters interact (e.g. Stanford and Ward 1988). The integrity of this three-dimensional *fluvial hydrosystem* (Amoros and Petts 1993; Petts and Amoros 1996) depends on the dynamic interactions of hydrological, geomorphological and biological processes over a range of time scales.

Rivers are characterised by strong hydrological and geomorphological gradients which relate to highly dynamic processes of three types:

- Hydrological processes (e.g. flooding, desiccation, surface-water and groundwater interactions);
- Geomorphological processes (e.g. channel bed degradation and aggradation, bank erosion, floodplain accretion, channel avulsion);
- Hydraulic processes (including high shear stresses during spates, and stagnation in dead zones during low flows).

Managing the ecological integrity of rivers in the face of development pressures, requires a knowledge of the physical processes responsible for sustaining the structural features of fluvial hydrosystems, and their dynamics, over a range of spatial scales:

(I) The regional scale;
(II) A linear sequence of sectors (10^8 - 10^5 m^2) within catchments;
(III) Habitat patches (10^4 - 10^2 m^2) within sectors;
(IV) Micro-habitats (10 - 10^{-1} m^2) within individual land forms.

3. The Problem for Management

Human impacts upon riverine landscapes across Europe have a long history. In the UK, the creation of the modern cultural landscape began quite suddenly with the onset of the Neolithic period about 6000 years ago (Rackham 1997). Most of the uplands had been deforested by 4000 BP and floodplain woods were cleared by about 2500 BP. By the Roman period (AD 40 - 410) much of the lowlands had experienced a long history of cultivation.

Pollution of the aquatic environment was regarded as an environmental problem as early as the 13th century (Sweeting 1994). Chronic conditions were reached in the 1840s; and all commercial fishing in the Thames through London, for example, had ceased by 1850. In England, 1858 became known as the 'Year of the Great Stink' because the condition of the London section of the River Thames was so bad. The magazine 'Punch' in that year (volume xv, p.16) characterised the Thames as one vast foul, stinking gutter. Problems of gross contamination by untreated sewage, high organic suspended solids and high ammonia levels, with high biochemical oxygen demand (BOD), were compounded by the accumulation of industrial and domestic refuse, and increasingly by effluent from heavy industry.

The control of nature and exploitation of natural resources became the heart of the industrialisation process and of advances in the co-ordination and effective administration of water- and land-management schemes. Great river regulation and wetland reclamation schemes in 17th- and 18th-Century Europe were not simply the result of technological advances. They symbolised power. Power of the emerging centralised state that was able to underwrite developments legislatively and financially. Power of a capitalist land market to realise the financial gains of improvement in increased land values.

4. Solutions for Management

Since the mid 1960s there have been major improvements in water quality led by advances in water treatment technology, in new legislation and changes in the industrial base with the decline of heavy water-using and waste producing industries. With improvements in water quality has come a realisation that opportunities exist for the rehabilitation of river corridors in the long-term, at the catchment scale, but also in the short-term, at the reach scale.

Channel Re-naturalisation

Simultaneously with the advancement of effective pollution control measures, developments were contributing to a re-examination of traditional management of rivers. Not the least important of these was the growing concern over the increasing cost of flood damage, despite engineering efforts to control flooding, and documentation of the long-term environmental effects of dams and channelisation schemes.

Across Western Europe, there is more than 20 years of experience of 'designing with nature' (Brookes 1988). Early efforts to restore stretches of small streams were made by enthusiasts in the 1960s and 1970s, notably in the German state of Baden-Württemberg (Larsen 1994). The first guidelines on 'nature-related river training and maintenance' date from around 1980, and the emphasis on 're-naturalisation' has been strengthened by laws in most German states. In Baden-Württemberg, a recent modification of the water law requires that a 'nature-like' condition must be strived for; the conservation and restoration of the ecological function of a watercourse has to be given priority.

Environmental Assessment legislation implemented following the European Commission Directive of 1985 makes provision for certain types of projects to be assessed prior to an application for planning consent, and in the UK this has resulted in environmental issues receiving greater attention in the decision-making process. The *New Rivers and Wildlife Handbook* (Ward *et al*. 1994) provides a comprehensive review of a range of rehabilitation projects carried out in the UK over the past 20 years. However, progress has been slow with most countries focusing on water quality and public-health-related issues, and fisheries - usually fish stocking (see e.g. Petts and Calow 1996) - and in most countries the length of channelised river restored with 'nature-like' features remains less than 1% (Brookes and Shields 1996).

Flow Regime

Traditionally, river flow patterns, which are critical to the maintenance and restoration of ecological integrity, were of concern only in relation to dilution of effluent, assimilation of organic wastes, and flushing of solid waste materials. However, twenty years of research during the 1970s and 1980s firmly established the importance of

(a) The flood pulse;
(b) Channel-forming discharges;
(c) The interaction of flow and channel form;
(d) Exchanges between surface waters and ground waters in sustaining the biological diversity and productivity of river corridors (Petts and Amoros 1996).

However, the incorporation of 'environmental' needs into flow allocation remains a key issue for water resource and river basin managers (Petts and Maddock 1994).

In small catchments and as part of a long-term policy, the re-establishment of a more natural water and sediment regime is possible, through upland catchment treatment, detention basins in urban areas, de-channelisation of selected tributary reaches, restoration of selected wetlands and riparian zones, modification of dams and dam operating procedures, and reconnection of more of the floodplain to the rivers.

5. European Approaches to Restoration

In Europe, catchments, streams, and rivers were extensively altered starting centuries ago, and it may not be feasible to restore substantial lengths of rivers, and besides, the managed and naturalised systems have their own values defined in historical, aesthetic, recreational and conservation terms. Indeed, a popular landscape in England remains the rolling green pastures, punctuated with clumps of trees, bordering broad streams or ribbon lakes; fundamental elements of the landscapes created by the 18th century landscape 'improver' Lancelot ('Capability') Brown (Burke 1971). Such landscapes are often perceived to be 'open' and 'safe', providing individual and family 'space' within a densely populated country, whereas wet woodland corridors - the natural landscape - are often seen as 'dark, damp and dangerous' (Petts 1990). 'Naturalisation' appears to be the best practicable option: it is defined (Brookes and Shields 1996, p.4 and illustrated by Rhoads and Herricks 1996) as the process which determines the morphological and ecological configurations that are compatible with contemporary magnitudes and rates of fluvial processes, that is with an anthropocentric vision of riverine landscapes.

In Europe, the need to advance knowledge of channel restoration led to a Demonstration Project partly funded by the European Community Life Fund (Brookes 1996). The project was started in 1993

and aims
(I) To demonstrate the benefits of channel restoration, and
(II) To involve, motivate and train all those involved with river management.
It involves three rivers with one site of 3-12 km on each, two in lowland England and one in Denmark. Independently, a number of pilot projects, typically on reaches of 2 km or less, are being undertaken elsewhere and in Baden-Württemberg plans are being formulated to 're-naturalise' 160 km of the River Danube (Larsen 1994).

Frameworks have also been established for the management of international river basins. A good example of the latter is the Rhine Action Plan (Van Dijk *et al*. 1995). In 1963 'Europe's largest sewer' was the subject of an international agreement, the Convention of the International Commission for the Protection of the Rhine (ICPR), involving five states bordering the Rhine and, since 1976, the European Union. The first focus was on water quality. The second was on habitat improvements. The latter aims
(a) To encourage the return of migratory fish, to allow free fish migration and to restore spawning and nursery grounds, and
(b) To restore all connected habitats to allow the development of self-regulating biocenoses with food chains intact.
The Rhine Action Programme is not only the first programme for a major transboundary river to include clear ecological objectives; it will also serve as an important demonstration project.

Within this framework, river reaches, corridors and networks offer opportunities for the achievement of sustainable management incorporating all user needs and meeting social, economic and ecological goals. The major problem is the restoration of streams in urbanised catchments. Water quality problems and channelisation appear to limit options. In such areas the restoration of the river corridor is not possible. However, the extent to which physical habitat naturalisation can achieve ecological benefits without changes of the fundamental processes in severely disturbed urban rivers remains to be evaluated. Current research using the hydrosystems approach to analyse urban streams suggests that considerable improvements can be achieved even in the most degraded systems to re-establish green and clean corridors.

Using modern knowledge, rivers can again become the life blood of societies providing water supplies, hydro-electric power, disposal for treated waste waters, flood channels, and opportunities for navigation, recreation, amenity, fisheries and nature conservation. However, the benefits of re-naturalising rivers in urban catchments extend beyond these traditional uses. Water frontages provide focal points for new developments. River corridors, even along small streams, can be the arteries for transforming not only entire urban conurbations but also whole catchments. They can create confidence in an area and enhance economic competitiveness and contribute to improving social cohesion. In this context, the management of rivers and streams encompasses social, economic and aesthetic concerns, as well as water management and nature conservation.

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RIVERS IN EUROPE: OPPORTUNITIES FOR RESTORATION–INSTITUTIONAL ASPECTS AND CO-OPERATION

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Abstract
The paper presents the case study of the River Po as an example of a river corridor system compromised and damaged by human-induced disturbance. The questions and issues arising are discussed in the context of anthropogenic pressure on European river corridor systems and policies and strategies available to assist the restoration process.
The processes modifying the hydrological conditions of the river are reviewed in a historical context with specific regard to the processes of reclamation, use of water resources and flood protection. Today's degradation of the river ecosystems is examined as a result of intensive exploitation of water resources and urbanisation of the territory.
The large scale economic and urban transformations in course, in Europe, today, can be seen as significant opportunities for inverting the trend towards an indiscriminate and damaging use of water resources, thanks to a stronger international co-operation, too.
The basin scale planning for the River Po presents an overview of strategic guidelines for active intervention and restoration goals for river systems. Opportunities and limitations related to the Italian scenario are analysed in relation to the methods and tools available to the practitioner.

1. River Restoration: Principles and Applications

The European continent, with a surface of around 10 million km^2, contains several million kilometres of rivers and streams, which together with the adjacent flood plains form *complex ecosystems* representing an important economic, social, cultural and environmental resource.
Today, the condition of many European rivers is the result of profound anthropogenic manipulation, induced by urbanisation and the intense exploitation of water resources. The cumulative pressure has a major impact: deterioration of water quality, reduction of floodwater storage, loss of habitat for plants and animals.

The accepted definition of '*ecological river corridor restoration*' is the process whereby an ecosystem returns to its antecedent, natural condition by re-introducing processes that aim to re-establish the general functions and dynamic characteristics of the system (Figure 1).

In the case of many large European rivers the basin is shared by two or more nations. Co-operation between riparian states has, in some cases, established a basis for the conservation of water resources; more than 100 bilateral and multilateral agreements regarding water quality and water use in Europe have been signed. These treaties have, to some extent, reduced the conflicts between states on the exploitation of natural water resources in Europe.

To study in more detail the impact and the dynamics of natural and human-induced disturbances, and, to take a closer look at the opportunities for restoration, we have selected the case study of the River

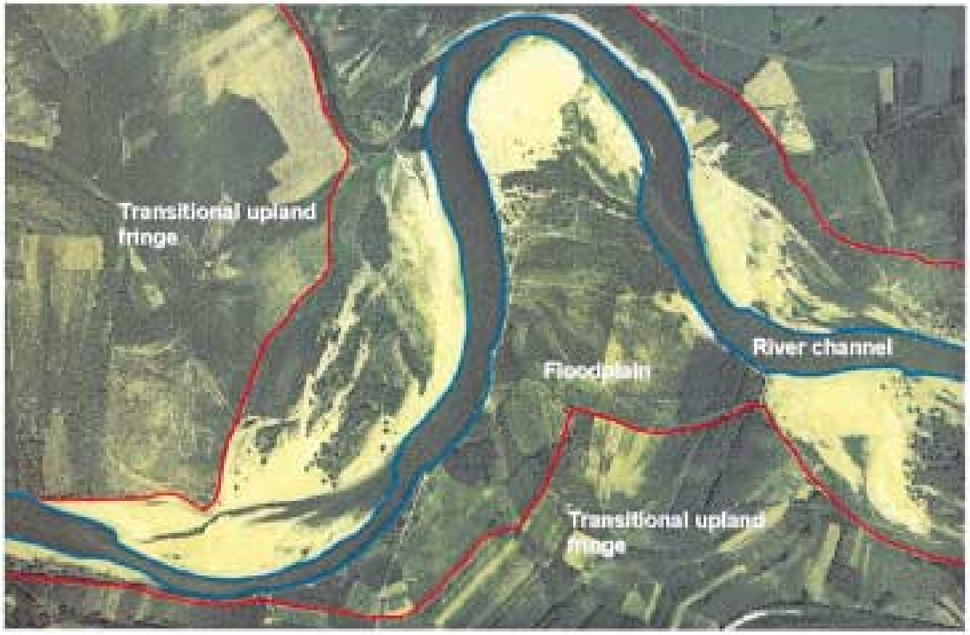


Figure 1. Overview of a river ecosystem.

Figure 2. The Po river watershed.

Po. A case very familiar to the author of this paper. We believe that the processes outlined, together with the causes and effects, the analysis of the opportunities and the application of restoration goals can be used as a concrete example applicable to other European rivers with similar physical characteristics and history (Figure 2).

2. The River Po Case Study

2.1. Historical transformation of the river network

The main river network of the Po basin is made up of the Po River and 141 tributaries extending for approximately 6750 kilometres. The length of the total river network exceeds 40 000 km.

The present course of the River Po was formed following the famous 'Ficarolo Break' around 1140 AD; The old river-bed was gradually abandoned, and, downstream of the town of Ferrara, split up into two tributaries, the Volano and the Primaro. The Reno, previously a Po tributary, was cut off and the newly formed riverbed produced the origin of what is, today, the Po Delta. This transformation was completed in 1600 with the Porto Viro diversion.

Today's plain is the result of reclamation, which started in the year 1000, followed by large scale implementation of diversion structures and further hydraulic regulations in the 14th century. The most recent radical reclamation activities were completed in the 1930s.

A regular and continuous flood protection system has only existed as of the second half of the 19th century, and contains the River Po floodwaters in an embankment system from the River Ticino to the Sea. Previously, the Po River was only embanked in its lower stretch (downstream of the River Mincio). These radical transformations have increased flood levels, as was seen during the 1907, 1917, 1926, 1951 floods. Creating a vicious circle, this increase in flood levels caused the construction of further and ever higher embankments.

Channelisation works of the low-water riverbed were implemented between 1920 and 1970 in the lower-middle stretch of the Po. The aim was to facilitate navigation by concentrating low waters in a single-channel riverbed (Figure 3).

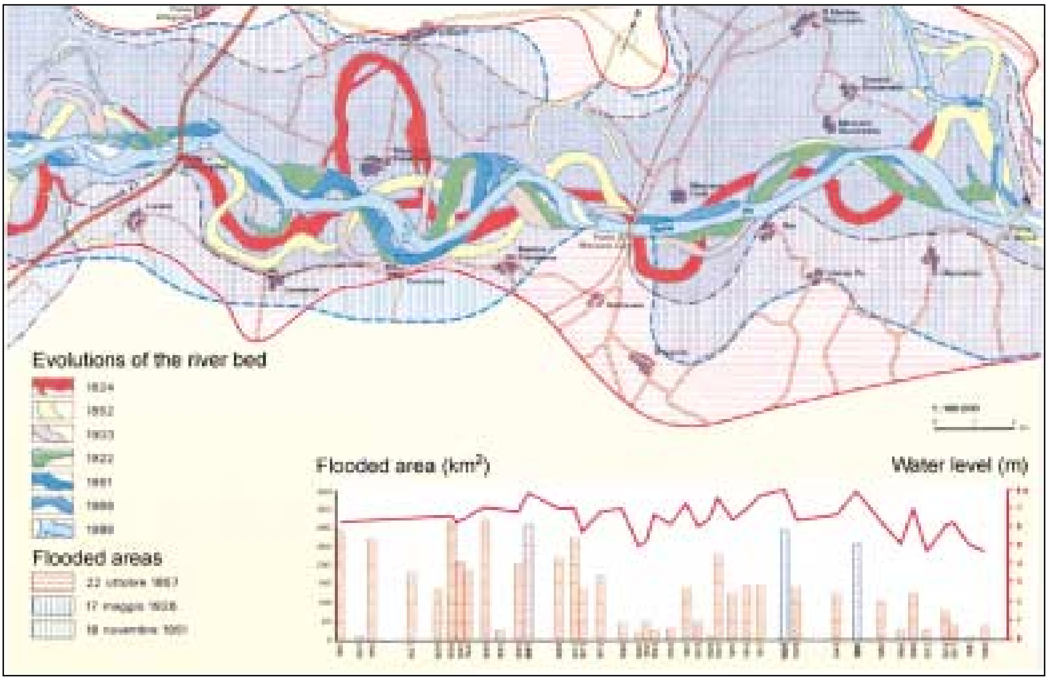


Figure 3. Modifications of the Po riverbed in the midstream.

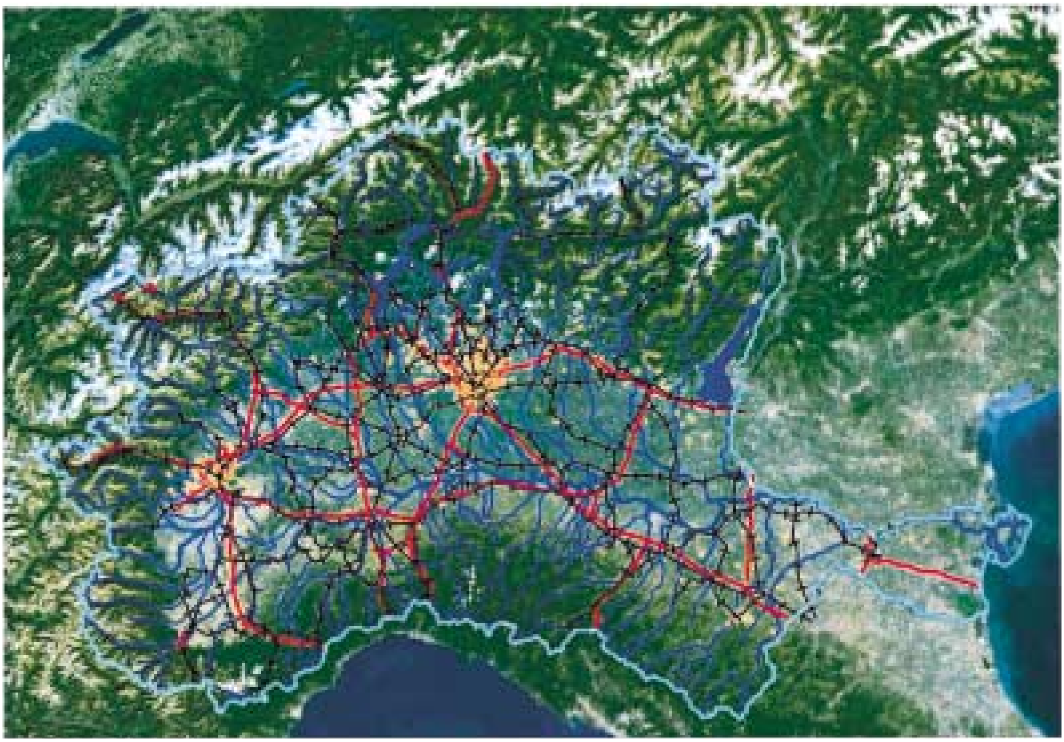
From 1960, as a result of continuous dredging along the whole length of the riverbed, a significant process of riverbed erosion is under way, aggravating the impact of embankments and channelisation on the river ecosystem.

2.2. Main processes of anthropogenic induced pressure

The river Po and its tributaries are, today, sitting-targets for anthropogenic pressure.
Two main kinds of pressure strongly accelerated the degradation of river systems in the second half of the 20th century:

- *Use of the territory* for residential and economic purposes, for roads and railways;
- *Use of water resources*, for domestic and industrial supply, irrigation, waste disposal and flood control.

The mutually dependent relationship between river systems and land use involves, above all, the continuous containment of rivers to reclaim areas for croplands, and in more recent times, for residential and manufacturing activities. As a result, the river corridor has also become the prime communications corridor.
The scattered nature of urban planning is a further disturbance that has a negative impact on the environment; residential, industrial and commercial complexes are serviced by a very dense network of roads, in a web-like configuration. In this situation disconnected territorial zones have been completely annexed and deprived of their natural ecosystems, precluding a rational agricultural use for those areas (Figure 4).



Urban areas (▬), highways (– – –), railroads (+++) and rivers (– – –)

Figure 4. Urban areas, highways, railroads and rivers.

Urbanisation of natural areas also increased the risks of flooding. The result is an increasing demand for flood protection works, which will further contribute to river channelisation.
The exploitation of water resources to satisfy the ever increasing domestic and commercial demands is often characterised by a passive response to the demand-supply process.
The constant need to make water readily available and instantly usable has meant that the construction of various types of plants for storage, production, supply and re-cycling have proliferated. The man-made water system, therefore, superimposes itself on the natural network modifying the quality and quantity of surface water resources.
The most severe problems in the Po River basin, generated by anthropogenic pressure, occur along the lower plain corridor, where, traditionally, there is:

- The highest concentration of residential towns;
- The greatest demands on water resources;
- Flood protection intervention is diffuse.

The course of the River Po is for the most part unnatural, due to the embankment system constructed along its entire length of 2300 km. This unnatural system now shows its limits in flood control, and has produced the following negative effects:

- Increased high-water levels and unnatural flow regime;
- Reduction or elimination of riparian plants;
- Reduction of river self-purification potential.

Contaminants in surface water and groundwater in quantities that exceed the self-purification potential of the system negatively, affect the water quality, most of all in the plain areas. In these areas is a greater concentration of anthropogenic activities and water supply demands and pollution are highest.

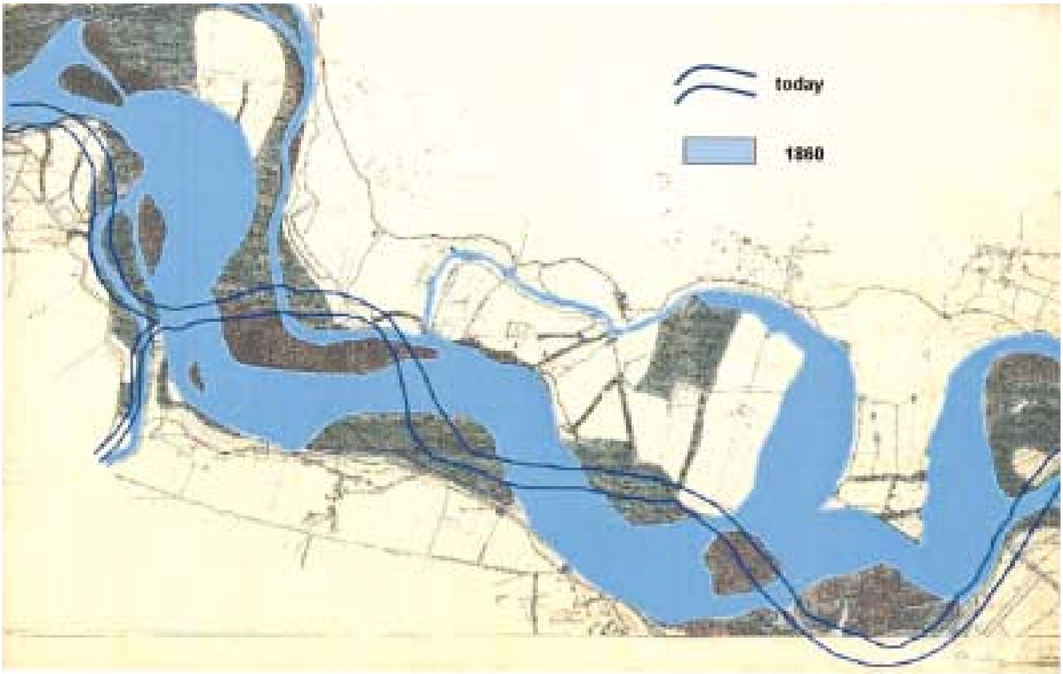


Figure 5. A Po river stretch today compared with the same in 1860.

The water quality along the River Po for contaminant levels, mainly nutrients, is classified as 'average' for 58% of its course, 'poor for 23%, and 'very poor' for a stretch downstream of the confluence of the Rivers Olona and Lambro.
The rivers and streams are the most important sources for irrigation (more than 17 billion m³ per year). Irrigation is the major water consumer in the Po basin, while other usage put less burden on the hydrological network (drinking water supply accounts for around 5%).
A great number of structures for large and small hydroelectric power production have been constructed, for the most part, along the alpine rivers and streams, and the main river corridors. Extensive man-made channelisation networks servicing hydroelectric power production and irrigation systems are the main disturbance factor in the plain, causing significant alteration, at a local level, to natural riverbed geomorphology and flow.
The River Po was used for navigation along the lower middle section and is navigable, today, from Cremona to the sea. The previously mentioned channelisation of the low-water riverbed eliminated natural river meanders and attenuated river bends (Figure 5).

2.3. Goals and criteria

The goals and criteria of the River Po basin planning were defined by the Po River Authority, which is made by the central government and the involved Regions.
One of the strategic goals of the River Po basin planning is the restoration of the river environment to a condition as close as possible to a natural one. This goal should be achieved by activating an integrated, shared decision-making process, in concert with institutions, and by gradually modifying collective and individual behaviour.
The basis of any restoration plan is to acknowledge the complexity and interdependent nature of land protection, water conservation and urban and territorial planning, as well as between local events and system dynamics.
The environment and landscape restoration of the Po River corridor on a basin scale must focus on:

- The modification of the hydraulic system;
- The restoration and protection of river ecosystems;
- The re-establishment, where interrupted, of the continuity between the river and riparian areas;
- The conservation and re-qualification of historical heritage of the basin.

2.4. Opportunities and limitations of river corridor restoration

River restoration activities must take into account the wide variety of situations and problems that can be encountered at the different sites. It is, therefore, essential that a correct evaluation be made of the opportunities and limitations of a project design.
The opportunities for restoration should focus on the following distinctive elements:

- The management of public property alongside the main rivers, mostly exploited for intensive farming and currently under government concession to private owners;
- Reduced interest from agriculture for riverside lands, which offers the opportunity, if incentives are provided, to re-convert this property for more environmental- and ecological-friendly uses;
- Re-conversion of ex-residential and industrial zones currently in a state of disuse.

Restoration projects are limited by the high costs of restoration, especially in situations where active intervention is needed. Therefore, it is essential that such projects are both public and private funded, by creating models of intervention ensuring a return on private capital investment.

The general constraints with respect to the restoration goals include also institutional and legal aspects of land ownership or water use. These aspects can block a restoration project. It is, therefore,

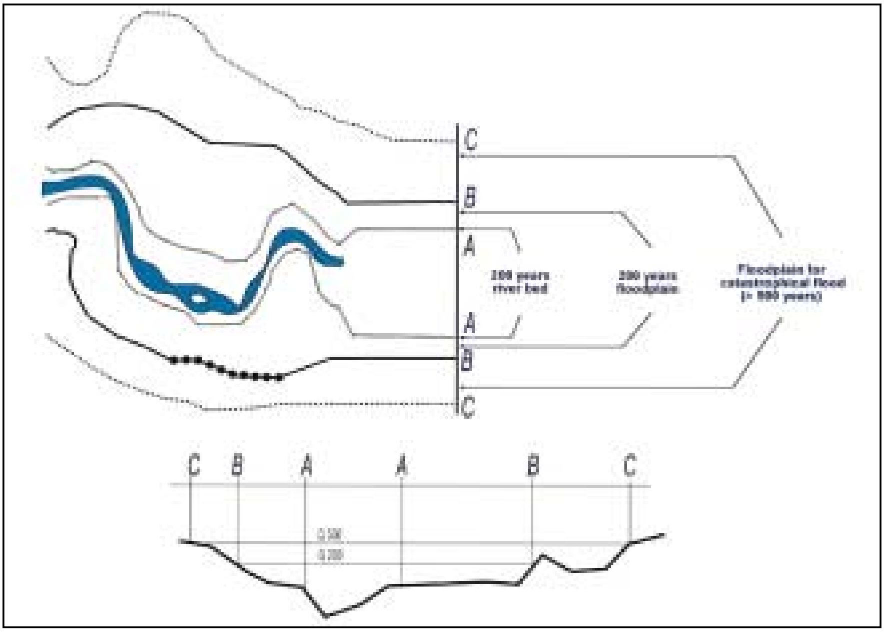


Figure 6. Flood hazard protection areas.

important that all parties share the goals and the contents of the restoration project through active communications and investigations.

2.5. The river corridors plan

The Po river corridors plan was approved in 1999 and, through the delimitation of river corridors, establishes the guidelines for the restoration of the hydraulic functions and the ecological systems of river environments. The main criteria for river corridor delimitation are the floods with 200 and 500 years return period, together with geomorphologic and ecological analyses (Figure 6).

The portion of territory recognised as being necessary for the natural dynamics of the river is considerably large and extensive; the previous regulation was limited to the ordinary flood riverbed (4 years return period) and to hydraulic works.

The relevance of the plan for the Po basin is most evident: the territorial area within the boundaries of the river corridors amounts to approximately 2600 km^2, equal to 3.5 % of the total basin territory. The area includes 1100 municipalities, equal to a third of the total. The boundaries represent the river project conditions and apply the principle, where possible, of respecting natural river characteristics and flood storage areas, limiting the sites for new hydraulic works activities to flood protection of residential areas and infrastructures.

As indicated earlier, a network of ecosystems along the River Po is being planned, same as the International Commission for the Protection of the Rhine has done in the early nineties along the Rhine. The above can be achieved by regulating land and water usage, halting incompatible activities and providing incentives to promote natural environment restoration.

2.6. The role of parks in river protection

Natural parks are a frequent and consolidated asset of the River Po basin. River parks cover 3.5% of the territory and 14% of the basin municipalities. Significant stretches of the River Po and of its

tributaries are protected as parks and cover a length of approximately 925 km of the 6750 km main river network. The corresponding land surface covers an area of 2430 km^2.
The main goal of parks is the protection and valorisation of the natural characteristics of river ecosystems, such as landscape, vegetation and fauna, also by stimulating local communities to become an active part in the conservation and maintenance of protected areas.

2.7. Institutional aspects

The laws pertaining to river corridor jurisdiction were completely reviewed in 1989. Law 183 '*Norms for the protection of the territory*' establishes the river basin as the spatial unit for which river evolution and degradation were to be read.
Up to 1989 jurisdiction on river intervention was divided between the Central State and the Regions, depending on location, dimension and importance of flood control works.
Above all, the Law reviews the approach to territorial protection, no longer dictated by a logic based on invasive modifications to rivers but by a logic advocating the conservation and preservation of residual natural characteristics.
With the institution of the River Authority it was finally possible to establish the basis for co-operation between central and different regional institutional authorities, by the creation of a shared project for river conditions and exploitation of water resources.

3. River Restoration: a Programme for Activities in Europe

Guidelines and procedures concerning the management and the restoration processes for basin river networks are clearly laid down in two programmatic European Community documents: the aforementioned 'Development Scheme for Europe's Space'/DSES and 'A common position (CE) 22nd October 1999' specifically dealing with the Water Framework Directive.
The co-operative planning approach, indicated by the DSES for the application of these programme guidelines, aims at involving all local authorities included in river ecosystems and at strengthening the co-ordination of neighbouring regional interests. This approach was started in the EU in 1990 with the Interreg programme. With reference to co-operation projects of river basin management and restoration, the DSES promotes the co-ordination of the restoration activities of the various sectors, through *'(…) a policy of landscape development and environment protection of areas at ecological risk, thereby creating a transboundary mosaic of biotopes'*.
This aspect is an interesting way, in terms of procedure and method, of activating projects of river ecosystems restoration, with the aim of restoring specific parts of the river system (sub-basins, districts) that are particularly vulnerable. A particular emphasis is placed to the re-establishment of the natural environment equilibrium among all the elements that make up the river ecosystem.
The same philosophy and approach to water resource management is repeated in the European Community proposal for a Water Framework Directive (A common position (CE) 22nd October 1999). The main purpose of the document is to define water body status, and includes river restoration as one of the activities to be planned and implemented in River Basin Districts. The term 'River Basin District' means the area of land and sea, made up of one or more neighbouring river basins together with their associated groundwaters and coastal waters. The River Basin District is the main unit for management of river basins, and promotes administrative procedures at a regional and inter-regional level for the co-ordination of strategic objectives.

RIVERS IN THE EUROPEAN UNION: WATER QUALITY, STATUS AND TRENDS

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Note: Any opinions expressed by the author are of a personal nature and do not necessarily reflect the views of the EEA, the European Commission or any other Community Institute

Abstract

This paper analyses river water quality in the European Union in terms of nutrients (nitrogen species and phosphorus) and organic matter and relates concentrations and trends to main pressures arising from land use and sewage treatment capacities within the catchments draining to the site of observation.

The concentrations of both phosphorus and ammonium have been decreasing in EU rivers in the 1990s reflecting the general improvement in waste water treatment over this period.

However, the current concentrations are still way above what might be considered to be 'background' or natural levels. Such levels are found in parts of the Northern countries such as Finland. The relatively high concentrations of phosphorus compared to natural levels in all sizes of river is also of concern in terms of potential ecological impact.

Nitrate or total oxidised nitrogen levels have not changed over this period. The levels of nitrogen in smaller rivers are also relatively high perhaps reflecting the impact of agriculture on smaller rivers. The impact of human activities on small and medium sized rivers is particularly evident from the relatively high concentrations of orthophosphate, and of nitrate and total nitrogen found in catchments with high urban land use and high total agricultural activity, respectively. This reflects, respectively, the effects of discharges of orthophosphate from urban waste water treatment works and the emissions of nitrate (and other forms of nitrogen) from agriculture.

BOD levels generally decreased in the early 1990s in all river sizes. In more recent years levels appeared to have increased again in all but the smallest rivers. However, recent data indicate that many European countries had a majority of river stations with low concentrations of BOD. The levels of BOD are generally lower in Northern countries than in Southern or Western Countries.

The Northern and Western European countries with the longest tradition for purification have a high proportion of treated waste water, the development primarily being continual improvements in treatment level. Southern countries have also improved the level of treatment.

1. Introduction

The European Environment Agency/EEA is developing key indicators to provide a tool to monitor and assess water policies to improve policy effectiveness in promoting sustainability. At international level the Agency has developed EUROWATERNET/EWN which is the process by which the Agency obtains the information on water resources (quality and quantity) it needs to answer questions raised by its stakeholders. The key concepts of EUROWATERNET are: it samples existing national monitoring networks and information databases; it compares like-with-like, and it is based upon a statistically stratified design, 'tailor-made' for specific issues and questions. The network is designed to give a representative assessment of water types and variations in human pressures within a member country and also across the Agency area.

This paper aims to assess at the European Union level the severity of two important water pollution problems in rivers created by excessive nutrients and organic matter. The assessment is based upon data provided by member countries through the EWN process and maintained in WATERBASE.

2. Nitrogen and Phosphorus Levels in EU Rivers

Large inputs of nitrogen and phosphorous to water bodies can lead to eutrophication causing ecological changes that result in a loss of plant and animal species, and have negative impacts on the use of water for human consumption and other purposes. Ammonium is also toxic to aquatic life at certain concentrations in relation to water temperature, salinity and pH. It also exerts a demand on oxygen in water as it is transformed to oxidised forms of nitrogen.

In many catchments the main source of nitrogen pollution is run-off from agricultural land, though discharges from waste water treatments works can also be significant. For phosphorus, industry and households is often the most important source. Control of these nutrient discharges is needed to reduce pollution levels in water bodies. These indicators illustrate the current situation regarding nitrogen and phosphorus in rivers. Good water quality is needed in all sized rivers, not just large rivers, as small and medium rivers are very important ecologically. These indicators show the differences in water quality in all sizes of river.

Natural concentrations of total phosphorus and orthophosphate will vary from catchment to catchment depending upon factors such as geology and soil type. Natural ranges are considered to be approximately 0-10 µg P/l for orthophosphate and 5-50 µg P/l for total phosphorus. Waters containing concentrations above 500 µg P/l would be considered as being of bad quality as significant effects of eutrophication would be expected.

Concentrations of nitrate below 0.3 mg N/l would be considered to be natural or background levels for most European rivers though for some rivers levels of up to 1 mg N/l are reported. The corresponding value for total ammonium would be 0.015 mg N/l. Concentrations of nitrate above 7.5 mg N/l would be considered to be of relatively poor quality and would exceed the guideline concentration for nitrate of 5.6 mg N/l as given in the Surface Water for Drinking Directive (75/440/EEC). Concentrations of total ammonium exceeding 9 mg N/l would be expected to have significant toxic effects on aquatic life.

Figure 1 indicates that phosphorus has been generally decreasing in European rivers in the 1990s. In terms of total phosphorus there appears to be no differences between the different sized rivers over this period. However, there are clear differences in terms of orthophosphate between different sized rivers with medium rivers having higher orthophosphate concentrations than the others. There are also clear differences between the regions of Europe in terms of phosphorus concentrations with Finland having far lower and stable orthophosphate concentrations over the 9 year period (Figure 1c). The Western countries appear to have similar median orthophosphate concentrations over this period. Northern countries such as Finland and Sweden have the highest proportion of river stations with low concentrations of total phosphorus and orthophosphate, and Western countries such as Belgium, Denmark, France, Germany, The Netherlands and the UK, the lowest proportion.

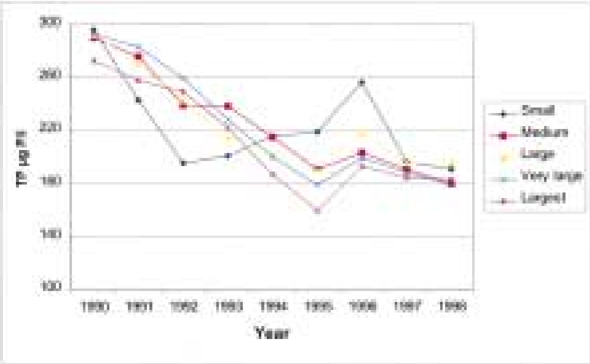

Figure 1a)

Figure 1b)

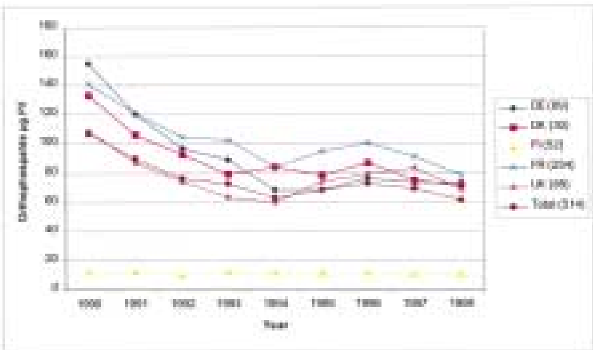

Figure 1c)

Figure 1. Trends in phosphorus concentrations in rivers by size and country.
1a) Trends in the median of the stations' annual average total phosphorus concentrations by size.
1b) Trends in the median of the stations' annual average orthophosphate by size.
1c) Median of the stations' annual average orthophosphate concentrations by country.

Note:			
	Small	catchment area upstream of station	<50 km^2
	Medium	catchment area upstream of station	50 km^2 to <250 km^2
	Large	catchment area upstream of station	250 km^2 to <1000 km^2
	Very large	catchment area upstream of station	1000 km^2 to <2500 km^2
	Largest	catchment area upstream of station	≥2500 km^2

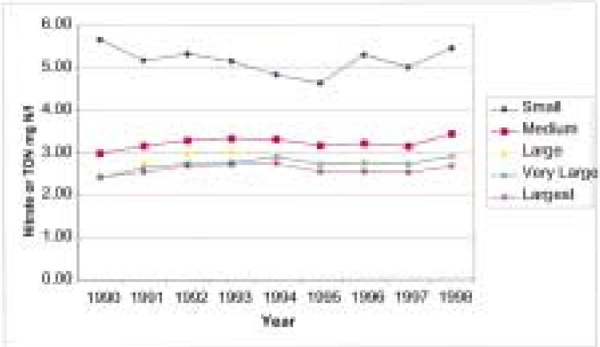

Figure 2a)

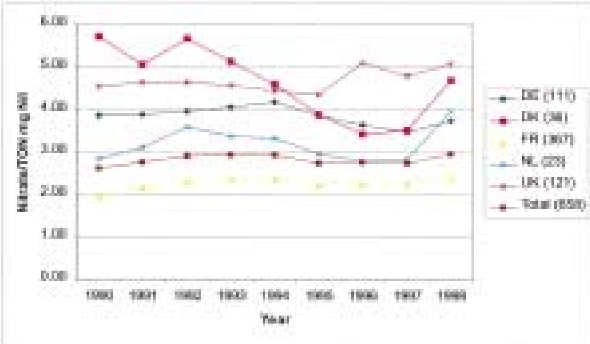

Figure 2b)

Figure 2. Trends in nitrogen concentrations in rivers by size and country.
2a) Trends in median of the stations' annual average nitrate or total oxidised nitrogen concentrations by size.
2b) Median of the stations' annual average nitrate or total oxidised nitrogen concentrations by country.

Note: see figure 1.

The corresponding data for nitrate or total oxidised nitrogen show a different pattern with no trend with time over this period (Figure 2). Small rivers, however, have higher concentrations than the other size categories. Of the Western European countries for which there are consistent time series, it appears that France had the lowest median nitrate or Total Oxidised Nitrogen/TON concentration, and Denmark and the UK the highest. The lowest concentrations of nitrate or TON are generally found in Norway, Portugal and Ireland, and the highest in Denmark, Belgium and Germany.

Total ammonium concentrations (Figure 3) have also decreased over the same period but this time, in those countries for which there are data, the highest median concentrations have tended to be in the larger rivers and lowest in the smallest. The United Kingdom, Denmark, Finland and France had the lowest concentrations of total ammonium at the stations provided, and Austria and Greece the highest. There is an increase in total phosphorus and orthophosphate concentrations with increasing total agricultural land use in the upstream catchment. The differences between the different sizes of rivers are not as marked for orthophosphate as they are for total phosphorus though medium sized rivers generally have higher concentrations of both forms of phosphorus than the other size rivers. The concentrations of total phosphorus in all sized rivers with total agricultural land use in their catchments

Figure 3. Trends in median of the stations' annual average total ammonium concentrations (µg N/l) in different sized European rivers, 1990 to 1998.

Note: see figure 1.

above 25% are at levels where eutrophication would be expected to occur with the accompanying adverse effects on the aquatic ecosystem.

There is also an increase in orthophosphate concentrations with increase in percentage of urban land use in the upstream catchment particularly so in relatively highly urbanised catchments of medium, large and very large rivers (Figure 4). The concentrations of orthophosphate are also higher in urbanised catchments compared to mainly agricultural catchments probably reflecting the relative importance of both sources of orthophosphate.

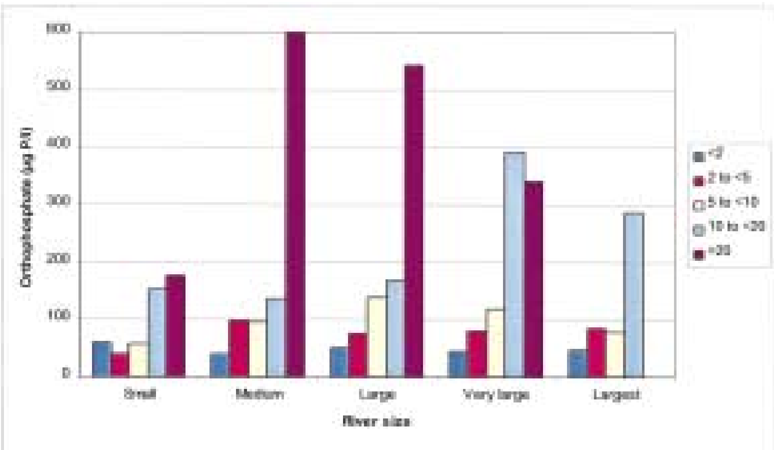

Figure 4. Median of the stations' annual average orthophosphate concentrations (µg P/l) in different sized rivers in relation to percentage **urban** land use in upstream catchment.

Data from Denmark, France, Portugal and UK

In terms of nitrogen there is also an increase in total nitrogen and nitrate/TON concentrations with increasing total agricultural land use in the upstream catchment (Figure 5). The highest concentrations of nitrate/TON, in particular, are found in the small and medium sized rivers compared to the larger rivers. Median concentrations of nitrate in small rivers on the most agricultural catchments exceed the Directive on Surface Water for Drinking (75/440/EEC) guideline concentration for nitrate of 5.6 mg N/l.

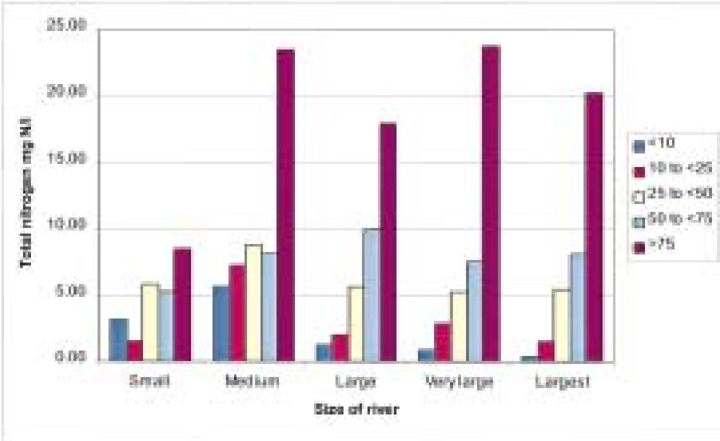

Figure 5. Median of the stations' annual average total nitrogen concentrations (mg N/l) in different sized rivers in relation to percentage **total agricultural** land use in upstream catchment.

Data from Denmark, France, Germany, Sweden and UK.

3. Organic matter

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are the main parameters of the oxygenation status of water bodies. High BOD is usually a result of organic pollution, caused by discharges of untreated waste water from treatment plants, industrial effluents and agricultural run-off. BOD is the oxygen demand arising from biological activity. COD will also include the oxygen demand arising from the oxidation of chemical substances. High BOD and COD will have several effects on the aquatic environment including reducing river water oxygen levels thus reducing biodiversity of aquatic communities. Improvements in the levels of BOD and COD in rivers illustrate general improvements in river water quality in terms of the chemical properties of the river. BOD is increasingly being replaced by total organic carbon measurements in many European countries.

Figure 6 indicates that BOD levels have decreased during the 1990's in all sizes of river in the EU. Small rivers have the lowest concentrations of BOD and very large rivers have the highest concentrations probably reflecting the discharges from sewage treatment works and industry the largest of which tend to be on the larger rivers. Levels of BOD less than 2 mg O_2/l (<10 mg O_2/l COD) are indicative of relatively clean rivers, and concentrations of BOD greater than 5 mg O_2/l (>25 mg O_2/l COD) of relatively polluted rivers. In recent years, the majority of rivers in Western European countries had low levels of BOD with a large percentage with concentrations below 2 mg O_2/l indicating relatively clean water. Austria and Denmark had lowest levels of BOD at the stations provided. The decrease in BOD is due to the implementation of the Urban Waste Water Treatment Directive/UWWT Directive and

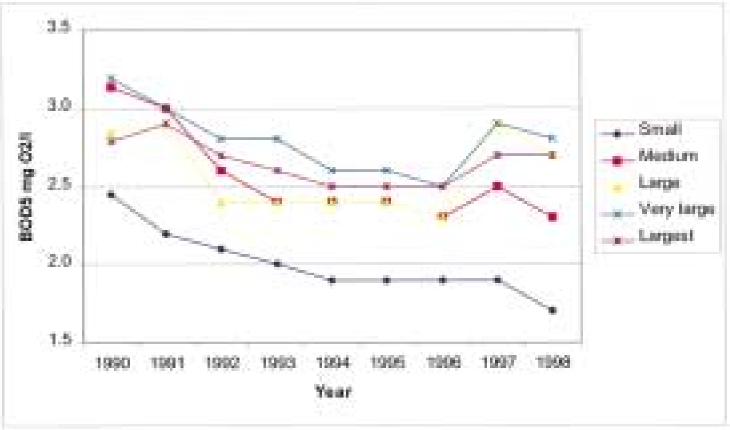

Figure 6. Trends in the median of the stations' annual average concentration of BOD5 in different sized European rivers, 1990-1998.

Note: see Figure 1.

hence an increase in the treatment level of waste water.

Due to a lack of data, time trends for COD in European rivers could not be developed as data were only available for Finland. However, data for recent years shows that a large proportion of some countries' rivers had medium to high concentrations of COD. All stations with data in the United Kingdom and Belgium had concentrations above 20 mg O_2/l, but only data for a few stations were available for this assessment. It is likely that these stations in the United Kingdom and Belgium represent only the most polluted locations rather than giving a representative overview of water quality in those countries. Four out of the 7 countries assessed had at least 50% of the stations with concentrations below 15 mg O_2/l. Austria and Germany had 90% of stations with levels of COD below 10 mg O_2/l. COD levels therefore vary throughout Europe with some countries' rivers still with relatively high concentrations.

Simultaneous with the decrease in organic matter in rivers marked changes have occurred in the proportion of the population connected to waste water treatment as well as in the waste water treatment technology involved (Figure 7) and forecasts show that these capacities will increase even further over the next 5 years.

Southern countries, such as Portugal and Spain, have planned large increases in the capacity of collecting systems, whereas most Northern and Western countries have planned no increase or only a small increase since these countries already had a high capacity per p.e. before the implementation of the Directive.

The increase in the capacity of treatment works is significant for all Member States except for Sweden, Finland and The Netherlands as these countries' treatment works already had a very high capacity. The greatest increase is in Southern countries such as Spain, Portugal and Greece but a large increase is also planned in Ireland.

In general, the planned developments are that collecting systems capacities should increase by 22% over the 13 years of implementation of the UWWT Directive and that treatment capacity should increase by 69%. It is projected that by 2005, the capacity of collecting systems and treatment works will be greater than or equal to the organic load in most Member States.

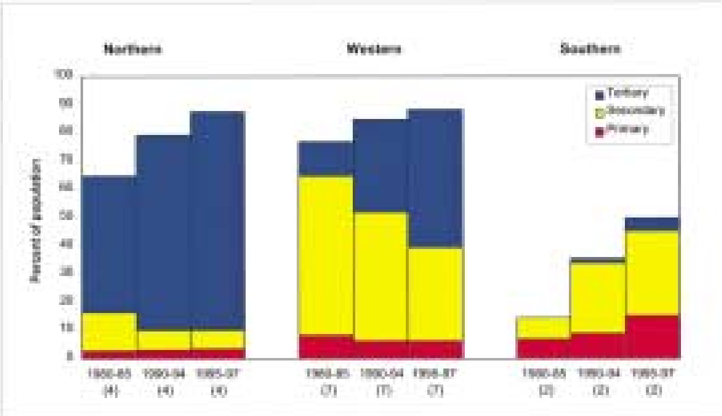

Figure 7. Change in waste water treatment in regions of Europe between 1980/85, 1990/94 and 1995/97.

Northern:	Iceland, Norway, Sweden, Finland
Western:	Austria, Ireland, United Kingdom, Luxembourg, The Netherlands, Germany, Denmark
Southern:	Greece, Spain
Missing data from:	Liechtenstein, Belgium, Italy, France, Portugal

The percentage of the population connected to tertiary treatment has increased since 1980 in all European regions. In Northern countries such as Finland and Sweden, the majority of the population was connected to sewers with waste water treatment early in the 1980s, while in many of the other countries a marked increase in the population connected to sewers has occurred over the last 10-17 years. In Austria and Spain, the proportion of the population connected to sewers and waste water treatment has more than doubled over the last 17 years. In Spain, however, only around 50% of the population had their waste water treated in treatment plants by 1995, some of the waste water to sewers was discharged untreated.

In the 1980s many Western countries, such as The Netherlands and Austria, secondarily treated most of the waste water, however, in countries like Finland and Sweden most of the waste water was already treated in plants with tertiary treatment in the 1980s. In the late 1980s and 1990s, many of the Western countries constructed treatment plants with nutrient removal (e.g. the marked increase in tertiary treatment in Austria and The Netherlands from 1990 to the mid-1990s). In Germany the majority of waste water treatment plants with phosphorus elimination (tertiary treatment) are also run with nitrification/de-nitrification.

4. Policy Responses

Most EU water legislation dates from the 1970s and early 1980s - directives on the quality of water for specific purposes, the control of discharges, and the protection of waters from specific sources of pollution. In the 1990s, directives were adopted on urban waste water treatment and the protection of waters against nitrate from agriculture, and a directive on the ecological quality of water was proposed. Also, the Commission proposed a groundwater action programme, and updates to the bathing water and drinking water directives.

The Nitrate Directive (91/676/EEC *Nitrates from agricultural sources*) aims to reduce water pollution caused by nitrates by reducing the nitrogen input to agricultural land. The Directive sets limits for the amount of manure that can be applied to land every year. This will decrease the nitrogen run-off from agricultural land to surface and ground waters but its implementation has been unsatisfactory in many Member States.

The Urban Waste Water Treatment Directive (91/71/EEC) requires waste water to be treated to the secondary level for all agglomerations of more than 2000 population equivalents (p.e.) discharging to fresh waters and estuaries and for all agglomerations of more than 10 000 p.e. discharging to coastal waters. Collecting systems must be provided for all agglomerations larger than 2000 p.e. Sensitive water bodies must be identified according to the criteria in the Directive and in these areas and the catchment of sensitive areas, more advanced treatment with nutrient removal must be provided. This Directive will lead to a reduction in nutrient discharges from point sources but as for the Nitrate Directive implementation has been patchy and slow. Despite the delays considerable investment programmes are in place in all Member States to comply with the Directive's objectives.

The IPPC Directive (96/61/EEC *Integrated Pollution Prevention and Control*) aims to control and prevent pollution to water by reducing or eliminating emissions from industry. Industrial emissions can result in high phosphorus loads which can cause eutrophication in water bodies.

The Water Framework Directive (2000/60/EC) will rationalise EU water legislation. Its aim is to establish a framework for water protection, both to prevent further deterioration and to protect and enhance the status of ecosystems. It would:

- Require achievement of ‘good’ surface water and groundwater status by 2015;
- Promote sustainable water use based on long-term protection of available resources;
- Support the protection of transboundary, territorial and marine waters;
- Stimulate the progressive reduction of pollution by hazardous substances.

Key features include a requirement to manage surface and ground waters at River Basin or River Basin District level, and an emphasis on the importance of ecological – as well as physical and chemical – quality.

As with all water legislation, the availability of sound and reliable information, and appropriate methods for its assessment and evaluation, will be vitally important.

ASSESSMENT OF WWF RIVER AND FLOODPLAIN RESTORATION PROJECTS IN EUROPE

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Abstract
A database was constructed of all WWF river and floodplain restoration projects implemented in the last decade in Europe. A detailed assessment was made of a selection of 12 of these projects in order to assess the effectiveness of past efforts in relation to stated objectives, to determine the key criteria for success, and to prepare an idealised framework for project development. Most projects included the restoration of natural processes and increasing habitat diversity as the main objectives, but in many cases the promotion of sustainable use of the river and floodplain was a secondary objective. Only 4 of the 12 projects had a sufficient monitoring programme to enable a full post-project appraisal. However, the results showed that all of the projects had been successful in terms of ecological and socio-economic benefits to some extent, but that there were many unexpected outcomes and projects needed to be adjusted to take account of these. The key criteria for success included thorough project planning especially concerning hydrological aspects, the long term commitment of project partners, the development of a shared vision between partners and stakeholders, public awareness activities, an experimental approach and the building in of socio-economic aspects into project planning from the beginning. Some of the projects act as 'models' for similar river systems elsewhere, although there are many constraints to the restoration of natural dynamics of lowland rivers.

1. Introduction

Nearly all of Europe's rivers have been significantly affected by pollution, fragmented by dams and other river infrastructure or reshaped by altered flow regimes. WWF's 'Living Rivers Initiative', therefore includes river restoration as a key component, although this takes second place to the conservation of remaining near-natural systems. Many small-scale river restoration projects have been developed over the last decades by nature conservation and fishery specialists, especially in countries where agricultural intensification has been the most severe, such as in the UK, Denmark and The Netherlands. Now, there is substantial investment in floodplain restoration along some of Europe's biggest rivers, including the Rhine and the Danube as part of international programmes to address damaging floods, water quality and water resource problems. Yet in Eastern and Southern Europe floodplains continue to be embanked and drained and rivers continue to be dammed, straightened and deepened, as a result of the dominance of a traditional engineering approach and the lack of recognition of the full values of more natural river and floodplain systems.

The project was developed in response to two clear needs.

1. The need for practitioners across Europe to share experiences concerning river restoration so as to identify the key 'ingredients' of success and the main constraints;

2. The need to evaluate the costs and benefits of these projects to inform future planning, taking account of different regional needs.

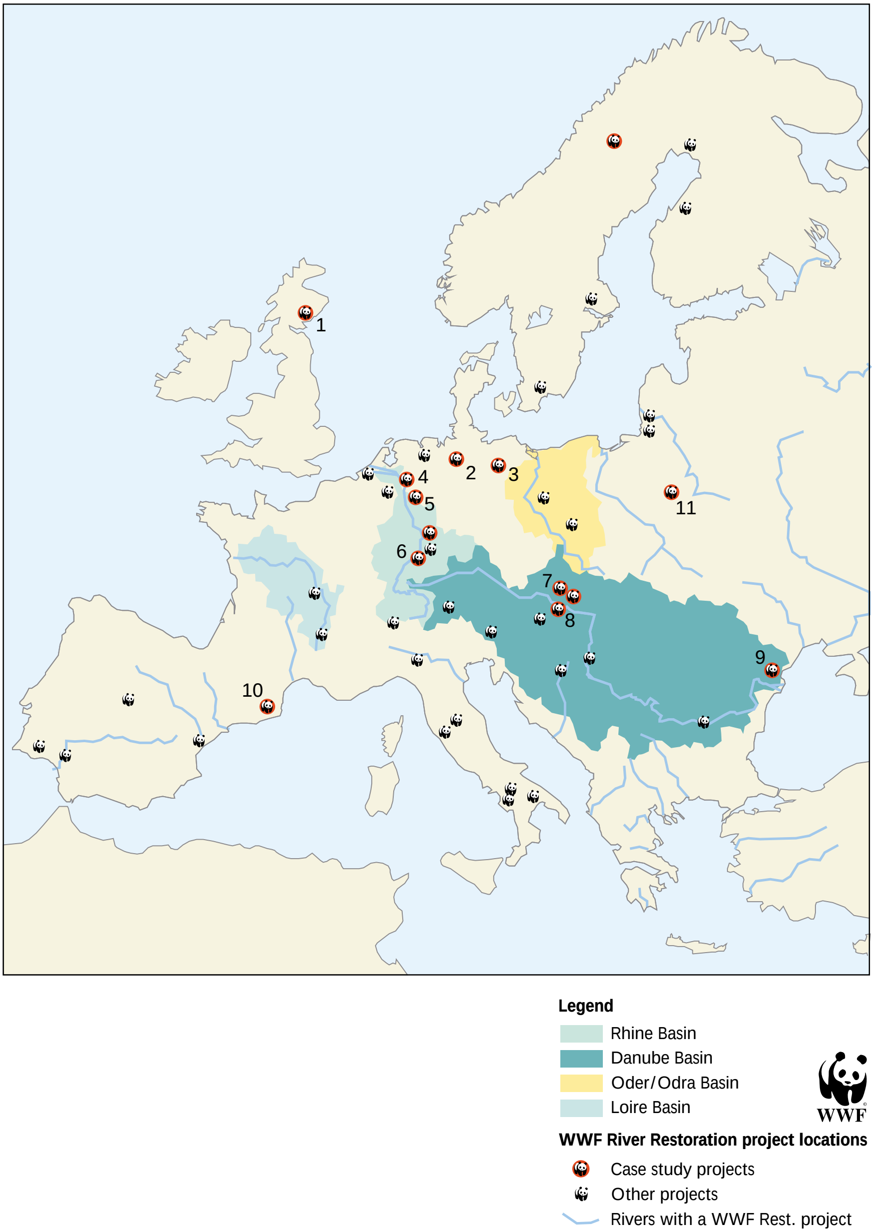

Figure 1. Location of WWF Floodplain Restoration Projects in Europe.

1. West Water
2. Wümme
3. Ringfurth
4. Gelderse Poort
5. Bislicher Insel
6. Rastatter Aue
7. Morava (Austria) and Morava (Slovakia)
8. Regelsbrunner Au
9. Danube Delta
10. Cap de Terme Canal
11. Biebrza

The project formed the first part of a larger, multi-organisational partnership project called 'Wise Use of Floodplains', which was supported by the EC LIFE-Environment Programme. The specific purpose was to develop a better understanding of what had been attempted and achieved so far with river and floodplain restoration projects by WWF working in separate country programmes across Europe. The results of the project will contribute to the identification of a set of approaches and tools for river and floodplain restoration that would have a wider applicability. This will include the identification of potential legal, policy and economic instruments that could be adopted at the European or national level to facilitate effective restoration programmes. The project was considered timely with respect to the future requirements of the forthcoming EU Water Framework Directive which will require all member states to adopt and implement river basin planning.

2. Methodology

The first step in the project was to develop a database of all current WWF river and floodplain restoration projects in the European Programme area. This database was then used as a basis for the selection of a representative sample of the projects, in terms of:

- Geographical location;
- Scale of projects;
- Size and type of river;
- Objectives of restoration;
- Degree of WWF involvement;
- 'Age' of the project;
- The approach taken.

Twelve case studies were selected and then information was gathered through interviews, questionnaire, site visits and literature review (see Figure 1; Table 1).
For each case study, an analysis was made of:

- The restoration objectives;
- The approach taken;
- The project activities;
- The organisational and legal framework of the project;
- The ecological and other project results;
- The cost-benefit of the projects;
- The constraints in achieving the objectives.

The conclusions from each case study were summarised. Finally, an overview report was made, drawing together the sum of the experiences in these 12 projects and highlighting the 'lessons learnt'. From this, an 'idealised framework' for approaching river restoration projects has been developed.

3. Context and Motivation of WWF in Establishing River Restoration Projects

WWF was rarely acting alone and our role varied from project to project from initiator, adviser or mediator to fund-raiser, landowner and manager. The projects differed considerably in scale and purpose but in most cases they were established to demonstrate what is possible in a wider area and to facilitate similar actions elsewhere. Many of these types of projects had been stimulated opportunistically. For example, the Regelsbrunner Au project, near Vienna in Austria was developed as a showcase National Park following the rejection of a major hydro-electric power station proposal. This involves a long-term commitment by WWF to restoration management and public involvement through land purchase. In some cases the restoration project formed an important component of a wider commitment to conserve a protected area in co-operation with others, for example the hydrological restoration of the Middle Basin in the Biebrza Marshes National Park and restoration of the Danube Delta islands within the Danube Delta Biosphere Reserve. Others, such as the West Water project in Scotland were one of a series of small-scale demonstration projects where WWF played a crucial design and facilitation role but where the landowner took the long-term responsibility. The series of projects together support a country-wide 'Wild Rivers' campaign which aims to influence land-use and water policy and to secure effective partnerships for river conservation. Others, such as the string of model projects along the Danube and along the Morava-Thaya, Odra and Rhine Rivers, are developed and seen by WWF as crucial to the adoption of international, transboundary commitments for integrated river basin management.

Table 1. Major objectives of the selected case studies.

Objective	Case study sites
Natural Processes	Gelderse Poort, Wümme, Kühkopf, Danube Delta, Bislicher Insel, Regelsbrunner Au, Morava, Biebrza
Species Diversity	Wümme, Biebrza, Danube Delta, Regelsbrunner Au, Morava
Habitat Diversity	All
Sustainable Fanning	Biebrza, Wümme, Morava (5L), West Water, Bislicher Insel
Sustainable local economy	Danube Delta
Sustainable Forestry	Rastatter Aue, Morava (A)
Sustainable industry	Gelderse Poort (Clay extraction)
Sustainable transport	Ringfurth
Wildlife corridors	West Water
Open landscapes	Biebrza, Ammarnäs, (Wümme)
Water availability and sustainable resources	Biebrza, Cap de Terme
Water purification and quality	Biebrza, Danube Delta, West Water
Flood control	Gelderse Poort, Rastatter Aue, Danube Delta, Regelsbrunner Au

4. Restoration Objectives and Approaches

Not surprisingly, a wide range of objectives was revealed amongst the projects. It is expected that target habitat types will differ for river systems in different parts of Europe, for example open floodplain fens are more prominent in Northern and Central Europe and restoration of riparian forest is a priority in many river systems of Southern Europe. Most projects had multiple objectives but all aimed to increase the habitat diversity and natural functioning and dynamics of the river and floodplain. It is interesting to note the relative strength of the objectives. The restoration of natural processes was a dominant objective in most projects. In the Biebrza National Park, the restoration of the peat formation and water purification functions of the Middle Basin fens through counteracting past drainage are key objectives. However, here some compromise in water level restoration and management regime will be needed to incorporate the objectives of local farmers and the biodiversity objectives of the National Park. In the Regelsbrunner Au, Morava, Rastatter Aue and the Danube

Delta projects, the restoration of more natural and dynamic erosion and sedimentation processes in rivers and formerly embanked floodplains or polders were the primary objectives. However, here it was also anticipated that as a result of the restoration of natural processes, there would be significant benefits for flood storage, nutrient retention, habitat and species diversity, landscape and sustainable use by local people, such as farming, forestry or fisheries.

Projects that were developed in more managed landscapes e.g. at the River Wümme (tributary of River Weser, Germany), West Water (River Esk, Scotland), Bislicher Insel (Rhine), and Ringfurth (Elbe), tended to be smaller scale and less ambitious. Here, the potential to fulfil objectives for restoring natural processes was constrained from the beginning by the impacts of former uses e.g. for navigation, gravel extraction, military operations, etc. and the desire to conserve some semi-natural habitats in the floodplain that are maintained by extensive farming practices. The Gelderse Poort (Lower Rhine) project is unusual in that a radical approach has been taken to convert an intensively farmed floodplain alongside the busiest waterway in the world to a more valuable and diverse range of habitats. Here, major engineering activities are being used e.g. removal of clay depositions and summer dikes and the construction of side channels, to restore natural processes (flooding, erosion, sedimentation, natural grazing and vegetation succession), as far as is possible.

5. Ecological Benefits

Table 2 summarises the major results of the 12 projects. The analysis is incomplete as most of the projects have been established for less than 5 years. It is considered that the full benefits of most of these ecological restoration projects will only be after a decade or more. Equally, only 4 of the 12 projects were considered to have a sufficient monitoring programme to enable effective post-project appraisal (Danube Delta, Regelsbrunner Au, Wümme and Morava). However, the analysis showed that it was possible to achieve some dramatic and fast positive results. For example, after just 18 months it could be seen that the lowering of river banks and roads and the re-connection of side channels from the Danube rivers to the Regelsbrunner Au had enabled flows to the floodplain to increase to 220 days per year from just 22 days. The resulting action of the river created channels, new gravel banks and hundreds of new river cliffs over the 500 hectares project area. In the Danube Delta, the strategic breaching of the dikes in the Babina (2200 hectares) and Cernovca (1580 hectares) polder islands resulted after only 5 years in the nearly complete replacement of terrestrial vegetation, dominated by ruderals such as *Cirsium arvense* and salt tolerant species e.g. *Sueda maritima*, *Artemisia santonicum*, by reedbeds and aquatic vegetation, including for example *Nymphoides peltata* and *Potamogetum* species. The diversity of birds in the Babina island increased from 34 to 72 species and the characteristic invertebrates, such as *Lycaena dispar rutilans* reappeared within 2 years of the reappearance of the reed stands and aquatic habitats.

Despite the greater limitations on restoring natural river dynamics, some quite rapid ecological benefits were also recognised in the River Wümme project. For example since the completion of the works to construct a new river arm and lowering of flood banks in 1994, a more diverse fish community has developed and kingfisher (*Alcedo atthis*) has returned to the area. Over the same period, in the Gelderse Poort project, 33 new plant species have been discovered in the Millinger Waard floodplain following de-claying of intensive grassland. A varied vegetation mosaic has developed under the influence of extensive grazing by Konik ponies and Galloway cattle, which now supports breeding corncrake (*Crex crex*) and stonechat (*Saxicola torquata*).

Since river and floodplain restoration is a relatively new science, it is normally impossible to predict precisely the outcome of different restoration activities, even when thorough research is conducted beforehand. Very often there are no other references to guide project managers (e.g. as in the Danube Delta and Gelderse Poort projects). In many cases, there were unexpected results, some of which may be considered beneficial (e.g. the recovery of populations of characteristic species) and others (e.g. the dominance of *Cirsium arvense* thistles in the first years after land use change at Gelderse Poort) which can be initially unwelcome. In other cases, such as the rapid siltation of reconnected side-arms in the first attempts at restoration in the Morava floodplain, the negative results could have been anticipated by a more thorough research and planning stage, which was subsequently implemented.

6. Socio-economic Benefits

Many of the projects have provided substantial socio-economic benefits through the results of restoration activities. There were some very tangible, direct benefits. For example in the Danube Delta, 15 fishermen can now make their living as a result of the polder restoration. There are benefits to anglers and for local recreation as a result of the Regelsbrunner Au project. In the Gelderse Poort project, the Millinger Waard floodplain area has become very important as a local, low key recreational area and there are significant benefits to local businesses.

In some cases, gains have balanced out losses for local people. In the Morava-Drava floodplain project, 150 farmers benefited directly from generous compensation that enabled the conversion of intensive cropland to grassland. The landowner in the West Water project (Esk River, Scotland) has gained a more attractive and diverse river system with only a small loss of farmed land. In the Rastatter Aue along the Upper Rhine, the economic benefits of forestry will decline as the hybrid poplar plantations are gradually replaced by a more natural forest dominated by oak, ash and elm. However, as the floodplain function is being restored, a reduction in flood damage to properties in the nearby town of Rastatt are expected to diminish and local people are keen to promote associated recreational facilities, such as a cycle path. Generally, the small-scale nature of the most projects prevents major benefits for flood defence.

7. Key Constraints

A fundamental constraint in EU countries is the continued support of intensive agricultural use of floodplains by the EU Common Agricultural Policy and the lack of any substantial EU incentives for river and floodplain restoration. At Gelderse Poort (Rhine) and Wümme, this meant that floodplain restoration was only possible through land purchase of a limited area. So, whilst both projects have acted locally as ‘models’ for reversal of the effects of diking, drainage and intensive farming, due to the commitment of government authorities, the land purchase cost and the mismatch between river restoration farming objectives are practical limits along similar lowland rivers elsewhere. The engagement of the clay mining industry in removing unwanted clay along the Rhine at Gelderse Poort is though an excellent example of a ‘win-win’ partnership with industry.

At the West Water site and the other WWF Scotland Wild Rivers Demonstration and Advisory Project sites, restoration activities depend on the willingness of the landowners to take actions on land that has been heavily impacted by the last 40 years of agricultural intensification. Some grants and compensation available through agri-environment schemes help to encourage certain restoration and management activities, but these are relatively small and short-term payments. The tangible benefits

Table 2. Major results of the selected river restoration projects.

Result	**Description**	**Case study site**	
		Successful	**Less Successful**
Natural Processes	Development of natural biogeomorphlogic river structures, such as sand banks, river cliffs and initial plant growth	Gelderse Poort West Water Wümme	
Retention and Flood Control	Increase of retention area and cut off of the flood peaks by leading water through largely vegetated areas	Gelderse Poort Danube Delta Rastatter Aue Regelsbrunner Au	Bislicher Insel
Water Table Increase	Increase of water table by counteracting the drainage system of the river flood plain	Biebrza (considerable increase only for a few months; further steps to ensure long-term success are planned) Danube Delta (opening of dikes) Regelsbrunner Au (opening of dikes) Rastatter Aue (re-connecting of side rivers)	
Water Purification	Measured decrease in nitrate and phosphate	Bierbza Danube Delta	
Regeneration of Vegetation	Reed belts re-growing after grazing removed; aquatic flora restored after opening of dikes	Bislicher Insel Danube Delta	Wümme (loss of original valuable vegetation)
Land Use Change	Successful transformation of farm land into natural riverine habitats	Gelderse Poort Bislicher Insel Wümme Danube Delta	Biebrza (conflict of interest only recently addressed)
New Species (Increased or established characteristic biodiversity)	Key species or unexpected new species, which have become established due to the restoration activities	Wümme (otter, kingfisher, dragon flies, beetles) Gelderse Poort (e.g. comcrake, otter) Bislicher Insel (cormorant colony) Danube Delta (beetles, reed plants, fish breeding grounds, birds)	
Re-introduced species	Re-introducing formerly native species in combination with restoration works	Gelderse Poort (beaver) Rastatter Aue (elm tree saplings)	
Unexpected Results			
New Species		Gelderse Poort (e.g. comcrake, otter) Bislicher Insel (cormorant colony) Wümme (plant species)	
Flood Resistance of Oak Trees	Ten years of WWF studies show that oak trees survive flooding longer than admitted by science or expected	Rastatter Aue	
Dutch Elm disease resistance (?)	There is slight evidence that elm trees might be resistant when growing in their natural hardwood floodplain forest habitat	Kühkopf Rastatter Aue	

from the restoration work will only be realised in the longer term and yet the EU financial support for the Scottish project was only for 3 years. There is greater potential in Central and Eastern Europe to use EU funds to promote large-scale floodplain restoration (as along the Morava river) since agricultural prices are lower.

The effects of past drainage, channelisation and flood defence linked to agricultural intensification cannot of course be completely reversed. For example, some weirs will always be needed to maintain high water levels in the floodplain of the Wümme and the Middle Basin of Biebrza marshes. The continued dominance of intensive forestry involving hybrid poplar plantations limits the scope for floodplain restoration in many areas. At Regeslbrunner Au, there was a need to pay compensation to the Austrian state owned forestry company who feared timber losses through the project. Continuing navigation obviously prevents full hydromorphological restoration as groynes must be kept to maintain the channel and minimum water levels are maintained along the Rhine, Danube and Elbe. Existing infrastructure such as dams and dikes, also place strong limits on restoration. For example, the impact of periodic flushing of the sediments from the hydropower dam upstream and the effects of the Gabchikovo dam on the fish populations at Regelsbrunner Au, may prove to be significant. In other projects, the local demand for new economic growth limits restoration possibilities, for example gravel extraction on the Slovakian side of the Morava floodplain.

One of the strongest constraints to designing and implementation of the river and floodplain restoration projects occurred when there was a complexity of land ownership, administration and land use, within on hydrological unit. For example, the restoration of the hydrology of the Middle Basin of Biebrza National Park (Elk and Jegrznia Rivers) despite its high priority for nature conservation, has been in a planning stage for almost 10 years. Here, not all of the area is in the National Park, some abandoned land is next to intensively used meadows and ecologically valuable areas are beside degraded ones. It is now realised that the project planning must include 3 groups of specialists: ecologists, sociologists and engineering technicians and their work must be cross-linked. Here and in other cases (e.g. Wümme, Regelsbrunner Au, Gelderse Poort), delays were caused by arguments amongst nature conservationists, since some favour the promotion of natural processes as the overall priority while others wish to retain the traditional farmed landscapes.

In the case of the restoration of the Danube Delta polder islands there was good public support from the beginning since the benefits for the local economy were recognised. Elsewhere, it was often hard to gain the understanding and acceptance of all stakeholders and the general public of the benefits of major changes to their locality, especially since it was not possible to predict exactly what the effects of increased river dynamics would be. In the Wümme and Rastatter Aue projects, starting with a relatively small-scale project and gradually expanding the restoration work to a larger area, has had the double benefit of securing people's trust and acceptance, while gaining experience of how the effects of increased river dynamics. The use of a regular 'round table' of stakeholders and a range of public awareness activities in the Regelsbrunner Au project and the White Stork Festival at Marchegg along the Morava River, were two more good examples of successful engagement of the public.

8. Cost-effectiveness

The cost of the projects ranged from 75,000 Euros (West Water) to several million Euros (Regelsbrunner Au). The funding sources were varied in each case and included GEF, PHARE and TACIS (from the European Commission), national governments and commercial sponsors as well as WWF.

The cost-effectiveness of the projects was hard to establish due to incomplete records of costs, the early stages of most projects and the difficulty in assessing the total value of environmental and economic benefits. However, some measurable benefits for example to water purification, fisheries and to habitat structure and biodiversity were recorded and it would be possible at a later stage to attempt an economic assessment at most of these sites.

9. Some General Conclusions

The following conclusions can be drawn from the above analysis:

1. The case studies show that river and floodplain restoration is not ‘all or nothing’ activity. Even where there were considerable constraints on the scope and degree of restoration even small alterations were seen to bring about significant benefits. In many cases land purchase was necessary in order to overcome conflicts between existing land uses and the effects of a more dynamic river system. However, land purchase by environmental NGO’s will always be limited and it can be seen from this selection of case studies that significant river and floodplain restoration can be achieved through partnerships with local people and industries.
2. Even when land purchase is used, other stakeholders will always be affected and it can be seen that it is worth investing in a participative approach from the beginning and carrying out public awareness activities to get local people interested and involved. A lot of time can also be required to develop strong project partners, to develop a common vision between the partners and the stakeholders and to carry out the necessary background research, before implementation begins.
3. Purely technical approaches rarely succeed as the ‘root causes’ of degradation are socio-economic. For this reason, projects that built in socio-economic aspects from the beginning were more successful. Often the engineering measures can be straightforward but if done in the wrong place or before local acceptance is gained, the project can fail.
4. Since river and floodplain restoration is a relatively young and inexact science, a step by step approach, based on sound ecological and hydrological research and involving experimentation and monitoring, is more likely to succeed. This ‘adaptive management’ allows for gradual adjustments over time, taking account of how nature responds to interventions and enabling a clearer picture to develop of what can be achieved through restoration activities. The case studies show clearly that a long-term commitment from all partners is needed to bring about effective restoration.
5. Many of the projects were intended to be demonstrations or ‘models’ for the whole river system, the region or the country. There is good evidence that these model projects work well in stimulating similar projects elsewhere. However, there is a need to use these and other model projects internationally to promote effective action.
6. Although all of the projects were successful to some extent in achieving their ecological goals, a lack of effective monitoring prevented proper post-project appraisal in most cases. In order to be effective in removing financial and policy barriers to river restoration, there is a strong need to quantify and explain the benefits of river restoration to a much wider audience.

These points are summarised in an idealistic framework for planning river restoration projects (see Figure 2).

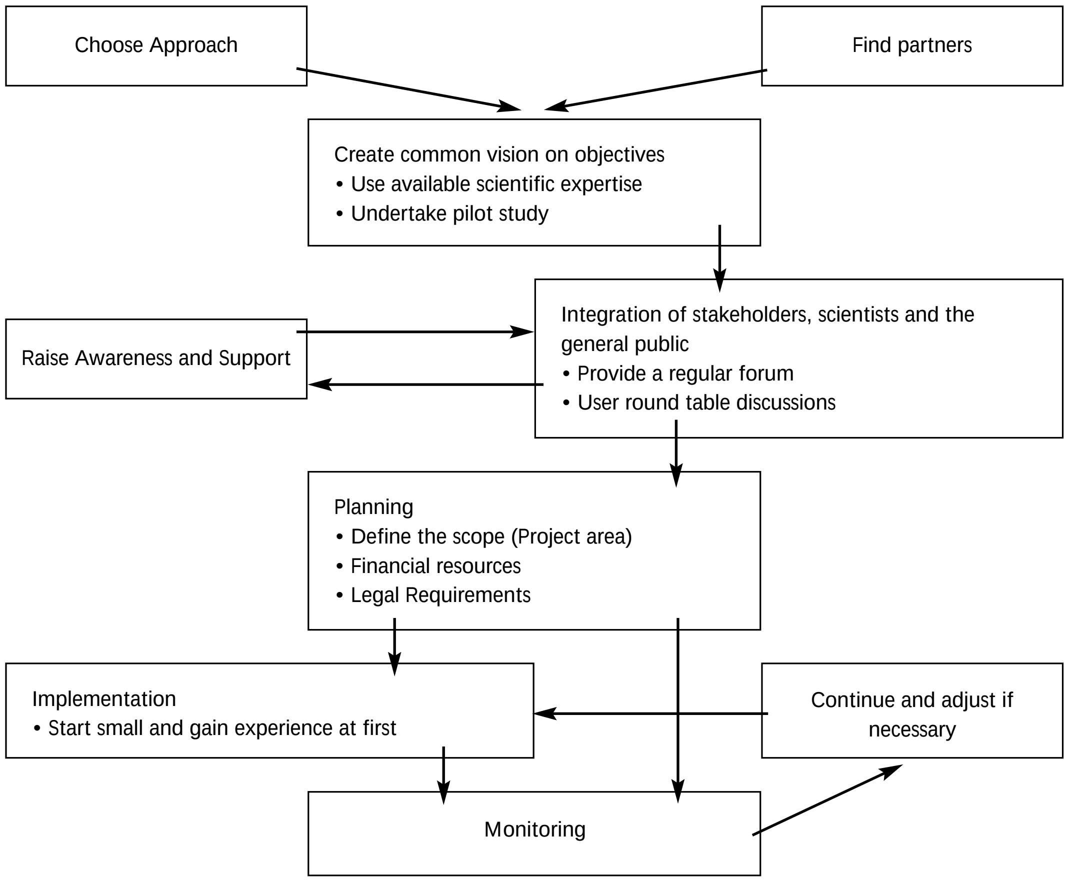

Figure 2. Idealistic Framework for planning river restoration.

Note

The project was initiated and shaped by the WWF European Freshwater Programme and carried out by a consultant working with the relevant European Freshwater Team members with the support of the WWF Germany Floodplains Institute. The full overview of 'Lessons learnt', detailed case study reports with location maps, database of WWF river restoration projects and contact information are available on the website: www.panda.org /europe/freshwater/.

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EASTERN EUROPE

THE DANUBE: A RIVER OF LIFE

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Abstract
The Danube binds together a multitude of different cultures and peoples as well as a diversity of ecosystems.
Human development over the past two centuries has seriously damaged the Danube: channelisation and straightening of the river constricted and shortened it. Dams for energy blocked it's flow; and land use alterations and pollution, all together, reduced the naturalness. A recent study completed by WWF for the Danube River Pollution Reduction Programme found that over 80% of the original floodplain area in the Danube has been lost since the turn of the last century. The consequences are both ecological and economic. A 1994 study placed an average economic value on the Danube Floodplains at 383 € per hectare per year. For all 1.7 million hectares of the Danube Floodplain from Germany to the Ukraine the annual value amounted to over 650 million €.
Since 1992, the World Wide Fund for Nature operates in Central East European countries. A mixture of field projects and policy activities is implemented in co-operation with governmental and non-governmental groups and is focused on conservation, restoration and sustainable management of the Danube.
The highlight of the this year activities is the agreement between the Governments of Romania, Bulgaria, Moldova and the Ukraine. By creating the 'Lower Danube Green Corridor', the countries recognise the importance of healthy floodplains for the maintenance of water quality and environmental health in the Danube River and as a basis for creating economic development opportunities for local populations.

1. Introduction

The Danube is a remarkable river, it binds together a multitude of different cultures and peoples as well as a diversity of ecosystems including the Black Forest, and the mountains tops of the Alps and Carpathians, the open plains on the Puszta and the extensive reed beds of the Danube Delta. About 80 million people call the Danube Basin 'home'.
The river, its tributaries, and its floodplains have greatly influenced human history, culture and development. In turn human culture and development have also greatly affected the Danube River and surrounding landscape.

2. The History

Up to the middle of the last century the Danube river was dynamic, free flowing with an extensive network of side arms and backwaters. The winding, weaving network of rivers and streams that made up the remarkable Danube ecosystem. Let me use a colourful picture to describe the value of the floodplains:

Like the blood in the veins of a human body, a natural river does not simply flow at a constant and regular rate. It pulses and ebbs both spatially and in time. Depending on the time of the year, the weather, and the location, the volume of water in the Danube varies considerably. The changing volume of water in the river has a significant influence on the relation with the floodplain – the dynamic interface between water and land. The floodplains of rivers can be compared with the kidneys of a human body because they cleanse and purify the river waters as they spill out over the land.
Unfortunately, human development over the past two centuries has seriously damaged the Danube ecosystems arterial system and its connecting floodplains. Important factors are:

- Channelisation and straightening of the river for transport and flood protection confined and shortened the river;
- Dams for energy blocked its flow;
- Land use alterations (draining of wetlands, forest clearing);
- Pollution.

These factors together reduced the naturalness and hence the vitality and life giving ability of the Danube and other rivers.

3. Recent Developments

A recent study completed by WWF for the Danube River Pollution Reduction Programme of the UNDP/GEF found that over 80% of the original floodplain area in the Danube has been lost since the turn of the last century (UNDP/GEF 1999). The paper by Mr. D. Günther-Diringer of the WWF Germany, Auen Institute, describes the details of this project.
The loss of these areas of floodplains has greatly reduced the biodiversity in the region. Breeding places for fish, such as the sturgeon have been destroyed and only remnants populations of these fish remain. Similarly, the distribution of the Black Poplar (*Populus nigra*) has been altered during the last decades.

The loss of floodplains is not only important because of the loss of this biodiversity which one might argue is only the concern of a few nature lovers. Floodplains serve important functions in nature, such as:

- Purification of water;
- Flood storage;
- Groundwater recharge.

The loss of floodplains has not only meant the loss of biodiversity but the loss of these functions, which have enormous consequences for the Danube as well as the Black Sea.
These consequences are both ecological and economic. A 1995 study (WWF 1995) placed an average economic value on the Danube Floodplains at 383 € per hectare per year. For all 1.7 million hectares of the Danube Floodplain from Germany to the Ukraine the annual value amounted to over 650 million €.

But in this paper, I don’t want to dwell on the negative consequences of certain developments in the Danube River basin. I want to emphasise the dramatic political changes in Central and Eastern Europe in the late 1980s and early 1990s. This created opportunities to bring environmental concerns to the forefront, to change the way of thinking about the Danube and to begin to treat river systems as living systems.

4. WWF Danube Carpathian Programme

The World Wide Fund for Nature has since 1992 operated a programme called the Green Danube (now called the Danube Carpathian Programme). This programme which has been implemented in co-operation with governmental and non-governmental groups throughout the basin is focused on conservation, restoration and sustainable management of the Danube, recognising the connection between the water and land.

WWF has been implementing model projects throughout the basin in Germany, Austria, the Slovak and Czech Republics, Hungary, Croatia, Slovenia, Bulgaria and the Danube Delta (Romania and the Ukraine). All of these projects are committed to reverse damage done in the past and to demonstrate that when humans live in a manner that is non-destructive to the Danube, humans and nature can both benefit.

I would like to highlight some of these projects and the successes which have been achieved together with our partners and which have been able to restore the natural flow of the river.

Donau-Auen National Park & Regelsbrunner Au
A struggle by WWF and others lasting over a decade led to the opening of the Donau-Auen National Park on the Austrian Danube in October 1996. The establishment of national park status was an important achievement but it was only one part of an overall strategy of WWF to restore and conserve the natural floodplain of the Danube. Unfortunately, the floodplain in the park was not flooded frequently enough and was slowly grown over. Water in the floodplain was confined to a narrow channel.

At the beginning of 1996, however, a bold experiment started to restore the original, natural dynamics in the floodplains. WWF, the newly formed National Park administration, the agency responsible for water management (including transport) and University scientists are involved in the project. The main goal of the restoration project has been to get the floodplains ‘breathing’ again, to restore their natural state, including old river branches or oxbows and dynamic river branches The objectives have been to:

- Allow the waters of the Danube to flow into the floodplain more regularly;
- Enhance erosion and clear old sediments;
- Improve the natural floodplain dynamics, thereby creating diverse habitat structures, improving fish breeding grounds and establishing favourable conditions for rare and endangered species, such as the Kingfisher and Little Ringed Plover;
- Set an example for river restoration throughout Europe.

Prior to restoration water reached the side branch system at Regelsbrunner Au for only 22 days per year. Sediments, mud and sand could not be flushed and choked the oxbows. Construction to open the oxbows and increase the flow of water in to the floodplains for up to 222 days per year began in May, 1996 and ended in April,1998.

600 hectares of floodplain forest and side branches have been reconnected to the river dynamics. The scale of the project at the Donau-National Park, Regelsbrunner Au, and its success make it unique to river management projects in all of Europe and perhaps the world. It has become a model project, demonstrating the value of ecologically sustainable river management.

Bulgarian islands
WWF assisted in the establishment of a Danube wetlands working group between the Ministry of Environment and Waters, the National Forestry Board and NGOs. This working group elaborated a strategy for the protection and restoration of floodplains and the Danube Islands in Bulgaria (WWF 1999). The partners prepared restoration concepts for two major former floodplain areas at the Bulgarian Danube – Belene and Kalimok Marshes. The involvement of local stakeholder groups in the development of the restoration concept was emphasised, especially in the case of Kalimok Marshes. A broad community assessment process and a series of meetings with the different stakeholder groups secured the integration of the interests of the local population into the restoration concept, and therefore their interest and support was secured.

The co-operation between the above mentioned groups and WWF finally led to the interest of the GEF (World Bank) in wetland restoration activities in Bulgaria. Currently a Bulgarian wetland restoration project (approximately 10 million US$) is in preparation. A project concept has been prepared and feasibility studies are under way. The project will include the restoration of the two above mentioned sites, as well as the preparation of a wetland restoration plan for Bulgaria. The main factors leading to the success were the co-operative and participatory approach in the project preparation phase, which led to the support of a broad range of different stakeholder groups.

The Danube Delta
Finally, I would like to mention projects in the Danube Delta (Romania and Ukraine).
The wetlands of the Danube Delta are rich in biodiversity and serve as a bird breeding and migration stop. 320 bird species have been observed. The largest populations of globally endangered Dalmatian Pelican and Pygmy Cormorant take refuge here. Fish species, including Sturgeon, Mullet and Black Sea Herring rely on the wetlands for spawning and feeding. Based on a recent assessment of the worlds Biodiversity by scientists from WWF, the Delta ranks as one of the worlds 200 most important areas of biodiversity.

Partners for Wetlands
Unfortunately, however, the Delta doesn’t just need protection it needs restoration. Tens of thousands of hectares of the Delta had been converted from wetland into what was intended to be agricultural land. The plans of the former governments to produce massive quantities of rice and other agricultural products in these areas, were, however, largely unsuccessful. Unsuccessful, because natural processes were ignored. In both countries, Ukraine and Romania, together with local partners, WWF has been working to restore these failed experiments. In the Ukraine WWF is carrying out a project called ‘Partners for Wetlands’ which aims at the restoration and protection of Danube Delta wetlands not mainly for biodiversity reasons but to create new opportunities for local economic development. Economic planning, such as the development of a tourism strategy and investments in eco-toursim development or assistance in the development of water saving agricultural practices accomplish the technical design of the wetland restoration projects. Only this combination guarantees success and sustainability of wetland restoration.

An existing pilot project in the Romanian part of the Danube Delta, covering 3680 hectares of the former polders Babina and Cernovka, has shown the potential for the ecological restoration of damaged wetland areas and created the initial interest in the Lower Danube countries (WWF 1997). The project has been carried out by the Danube Delta Institute, the Danube Delta Biosphere Reserve Administration, WWF and *RIZA* and was funded by the World Bank. Further planning for other polders is under way, building on the experiences on the technical and social aspects of wetland restoration. Parts of the Polder Popina (3600 hectares) will be re-opened this summer.

5. A Model for the Future

There are many more initiatives for wetland restoration going on in the Danube basin. Joint efforts of governments, the International Commission for the Protection of the Danube River/ICPDR, donors like the EU and GEF, NGOs and national as well as local stakeholders are needed to reach the vision to restore a major portion of the former Danube floodplains. Just like wetlands thrive best in an interconnected network, the restoration within the Danube requires a network of national and international partners. Like wetlands and floodplains do not respect borders, transboundary co-operation is required for viable implementation. Local, regional and national governments, NGOs, bilateral and multilateral donors, as well as citizens at large must work together for transboundary, integrated solutions.

The Lower Danube Green Corridor
The Governments of Bulgaria, Romania, Moldova and Ukraine are taking an extra-ordinary and very important step into this direction, just during the coming month. On June 5 (2000) the Ministers of Environment will sign the Lower Danube Corridor Declaration in Bucharest and present the Green Corridor as Gift to the Earth within the 'WWF Living Planet Campaign'.

The commitment of the Lower Danube countries includes about 400 000 hectares of already existing protected areas, about 100 000 hectares of newly protected areas and about 200 000 hectares of priority sites for restoration. In addition, the countries will commit themselves to an action plan which will detail implementation activities, identify additional sites for the Green Corridor, and require the regular exchange of information and experiences in wetland conservation, restoration, and pollution reduction, based on appropriate monitoring. The countries will further work to develop economic instruments to reduce pollution and to promote wetland conservation. They will actively seek local, national, regional and international partners who can co-operate and assist in the protection, restoration and sustainable management of the Green Corridor for the Danube. The result will be of regional, as well as international importance and should open the way for establishing a Green Corridor along the entire Danube and along its tributaries.

In this and also in other initiatives WWF sees its role as a facilitator, bringing together different countries, scientists and practitioners, conservationists and economists, initiators and donors, NGOs and governments. We are convinced that visions can become reality and that joint efforts can make the Danube a real 'River of Life'.

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EVALUATION OF WETLANDS AND FLOODPLAIN AREAS IN THE DANUBE RIVER BASIN

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1. Introduction

The potentially important role that natural floodplains can play in flood reduction, water quality improvement and maintaining biodiversity in the Danube River Basin has been documented in a number of studies and reports. There has, however, never been a comprehensive and systematic evaluation of the existing extent of natural floodplains in the Danube River Basin and the potential for restoration of former wetlands. UNDP/GEF commissioned this study as part of the Danube River Pollution Reduction Programme to address this shortcoming and to provide the basis for evaluation of the potential for wetland restoration to form a part of the strategies identified for bringing about environmental improvement in the Danube River Basin.

The study was conducted by the WWF Germany Floodplain Institute together with the WWF Danube Carpathian Programme Office and evaluated the potential for wetland restoration along the main branch of the Danube River and 5 main tributaries, the Prut, Tisza, Sava, Drava, and Morava.

2. The Study Area

Given the Danube catchment area's heterogeneous structure and the well known eventful historical conditions, homogeneous data/maps over the entire area are only to a very limited extent available. This is also true for data on recent and historical floodplain areas. On the basis of extensive investigation, however, the delineation of both the morphological and the recent floodplain could, in a first step, be determined for the whole Danube and for its larger tributaries (Morava, Drava, Tisza, Sava and Prut).

The total area of historical floodplain wetlands in the area of investigation was 41 605 km^2. The study found that the total area of remaining floodplain wetlands in the area of investigation was only 7845 km^2. The remarkable extent of floodplain loss in the study area is therefore in excess of 80%.

3. Ecological Evaluation

The investigated floodplain areas had to be divided into sections for the evaluation of their ecological value and their rehabilitation potential. The segmentation resulted from a combination of various factors: the first and determining factor was the floodplain width. This factor is in turn determined by geomorphological, river morphological and hydrological factors. Detailed land use data have been used for a further refinement of the segmentation. The minimum size of the sections was fixed at 15 km.

Selected bioindicators were expected to contribute to the estimation of the ecological value of the investigated floodplains. Extensive investigation in the Danube catchment area of bioindicator data demonstrated, that geographically extensive and current data are not available, or only very limited. There is only local or regional information on the distribution of certain species.

For the consistent evaluation of the whole area, factors, of which data were available everywhere, had to be selected. In addition to the data on floodplain size and type, surface-covering land use data were also available. They existed in the form of current CORINE-LandCover data for the major part of the investigation area. For the other areas of the Danube catchment area (Ukraine, Moldova, Slovenia, Croatia, Bosnia-Herzegovina, FR Yugoslavia, Albania), current land use data had to be elaborated through satellite image classification.

An evaluation procedure based on the following factors has therefore been developed:

- Floodplain type (recent floodplain (4), outlet section/polder (2), former floodplain (1));
- Floodplain width (> 5 km (4), 2.5-5 km (3), 1-2.5 km (2) and 0-1 km (1));
- Land use data (forest (4), swampland/water (4), meadows (3), farmland (2/1), settlements (0)).

The three factors were classified according to the values in between brackets. Floodplain type and width appear as multipliers of the actual land use in the specific section. The land use was valued and calculated as a percentage, in a first step. The results have been grouped in four classes, from a low to a very high ecological value. 450 sections have been evaluated. The result has been represented in the map ‘Ecological Potential of Floodplains in the Danube River Basin’ (Figure 1).

4. Potential of Nutrient Reduction

Besides the ecological value, the nutrient reduction potential had to be studied as well. It is an uncontested fact, that recent, inundated floodplains have a positive effect on water quality

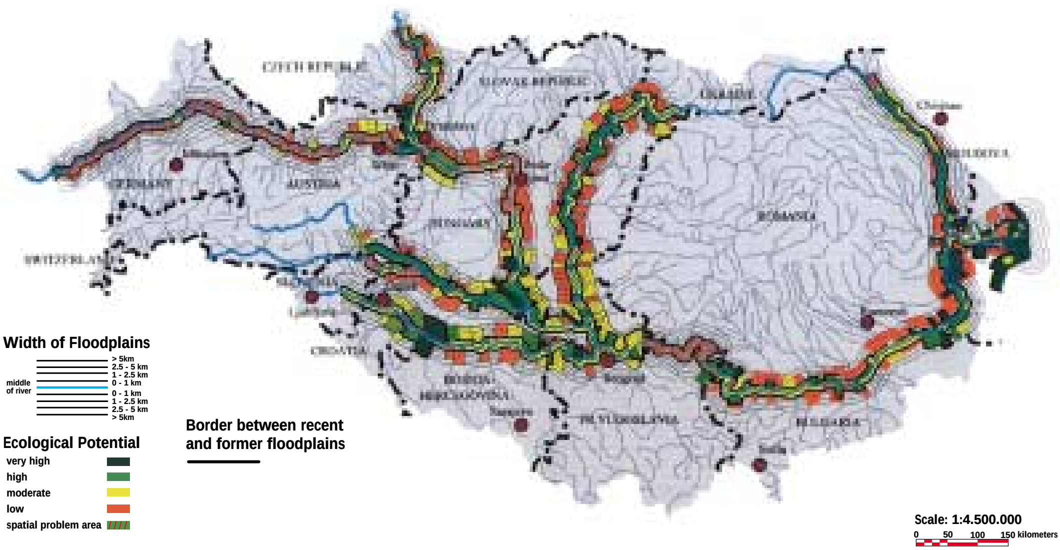

Figure 1. Ecological Potential of Floodplains in the Danube River Basin.

improvement and nutrient input reduction if they are not subject to intensive agricultural use. This is why one may suppose that all areas of the ecological potential map that have been considered as being valuable or very valuable have a high nutrient reduction potential (Figure1). The reduction extent, however, cannot be definitely quantified at the moment, because the data available are insufficient and heterogeneous. The required data and the methodology to do this have been described in the text. It can be argued, however, based upon review of the studies mentioned above and the general knowledge on all factors influencing the Danube basin, that a range of values for nutrient reduction can be proposed. The proposed nutrient reduction is:

- kg total N/hectare/year: 100-150
- kg total P/hectare/year: 10-20

As a result of numerous alterations to the Danube and the other rivers investigated, there is a general problem of deepening of the river bed which has an important influence on the restoration potential. In particular the deepening of the river bed reduces the frequency of flooding. This problem has to be addressed and measures to prevent this deepening as well as remedial measures are necessary.

5. Restoration Potential

The evaluation of the rehabilitation potential considered only former floodplains with a width of more than 1 km. Both, the existing segmentation and the land use data have again been used. The evaluation results have been grouped in four classes. The main factors used in the evaluation were: unsettled or scarcely settled areas; connected areas; large old floodplain structures.

Experience shows that political and socio-economical conditions (property structure, status of the area, political decision-makers) play a far more important role in the realisation of rehabilitation projects than the actual land use. These factors, however, have not been examined in detail and require further investigation. The results are represented in the map ‘Restoration of Former Floodplains in the Danube River Basin’ (Figure 2).

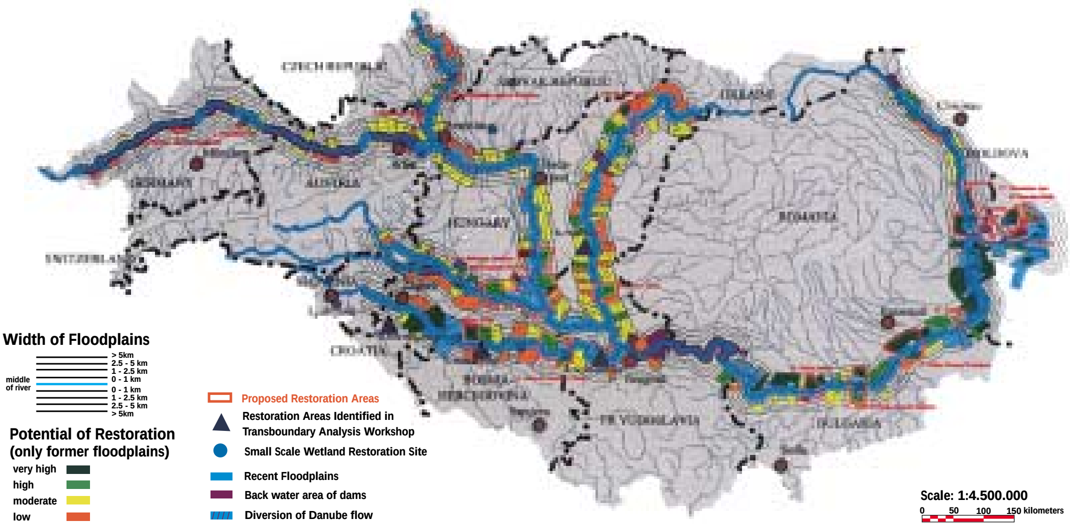

Figure 2. Restoration of Former Floodplains in the Danube River Basin.

The areas recommended for restoration are areas with a high or very high rehabilitation potential. The selection of these areas is based on criteria such as, chances to succeed in the realisation, transboundary character and regional knowledge of the ecological value.

The 17 sites identified are:

Upper Danube:
1. Floodplains near Ingolstadt (Germany)
2. Isar mouth (Germany)

Morava:
3. Drösing forest/Sierndorf (Austria)
4. North of Hodonin (Czech Republic)

Central Danube:
5. Area from Gemenc to Kopacki Rit (Hungary, FR Yugoslavia, Croatia)

Drava:
see central Danube, Kopacki Rit

Sava:
6. Drina mouth area (FR Yugoslavia, Bosnia-Herzegovina and Croatia)
7. Mokro Polje area (Croatia)

Tisza:
8. Upper Tisza/Bodrog mouth (Hungary)
9. Lower Tisza (FR Yugoslavia)

Lower Danube:
As can be seen on the map, many areas with a very high and high rehabilitation potential exist along the Romanian Danube. In principle, these areas should all be analysed with respect to their actual rehabilitation potential. In order to facilitate progress we propose four areas, one in Romania, the others in the transboundary area:

10. Balta Potelu (near Oriakovo)
11. Bulgarian Danube islands and opposite area in Romania
12. Balta Greaca (Romania)/Tutrakan (Bulgaria)
13. Balta Calarasi

Prut
14. Lower Prut

Danube Delta:
15. Liman lakes (Ukraine)
16. Pardina polder
17. Ukrainian part of the Danube Delta

Finally, we recommend that in addition to further examination and investigation of the proposed restoration sites, the following aspects should be considered for future work:
- Application of the methodology to additional rivers (e.g. Inn, Wag, Mures, Siret, etc.);
- Elaboration of protected area concepts for ecologically valuable areas;
- Publication of the results in a form that makes them accessible to a broader public;
- Organisation of a digital information system to make the extensive information of the floodplains in the Danube River Basin and the evaluation results in digital form available all over the world.

RESTORATION PROGRAMME IN THE DANUBE DELTA: ACHIEVEMENTS, BENEFITS AND CONSTRAINTS

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Abstract:
The human interventions in the Danube Delta are consequences of different land-use policies. In the end of the 19th century, measures to improve the navigability had no major impact on the natural delta's functions. Between 1903-1960, in so called 'capture fishery period', new channels have been built or enlarged, in order to activate water circulation inside the delta and to improve the fish production function.
A more intensive campaign of hydro-technical works has been undertaken between 1960-1970, so called 'reed period' in order to increase reed production and to facilitate reed harvesting and transport.
The 'fish culture period' between 1971-1980, followed by 'agriculture period' mostly between 1983-1989, altered the natural functions and increased the dammed areas from 240 km² to 970 km².
Since 1990-1991 the Danube Delta has become a Biosphere Reserve and a Ramsar site. One of the main management objectives was to 'Maintain or restore the natural operations and functions of the Delta's ecosystems'.
Out of a total area of 5800 km² of the Reserve, the restoration programme included engineering works for improving the ecological status of the natural ecosystems and restoration of 114.25 km² of polders in the first phase with further perspective of extending this to 263.40 km² and finally to 602.60 km²
The achievements so far are promising, despite of existing constraints that slow down the restoration initiatives and projects.

1. Introduction

The Romanian Danube Delta Biosphere Reserve (DDBR) is situated in the eastern part of Europe, at the intersection of 45°N (latitude) with 29°E (longitude).
The total area of the DDBR is of about 5800 km², more than half of which (3381 km²) belongs to what is commonly called the 'Danube Delta', while the remaining area is shared between the upstream Danube flood plain sector, the Razim-Sinoie lagoon complex, the neighbouring strip from the Black Sea up to the 20 m depth.
The Danube Delta has become a Biosphere Reserve in 1990 and a Ramsar site in 1991. The territory comprises 23 types of natural or partly man-induced ecosystems and 7 types of anthropic ecosystems (Gastescu *et al*. 1999). The abandoned polders under restoration works are component of the second category.
The overall restoration programme in the DDBR area includes engineering works for improvement of the ecological status of the natural ecosystems and the restoration of 114.25 km² of polders in the first phase, with further perspective of extension to 263.40 km², and finally to 602.60 km².

2. Historical Background

2.1 Management policies

The human interventions are consequences of different land-use policies, which changed the Danube Delta pristine feature (Hartley 1887).
At the end of the 19th century, measures were taken to improve the navigability of the middle arm of the river in the Delta. This had no major impact on the other functions of the Delta.
Between 1903-1960, in so called ‘capture fishery period’, new channels have been built or the older natural ones have been enlarged to activate water circulation inside the Delta, aiming to improve the fish production function.
A more intensive campaign of hydro-technical works has been undertaken between 1960-1970, so called ‘reed period’, in order to increase reed production and to facilitate reed harvesting and transport to the cellulose factory. Besides the channels, the first large areas have been dammed to regulate and optimise the water level, a key factor for the reed beds development.
The ‘fish culture period’, between 1971-1980, followed by the ‘agriculture period’, mostly between 1983-1989, altered the network of water courses. The dammed areas increased from 24 000 hectares to 97 000 hectares and have been cut off from the Danube River pulse system.
Due to political changes, the Danube Delta was declared a Biosphere Reserve in 1991 and the conservation of natural values and recovering of wetlands functions became priority objectives.
A restoration programme of damaged ecosystems started in 1993, heralding a new era in the Danube Delta history (Figure 1).

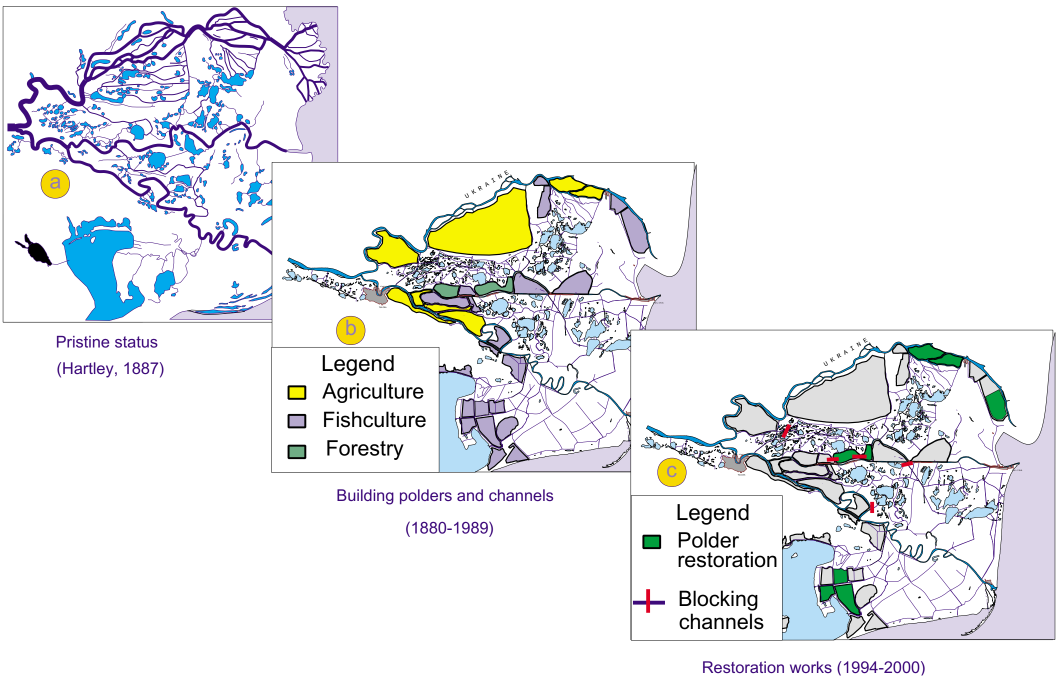

Figure 1. Phases in the Danube Delta recent history.

2.2 Management practices and effects

Building an extensive canal system

As a result of the extensive hydro-technical works for economic purposes, the total length of the channels increased from 1743 km to 3496 km (Gastescu and Driga 1983) and the discharge of the Danube River to the Delta's wetlands, increased from 167 m^3/s before 1900 to 309 m^3/s in 1921-1950 period, 358 m^3/s in 1971-1980 period and 620 m^3/s in 1980 –1989 period (Bondar 1994). The siltation of the natural lakes which are directly connected to the river accelerated, and the nutrients inflow increased even more than the water discharge due to increasing pollution of the river (Figure 2).

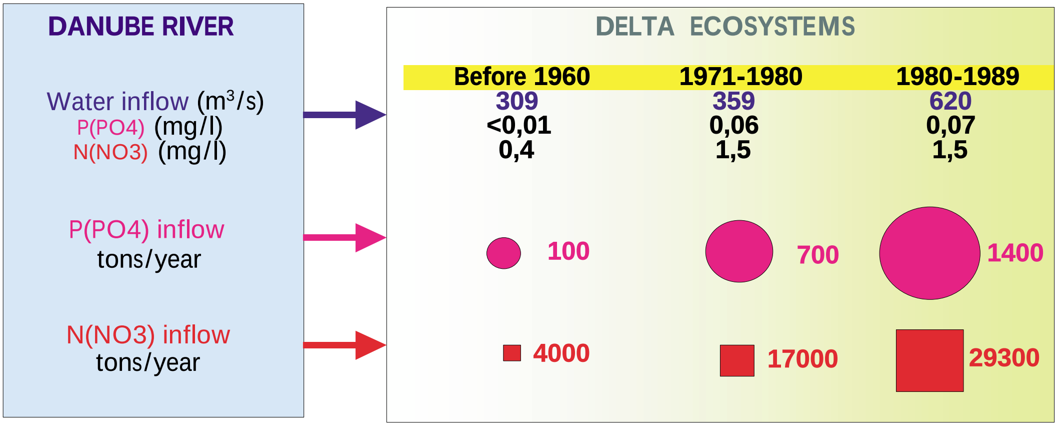

Figure 2. Changes in water and nutrients exchange between river and floodplain.

Building polders

The natural habitats of many plant and animal species were reduced and partly destroyed. Other functions, like acting as a biological filter of the water discharging into the Black Sea, or water storage have been diminished. The water balance was changed, as well as the exchange of water between the remaining natural ecosystems. The traditional life of the inhabitants has been altered.

After 1990, the agricultural polders were used ever less, due to the negative cost-benefit balance and the dry climate in the area.

The greater part of the fishponds is not suitable for the purpose they initially were designed for, because of the organic bottom layers. The productivity is low and the technological costs are high due to the high energy costs for pumping water.

The poplar plantations have only an economic utility, their role as habitat for animals being rather modest.

3. Restoration Programme

3.1 Objectives

One of the main objectives of the management of DDBR, as formulated with assistance of IUCN and UNESCO in 1991 was to 'Maintain or restore the natural operations and functions of the Delta ecosystem'.

The restoration objectives are derived from the Objectives of the Management Plan of DDBR.

The short term strategy had two priorities:
- To improve the ecological status of the natural ecosystems;
- To recover the former wetlands and their natural functions in the dammed areas when economic activities are not sustainable.

3.2 Achievements

Natural ecosystems
The restoration works have been focused on the following goals:
- Blocking short transversal canals to avoid direct access of river water and the fast siltation of the lakes;
- Dredging old natural longitudinal channels to improve hydrochemical regime in the downstream lakes where a huge amount of decaying biomass is accumulated, and which is able to induce anaerobic conditions;
- Reducing section of the built canals which are enlarging themselves and threaten the natural ecosystems or human settlements.

This programme started in 1993 and is now being implemented.

Polder restoration
Two agricultural polders (3680 hectares), some fish ponds (5630 hectares), and an unfinished forest polder (2115 hectares) were selected for ecological restoration, in the first stage, that will be followed by the ecological restoration of another two fish ponds (3600 hectares).
The two pilot projects of agricultural polders which have been connected to the river and flooded in 1994-1996, proved the amazing recovering potential of the former wetlands and, that the existing situation could be reversed. One year after the dam opening, the re-development of the aquatic communities, similar to those found in the natural conditions were observed.
The restoration of the fishponds area does not imply a shift from dry land to wetland features. A pilot study started in 1993 in the southern part of the Reserve, so called Holbina-Dunavat area (5630 hectares), aiming to restore lateral connectivity, maintain or improve existing ecological values and to prevent further deterioration due to the human impact. An adaptive strategy for establishment of a self-regulating wetland, with a gradient of decreasing riverine influence to the isolated parts has been outlined. The strategy involves integration of the separate fishponds to one unit. This strategy has not been implemented yet because this unit was not designated entirely for restoration, some basins are still used for fish culture.

3.3 Benefits

Use values for local communities
Based on correlation between damming rate and the decreasing fish yield in the Danube Delta, it could be assessed that each dammed hectare of wetland has resulted in a loss of 34 kg of commercial fish size per year. The evaluation of the restoration project in Babina-Cernovca polders showed that the fish production function has been restored and 3680 hectares of new wetlands provide sustainable fishing activities for 20-25 fishermen.
The reed dry biomass of the reed beds exceeds 10 tons/hectares/year (Hanganu *et al*. 1994) and by sustainable practices a minimum 1-2 tons/hectares can be harvested every year.
The seasonally flooded pastures are subject to cattle breeding with a carrying capacity of 0.4-0.5

cows/hectares/year. In economic terms, the benefits of the local people amount to 40-50 US$ from restored permanent wetlands, and about 100 US$ per hectare/year from seasonally flooded areas, with low costs instead of subsidised or abandoned agriculture in dry polders.

Non-use values

Using existing valuable aesthetic values of the restored wetlands, a substantially increase of the use values by ecotourism can be obtained. As an indicator of restoration success, the former monotonous dry landscape became a habitat for water birds where they are feeding, resting or even nesting.
After the dam openings, beside limnophilic fish species, the rheophilic fish species use the area for spawning. This is proved by observations of fish movement and fish larvae records.
It is evident that a significant floodplain specific diversity has been recovered as well as a considerable genetic potential that would have been lost if the areas remained impounded.
The assessment of overall nutrients and suspended solid balance in the Babina pilot area revealed a removal/retention capacity of 14.5 kg/hectare/year of phosphorous, 334.5 kg/hectare/year nitrogen and 11 508 kg/ha/year of sediments.

Cooperation opportunities

The restoration programme has benefited from international interest and support. It has been a good opportunity for starting and developing scientific cooperation with *RIZA*-Lelystad, The Netherlands and WWF-Institute for Floodplain Ecology - Rastatt, Germany. The institutional capacity and the field of expertise of the Danube Delta Institute increased. The partner institutions gained more experience for further projects in their own countries or world wide, as well.

3.4 Constraints

Learning from experience so far, the main group of factors which slow down or even can hamper the implementation of the wetland restoration in the Danube Delta originate from legal and institutional framework as well as stakeholder participation. In addition, the environmental status, the integrity of the ecosystems and their related functions could generate further constraints during implementation of the restoration strategy (Figure 3).

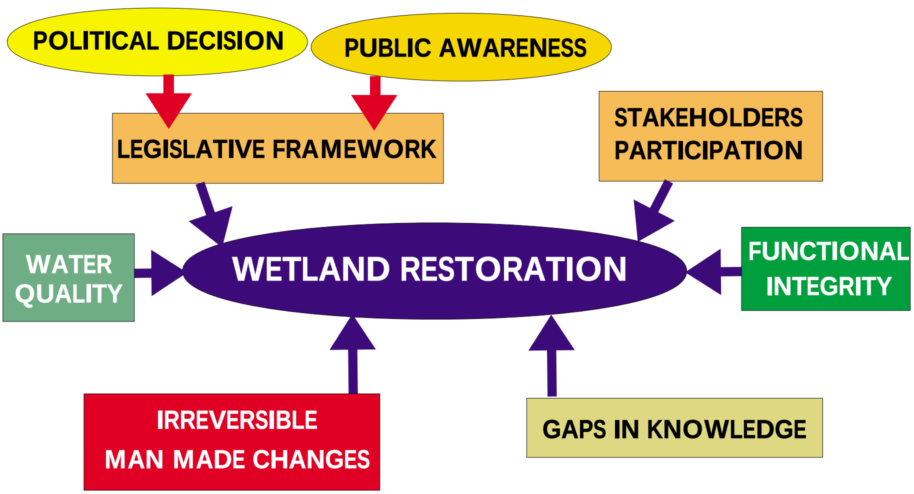

Figure 3. Floodplain restoration constraints.

Morpho-hydrology

The man-made polders are surrounded by dams which changed the natural morpho-hydrological features. Usually the lateral connectivity is restored by opening the dams, but the flooding regime differs from the natural conditions. The functions of the former natural levees between the river and floodplains are not restored. The natural levees do not accomplish any more their role in spring during high water level. The only way for water inflow during both high or low level are the new openings (Figure 4). The sedimentation process inside restoration area is faster than the natural ones and maintenance expenses for water inlet are expected in the short future.

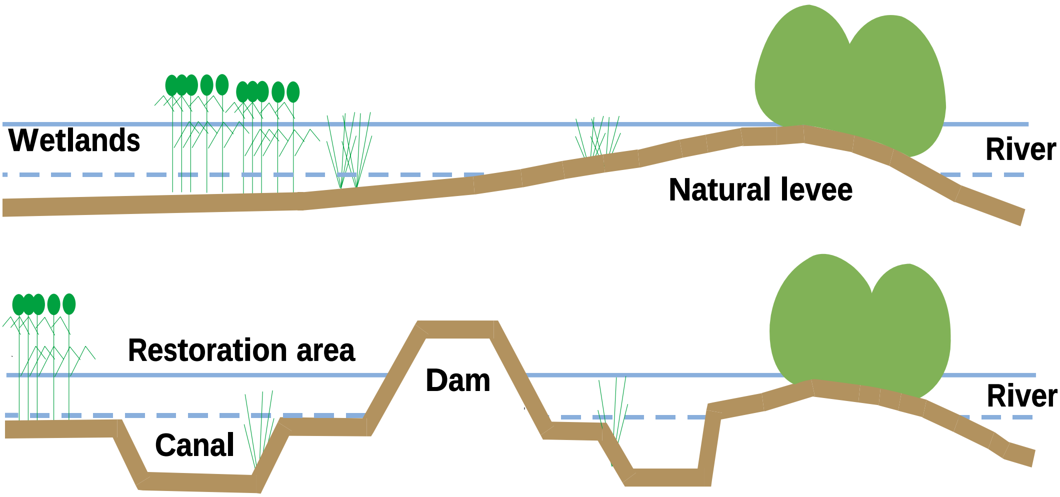

Figure 3. Floodplain restoration constraints.

Legislative framework

The restoration programme overlapped with the change in land owners. Whereas the polder areas became local public property by law, the surroundings dams remained state property, subject to privatisation. The unclear political objectives concerning the land use destination is a source of confusions and conflicts and has slowed down the restoration works.

Stakeholders participation

The experience so far in the Holbina – Dunavat area learned that the consensus between stakeholders, local communities and policy makers is essential.

The powerful local county council continued to grant concessions of the areas inside the polders to the private lease holders, as this is an important source of fund raising. As part of these funds are used for subsidising local people's costs for transport, electricity, water supply, the system has many advocates. The fact that the lease holders accepted the wetland restoration is positive from restoration point of view, but the benefits of the wetlands are not fairly distributed inside the local community .

Gaps in knowledge

It is fair to say that the studies so far has delivered a great deal of new knowledge, yielded a better understanding of the ecology of wetlands. However, the database is limited, there are gaps or uncertainties related to intimate knowledge of ecological processes.

Water quality
As long as the Danube river is polluted with nutrients, the former mesotrophic aquatic habitats and communities can not be recovered everywhere in the Delta. The management objectives must be adapted to the creation of a mosaic of habitats with different degree of eutrophication. The still existing valuable clear water habitats in the isolated lakes must be protected to avoid further eutrophication.

Functional integrity
When the restoration area is a part of a larger unit, the separate treatment should be a short-term step only. The original functions and features can not be recovered without restoring the physical and functional integrity of the whole unit. This could be a long-term process which needs a consensus on the future land use.

4. Conclusions

- The wetland restoration may be considered as an ecological-economical alternative to the management of the unprofitable polders in the Danube Delta;
- The restoration potential of the dry former wetlands is high and the recovery of the natural functions proceeds rapidly after re-flooding;
- There is not a specific restoration pattern, but restoration principles should be adapted to the existing conditions. Whereas restoration of the agriculture polders results in a fundamental change of the land use, the restoration of the fish ponds implies lateral connectivity and establishment of a near natural hydrological regime;
- The restoration programme in the Danube Delta creates supplementary economic values for local people which should be equitably distributed among community members;
- The stakeholder participation is a key factor of restoration success. When the land ownership is public, the state should play a decisive role in implementation of the restoration programme by appropriate legislative and institutional frameworks.

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IMPACT OF THE RIVER FLOW REGULATION ON THE HYDROLOGICAL REGIME AND ECOSYSTEMS OF THE VOLGA DELTA

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Abstract
Regulation of the flow of the River Volga for the production of hydroelectricity changed the hydrological regime in the Volga Delta. The reservoirs of the Volga-Kama Cascade works are operated on the seasonal regulation principle. The changes of hydrological regime cause changes in ecosystems of the Volga Delta. The fish spawning period becomes shorter and the conditions are bad for developing of young fishes in the temporary water bodies at spring. Shortening of spring floods influenced the productivity and distribution of plant communities. Winter floods influenced the mammals.
At the same time the results of the investigations showed that it is possible to create a favourable ecological regime provided that the mode of operation of the reservoirs of the Volga-Kama Cascade will be changed (Pavlov et al. 1989; Voropaev et al. 1994).

1. Introduction

Up to now, the Volga Delta is the cleanest delta compared with the deltas of the European rivers like Rhine and Danube (Winkels *et al*. 1998). Many natural processes survive in the Volga Delta. At the same time the regulation of the water flow from the reservoirs for electricity production has a great impact on the hydrological regime of the Volga Delta. This changes of the hydrological regime cause changes in ecosystems of the Volga Delta. Nowadays, there is the problem to bring the existing hydrological regime closer to natural conditions.

2. Description of the Volga Basin and Volga Delta

The River Volga is the largest river in Europe, 3530 km in length. The average discharge of the Volga is about 7710 m^3/s. About 200 tributaries flow into the Volga. The basin of the Volga covers an area of 1 360 000 km^2. With an area of 19 000 km^2, the Volga Delta is one of the largest deltas in the world. The length of the Volga Delta is about 120 km and its seaward edge is about 200 km. The Volga Delta is a flat alluvial plain with wide net of branches and channels and many islands. About 900 channels flow into the fore-delta (Gudkov 1952; Finlayson *et al*. 1993). The fore-delta is a vast shallow area overgrown with emergent and submerged vegetation.

3. Regulation of the Volga River Flow

Regulation of the flow of the Volga River for the production of hydroelectricity began in 1937. At present, there are nine large reservoirs in the Volga-Kama Cascade. These reservoirs have a total usable capacity of about 80 km^3 and cover an area of about 23 000 km^2. Furthermore, there are great number of medium and small reservoirs with a total usable capacity of about 14 km^3 (Voropaev *et al*. 1991).

4. Impact of the Volga River Flow Regulation on the Hydrological Regime of the Delta

Regulation of the Volga River flow changed the hydrological regime in the Volga Delta. The hydrological regime became was very much affected after the Kuibyshev and Volgograd hydro-electric stations had been brought into operation (Moscalenko 1971).
The reservoirs, as a rule, are filled during the spring floods. This water in the reservoirs is used for drier periods in summer, autumn and winter (Voropaev *et al*. 1991).
This means that the Volga flow was redistributed within an annual cycle (Figure 1). This result was a shorter duration of the spring floods, reduction of the flooded area, and changes in the floods character in the Delta. During spring floods water rise and fall became much faster then had been the case under the natural hydrological regime (Moskalenko 1971). At the same time the winter flow of the Volga River was increased. This induced the flooding of delta islands in wintertime (Rusakov and Moskalenko 1981).

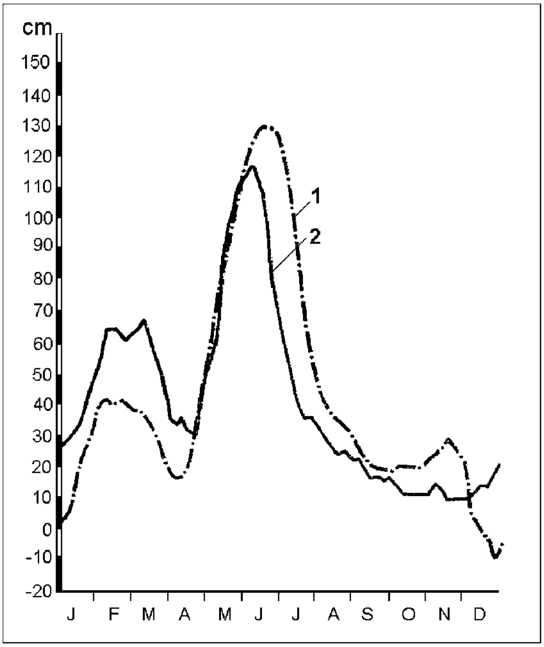

Figure 1. Water level seasonal fluctuations in the Volga delta (after Moskalenko, 1971).

1 – Before the dam near Volgograd was constructed
2 – After the dam near Volgograd was constructed

5. Local Modification of the Volga Delta Hydrological Regime

A water diversion structure was constructed in the Volga Delta in 1975 (Bukharitsin 1992). It consists of a regulation dam across the main bed of the Volga River at the apex of the Delta and a dam along the axis that divides the Delta in an eastern and western part (Figure 2).
The water diversion is designed to increase the volume, height and duration of the spring floods in the eastern part of the delta, supplying water to the spawning grounds in that area. The diversion dam

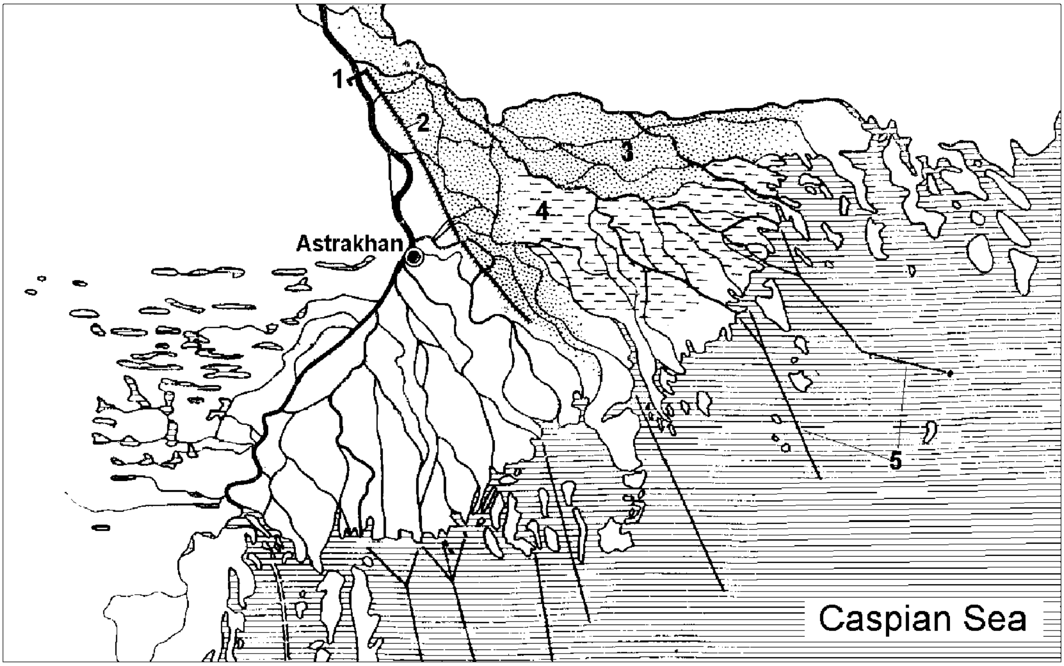

Figure 2. Schematic map of the Volga delta reclamation (compiled after Sadlaev *et al*., 1974 and simplified).

1 – The dam of the water diversion for regulation of the water discharge in the apex of the delta.
2 – The dam of the water diversion along the delta.
3 and 4 – The spawning grounds that were and will be reclaimed.
5 – Fish-passage canals in the fore-delta.

was used in 1977, 1978, 1982 and 1983 (Bukharitsin 1992). At present, the water diversion does not work because of conflicts of interest between the agriculture and fisheries industry (Voropaev *et al*. 1991).

Many fish-passage canals were constructed in the fore-delta to improve fish migration from the Caspian sea into the Volga River. This changed the hydrological regime of the Delta as well.

6. Impact of the Volga River Flow Regulation on the Biota of the Delta

The changes of hydrological regime changed the biota of the Volga Delta.

Zooplankton

In the years immediately after regulation of the Volga River flow the zooplankton populations in the Delta channels increased. Than in the late 1960s, early 1970s, the populations dropped. The zooplankton numbers started to increase again in the mid-1970s. After regulation of the river some northern species has spread into the Delta. The character of the floods has a great bearing on the zooplankton population composition in the temporary water bodies on the islands in the Delta, in the spring-summer. Favourable conditions for zooplankton occur when the temporary water bodies start to form in the late of April, early of May and when the water level rises slowly. Rapid increases in the water depth hamper the zooplankton population to develop. When the floods are late and of a short duration, blooming of species can coincide, a totally unnatural event. If the temporary water bodies dry out too early many species are not able to reproduce, resulting in a reduction of the population the next year.

Fish

The water discharge regulation reduced the fish breeding areas and fish breeding conditions in the Delta. The duration and time of growth, and the downstream migration of young fish changed as well. In natural conditions the downstream migration of young fish was at the end of June – July. At present, the downstream migration is observed in June. This results in weak young fishes (Koblitskaya 1971).

Birds

Lower flood water-level, shorter duration, increased number of late dates of the start of the flood, improved the breeding conditions of birds that build their nests on the ground. They are pheasant (*Phasianus colchicus*), quail (*Coturnix coturnix*), grey-lag goose (*Anser anser*) and some other species. For species, like pheasant and quail the reduction of the flooded area is very important. For grey-lag goose the increased number of late dates of the beginning of the flood is very important. At the same time the breeding season for water birds became less because of later flood beginning and reduction of flood areas (Krivonosov 1968).

Mammals

In general, the shorter duration of the flood improved the conditions for mammals. The winter floods, however, had a negative influence on mammals, for example on wild boar (*Sus scrofa*) (Kasatkin 1968).

7. Conclusion

The current hydrological regime of the Volga Delta depends on the water discharge from the reservoirs upstream the river. Special spring floods for flooding of fish spawning grounds are formed in the Volga Delta by water discharge from the reservoirs. But these floods are not enough in volume and duration. At the same time the results of the investigations showed that it is possible to create favourable ecological regime provided that the mode of operation the reservoirs of the Volga-Kama Cascade will be changed (Pavlov *et al*. 1989; Voropaev *et al*. 1994). Inventory and restoration of the natural spawning grounds for fishes must be the objectives for wetland management in the Volga Delta as well.

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ALLUVIAL WETLANDS PRESERVATION IN CROATIA THE EXPERIENCE OF THE CENTRAL SAVA BASIN FLOOD CONTROL SYSTEM

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Abstract
Large alluvial wetlands have been preserved until today in the Central Sava Basin, in order to reduce the maximum peaks of the Sava and Kupa rivers during high water. This concept has proved very effective since its design in 1972. It is an excellent model for flood control systems: not only are retention areas preserved as safety features, they also maintain a high biological diversity in the region. A new Environmental Assessment reviews the original concept, such, that in addition to flood control, the conservation of natural and cultural heritage is included in the project design. The World Bank has given Croatia a grant to fund the preparation of this Environmental Assessment. It offers a unique opportunity to the Croatian Water Management authority, in co-operation with EURONATUR and many Croatian organisations, to design and build a flood control system which will provide a model for flood control and regional development, also for other countries.

1. Background

Floodplains are the natural retention areas for the waters of rainfall and snow-melt flowing from the mountains. They are important for natural water purification and the regeneration of groundwater resources. Water management in Europe and other parts of the world over the last 150 years has, in retrospect, made some grave mistakes. In order to enlarge the area of agricultural land, for the production of energy and to improve shipping, rivers have been canalised and their floodplains 'ameliorated'. The formerly flooded lands were often quickly transformed by intensive agriculture, but also covered by towns, roads and industries: thus large retention areas, for the natural control of flooding, were lost. Such river regulation projects were regarded as secure and important for flood protection, without taking into consideration the higher levels of floods before this century, or the potential for greater damage resulting from the failure of constructed dikes and levees. Catastrophic floods in the valleys of the Rhine, Po, Elbe, Oder, Tisza, Mississippi and many other rivers have exposed the insecurity of these constructed 'control systems' against flooding (compare Philippi 1996). The problem of all such projects is that they do not allow the floodplains to fulfil their natural function of retaining water during times of high flow.

Croatia is a key Country for the preservation of flood plains in Europe (Schneider-Jacoby 1994). Along the Rivers Sava, Drava, Mura and Danube, the Country hosts the largest alluvial wetlands in the Danube Basin (DPRP 1999). The tributaries are important for the preservation of the high biodiversity and contribute to the ecological importance of the Danube River (Schneider-Jacoby 1996). The paper will focus on the Central Sava Basin/CBS, where large alluvial wetlands were preserved in the seventies as retention areas. The flood control scheme was developed by the UN with help of local and foreign specialist (Consortium 1972; Direkcija 1975) and was based from the beginning on a catchment area approach for the whole Sava River. In 1999, an Environmental Assessment/EA of the project was done for the World Bank with financial help of the Japanese Trust Fund. The study was aimed to define priority projects for funding to complete the flood control system and describe the ecological and cultural values of the area. The study was done by Croatian Waters in co-operation with VPB and EURONATUR plus a team of experts (sector studies on forestry, agriculture, biodiversity, cultural heritage, demography, hydrology and climate). It resulted in a proposal for an Integrated Central Sava Basin Programme with a special emphasis on floodplain preservation and restoration.

2. Importance of the Central Sava Basin for Flood Control

The basic idea of the UN programme for the Central Sava Basin (Consortium 1972), i.e. to store flood waters in the natural inundation areas, is very sound; it also fulfils international criteria for the management of catchment areas. The system, only partly completed so far, has proved to be very effective in recent years, protecting important towns such as Zagreb and Sisak, and large agricultural areas, against flooding. About 40 % of the flood control system was built before the war began in 1990, leaving large areas of alluvial wetland unregulated. With 112 000 hectares extent, it is the largest floodplain ecosystem in the Danube River Basin (DPRP 1999) and an important nutrient sink for the Upper and Central Sava Basin.

The study area is a key site not only for Croatia, but for the whole Sava Basin (Figure 1). It has to store water from the upper catchment area, which includes Slovenian territory, and to prevent the flooding of large drained areas downstream, some of which lie within Bosnia and Herzegovina and some in Yugoslavia. The effect on the lower Danube has not yet been evaluated.

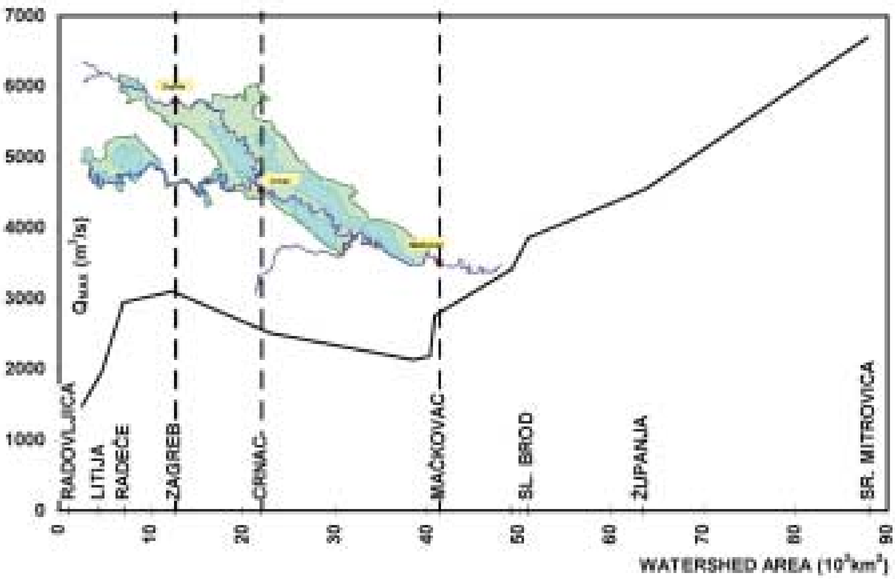

Figure 1. Effects of the Flood Control System in the Central Sava Basin on peak flood discharge in the Sava River (based on Direkcija 1975).

Manipulation of the water in the Central Posavina system is carried out via three relief channels protecting the towns Zagreb (Odra Canal), Karlovac (Kupa-Kupa Canal) and Sisak (Lonja-Strug Canal), fifteen distribution facilities and the alluvial retention areas, for storage. These channels and facilities are integrated into the existing limited flow river network. This is a system that, with the necessary retention and expansion areas in the low lying area of Central Sava Basin, and governed by the criteria established for the manipulation of the water masses, ensures an unaltered water regime in the Mackovac exit control profile (Figure 1, maximum = 3000 m^3/s) toward the lower Sava valley (Braun 1999).

3. Values of the Floodplains

The economic value of wetlands has recently gained more attention (Barbier *et al*. 1997; Skinner and Zalewski 1995). The Lonjsko Polje Nature Park as a part of the CSB and its the alluvial wetlands have environmental assets important globally, nationally and regionally (Schneider-Jacoby 1999). To assess the value of the inundation areas, the concept of ‘total economic value’ (TEV) was used (IUCN/WCPA 1998), which has been developed for protected areas. Because about half of the area is already protected as a Nature Park, and the rest has outstanding features and international recognition of its worth (Grimmett and Jones 1989), TEV seems to be the best means of estimating the value of the whole area. In addition, other alluvial wetlands have been evaluated using similar methods within the Danube Pollution Reduction Programme (DPRP 1999).

The most important direct-use values are:

- Recreation area for 1.5 million people living around the wetland;
- Fishing and angling: about 10 000 – 15 000 people already use the area;
- The sustainable harvesting of timber: the timber standing on only 1 hectare of alluvial forest is worth 41 000 DM and the annual growth rate, which can be harvested sustainable, is 1000 DM per hectare;
- Hunting: the value of hunting is about 133 DM/hectare – and grazing and winter fodder.

The area offers also great possibilities for education, research, the preservation of genetic resources, collection of medicinal plants and animals and the direct marketing of local products.

The main indirect-use values are:

- Flood control (about 2 billion m^3 of storage capacity);
- Climate stabilisation through the large forests;
- ‘Ecosystem services’, such as the self purification of water and ground water recharge, which affects the drinking water for over one million people.

Groundwater recharge is a vitally important function. In the Kupa depression and the upper part of the Sava in particular (where the river braids, upstream of Rugvica), the river and the inundated areas are closely connected with the ground water and large volumes of water are exchanged. In the meander zone of the Sava, those villages near the river use water which is recharged through the river banks. The quantity of water entailed has not been estimated, but the groundwater supplies from the study area.

The most important non-use values include biodiversity – there are two Ramsar sites, three Important Bird Areas (Grimmett and Jones 1989), and the Sava is a priority area in the Pan European Biodiversity and Landscape Strategy and a key site in the Danube River Basin programmes (EPDRB 1994). Cultural heritage, regional identity and cultural landscape - the landscapes of the Sava Wetlands, Odransko

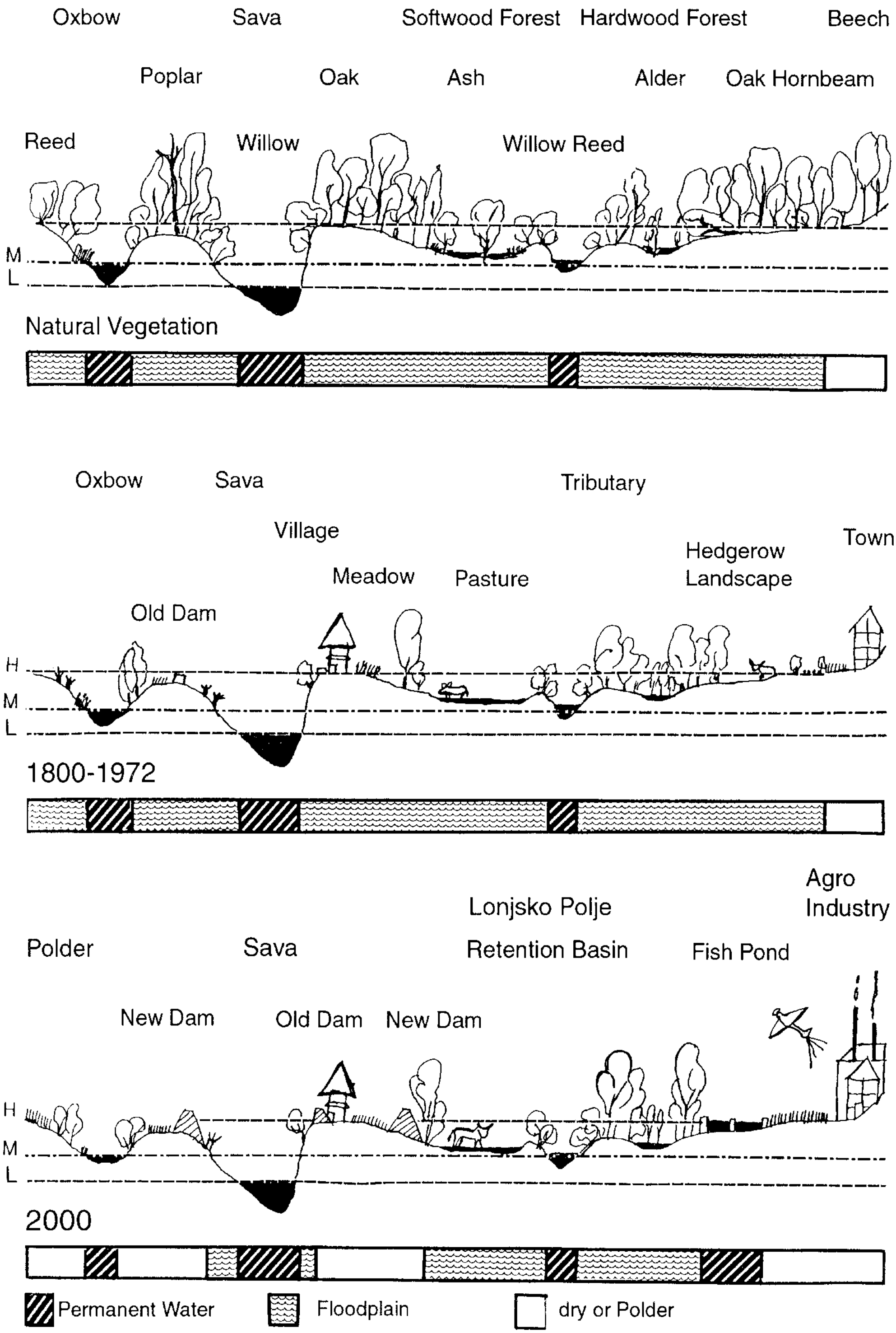

Figure 2a. Development of the landscapes of the Sava Wetlands.

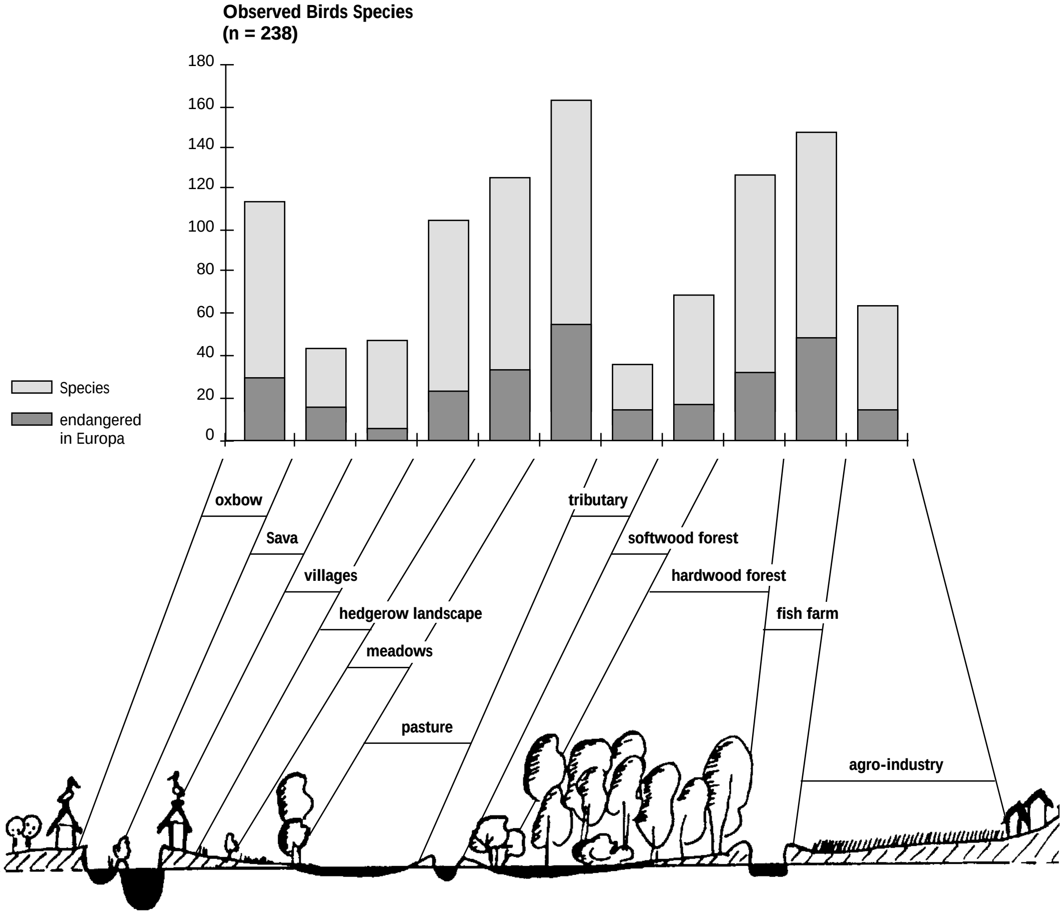

Figure 2b. Birds as indicator of the ecological importance of alluvial wetland. Most species have been observed in the large pastures characteristic for the alluvial depression in the Central Sava Basin (Schneider-Jacoby 1993).

Polje and the Pokupsko depression form an unique blend of natural landscape elements and of the European riverine lowlands (Figure 2). The landscapes of the Sava Wetlands are very impressive and have inspired, and will continue to inspire, artists to create new visions and new art, based on the ecology and the environment (Schneider-Jacoby 1992; Harrison and Harrison Mayer 1996).

4. The Proposed CSB Preservation and Restoration Programme

The preservation of floodplains for protection against flooding

The first step in the sustainable development of the Central Sava Basin is the preservation of the existing floodplains for flood retention (Figure 3). This is the most important basis for preserving the traditional economic activities of the large inundation areas (e.g. pastoralism, forestry) and their valuable natural and cultural assets (see values). The EA proposes the preservation of 99 600 hectares of inundation area in the Central Sava Basin, with a storage capacity of about 2 billion m^3 (Table 1).

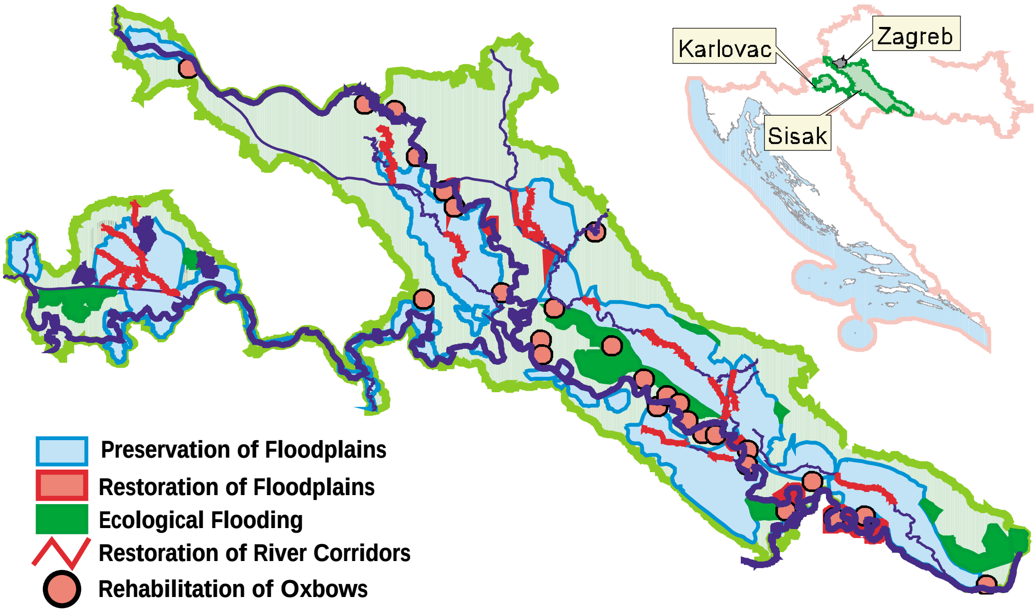

Figure 3. The proposed Central Sava Basin Preservation and Restoration Programme.

Table 1. Size (Hectares) and Storage capacities (Billion Cubic Metres/BCM) of the different sub-units of the Central Sava Basin before 1972 ('natural'), as planned by UN 1972 and proposed through the Central Sava Basin Preservation and Restoration Project.

Retention area	**Natural**		**Planned**		**CSB PRP**	
	Size of the Area (Hectares)	Storage Capacity (BCM)	Size of the Area (Hectares)	Storage Capacity (BCM)	Size of the Area (Hectares)	Storage Capacity (BCM)
Zutica + Lonjsko polje (*)	23 706	634	25 630	915	23 706	733
Tristika + Opeka Mokro Polje	22 294	611	20 510	581	22 294	611
Ribarsko Polje	16 956	175	7 400	132	16 956	175
Turopolje	15 630	316	0	0	15 630	316
Kupcina	22 242	203	5 050	150	13 599	150
Jantak	290	27	290	27	290	27
Kupa	5 899	50	0	0	5 000	50
Upper Sava	2 250	30	0	0	2 200	30
CSB Preservation and Restoration Project						
26 Flooded oxbows					**500**	**2**
8 Restoration areas					**1 200**	**20**
6 Ecologically flooded areas					**15 400**	**10**
Total	**109 267**	**2 046**	**58 880**	**1 805**	**116 775**	**2 124**

The territory has an international importance, safeguarding drained areas from flooding in Croatia, Bosnia and Herzegovina and Yugoslavia; it is also an important element in the Danube Pollution Control Programme, as a nutrient sink.

The reservation of land for restoration

In some places the polders, which were built during the first phase of the flood control programme (1972 – 1990), could be restored. In these territories, state-owned lands should be reserved for restoration and private land taken over in exchange for areas outside the floodplain during the de-nationalisation process. These restoration measures would increase the size of the floodplain and widen the Sava river corridor wherever possible. Only sites without settlements have been suggested. The area proposed for restoration extends to 1200 hectares, with a storage capacity of 20 million m^3. The projects considered also have excellent potential for the creation of new habitats, recreation sites and nature watching facilities, thus contributing to the development of the region.

Former floodplains proposed for 'Ecological Flooding'

Large and important alluvial wetlands were protected from flooding during the first phase of the project and some areas have been meliorated (e.g. Crnec polje, large areas downstream of the study area). On the other hand some alluvial landscapes retained their character even though they were excluded from the floodplain. Along the southern levee (dike) of Lonjsko Polje, the land outside the retention basin remains a typical alluvial landscape, flooded partially by surface water during high floods and also by standing rainwater, thus preventing the conversion of the grassland into arable land. Thus the important white stork habitats here have been preserved (e.g. Schneider 1988). Also large areas outside the Mokro Polje inundation zone are still flooded, maintaining important habitats such as pastures and lowland forest.

To maintain the alluvial landscapes, 'ecological flooding' is proposed (compare MUV 1997). This means that the areas cannot be restored now by re-inclusion into the flood prone area, but their water levels would be maintained; if necessary, water could even be introduced during floods. Through such measures, the character and value of the riverine landscape could be maintained and their ecological importance, which is of an international standard, preserved. The proposed areas extend to some 15 400 hectares and their storage capacity is about 10 million m^3.

27 oxbow lakes and floodplain areas, which were cut off from the 'live' river channel, need to be preserved in addition. The water levels should be managed in accordance with annual flood cycles, to maintain not only the important ecological conditions, but also important socio-cultural functions, such as recreation and semi-natural landscape features. An early example of such rehabilitation works is the management of the Spoonbill Colony at Krapje Dol (Dezelic and Schneider-Jacoby 1999). The ECONET Action Fund and the Zoological Society of Frankfurt did contribute to the rehabilitation project.

Excavation of material: New wetland sites

During the first phase of the Middle Sava Flood Control Project, good opportunities for creating new habitats were missed (compare Nienhuis *et al*. 1998). Nevertheless, in some areas such as along the southern dike of Lonjsko Polje, the excavation sites evolved into very valuable habitats, with very rare, even highly endangered, assemblages of flora and fauna, typical of oxbow lakes (e.g. Schneider-Jacoby 1990). Today these sites have a major role in the recreational aspect of the Nature Park concept, because many people use them for angling; in the park management scheme they feature as a visitor area (for nature observation and recreation).

In future, wherever excavations are intended to take place, ecological land use plans must be drawn up.

Because the exact locations of potential extraction of soil, sand and gravel are not known, only a draft plan can be made and general recommendations given. Detailed studies are needed in every case: where the material will be taken from and how the site will fit into the Integrated CSB Preservation and Restoration Programme. In the future, artificially created oxbow lake habitats will increasingly have to fulfil the functions of the natural oxbows of the Sava: even the rehabilitation measures cannot restore the alluvial cycles of the old lakes. Thus excavation sites will become an integral part of the floodplain morphology and become incorporated into the life cycles of the adopted fauna and flora.

Connectivity: Restoration of river corridors

A very important component of the CSB Preservation and Restoration Programme is the improved connectivity of water bodies. The restoration of river corridors is necessary for many reasons:

1. Some river stretches were straightened during the first attempts to drain the Sava Wetlands (i.e. the regulation of the Lonja, Sunja and Strug inside the floodplain);
2. The building of the Lonjsko Polje retention basin destroyed the parallel flows of the Lonja and the Strug though the floodplain;
3. Few roads cross the floodplain, thus there is little interruption of the wide flow of the water ‘front’. Openings for water access must be wide, to prevent the build-up of fast currents and high water levels upstream;
4. The construction of forest roads, channels and drainage inside the forest has changed the water regime inside the alluvial zone;
5. In some areas such as the Pokupsko depression, new roads (e.g. the highway) create a barrier between the hinterland and the floodplain;
6. The new channels and the canalised rivers now enter the floodplains at different sites. Measures are needed to mitigate negative effects.

Economic analysis and viability

The alternative development proposal will save considerable costs, by reducing the amount of water engineering construction: both the length of dikes and the number of distribution facilities will be lessened. Accordingly maintenance costs will also be reduced. Additional costs will be incurred for designing the new facilities, for modelling the flood waves and for carrying out the risk assessment on the new system.

Incremental costs are needed for important improvements to the system, which will secure the long-term sustainable use of the floodplains. In addition to the existing planning (the basic costs), restoration and rehabilitation projects are needed to achieve an integrated water management programme for the CSB. Value added by the preservation and restoration programme results from the improvement of the nutrient sink capacity, protection of the valuable cultural and natural heritage, and the long-term conservation of large inundation areas for transboundary flood protection.

In Table 1 the size of the inundation areas and the storage capacities of the different phases of the Sava Flood Control Project are compared. The planned maximum retention volume of 915 million m^3 for the Lonjsko Polje retention basin, is not used for the calculation of the alternative proposal (CSB PRP) because it should be only taken into account as a guarantee of the safety of the flood control system. The flood control problems should be solved without filling the retention basin above the natural water level. The impact on the alluvial forest can not been foreseen.

5. The Integrated Central Sava Development Programme

An integrated approach to the management of the Central Sava Basin is essential: this will combine the different use values to optimum effect and improve the development of the area. The first example of such an integrated management method is the Lonjsko Polje Nature Park. Although founded only recently and with its capacity limited by lack of staff, only 2 scientists, 4 wardens and one secretary, the park already co-ordinates and stimulates regional development and manages a large part of the still existing flood plain (Lonjsko Polje, Mokro Polje). The Dutch PIN MATRA Programme and EURONATUR supported the establishment of the protected area (Nature Park Lonjsko Polje 1999).

In Croatia the category of ‘Nature Park’ offers excellent opportunities for protecting cultural landscapes and promoting sustainable use, because it is as high ranked as a ‘National Park’. Nature Parks such as Lonjsko Polje contain only small areas which are strictly protected, but large areas in the ‘protected landscape’ category, where a controlled use of resources is permitted. For example, traditional agricultural practices and sustainable harvesting of timber is allowed. For such large areas as the Central Sava Basin, comprising over 100 000 hectares of highly valuable international habitats, the UNESCO Biosphere Reserve concept offers additional management strategies, such as involving local towns and stakeholders, based around the protected areas in the ‘Transition Zone’, in the process of organising and developing the region. In such a concept the park managers take part, as well as the national and regional administrations and those enterprises which use the area.

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REHABILITATION OF THE 'NOTCH'-SYSTEM AS TOOL FOR MULTIPURPOSE FLOODPLAIN MANAGEMENT ON THE UPPER-TISZA RIVER

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Abstract

The river Tisza is the axis of the Hungarian Great Plains both from economic and water management point of view. Before its regulation it flowed through the deeper parts of the Great Plains freely, causing damage to the arable-based agriculture. On the other hand, hunting and fishing brought significant economic benefits. The public appeal for river regulation grew in order to increase the productivity in the region. However, the realised measures created a new situation that is much debated when evaluated nowadays.

The dams built for the regulation of the river Tisza cut off the floodplains and runoff areas from the riverbed, thus minimising the flood-risk beyond the dams, but at the same time causing severe losses to natural values and biodiversity. A detailed study has been carried out on the opportunities for the reconstruction of 'notch'-systems, which formerly were the keys for the multipurpose management of floodplains and runoff areas.

The key element of the 'notch' system is the in/outlet that secured the connection between the river and the runoff area. Temporarily closing and opening the 'notch' enabled a harmonising water management and agriculture practice (especially important for spawning grounds for fish), with other favourable side effects.

One preliminary study revealed a location (Tímár) where a natural dune prevents the filling of the ancient 'notch' system. By creating an opening in this dune, the whole system can be revitalised, enabling the examination and evaluation of the former system. Besides offering excellent spawning ground for fish, the meadows and pastures and the existing orchards could also profit from it. The management of the water (retention) and fish stock can easily be done by using planks, traps to temporary close the 'notches'.

The implementation of the rehabilitation measures and the multipurpose floodplain management development is of especial importance after the cyanide and heavy metal pollution of the Tisza River. In the pilot project the necessary restoration tasks and land use propositions are described in detailed, creating ideal opportunities for multipurpose floodplain management.

1. Introduction: Principle and Operation of the 'Notch' and 'Notch' System

Different definitions of the 'notch' system are being used. In the literature of water management it is mentioned that the 'notch' systems are natural formations. Let us look at some descriptions of the 'notch' system in the literature. Lászlóffy (1982) describes it as follows:

'Where in case of high floods the water broke out of the river bed it deepened a 'notch', through which water could regularly flood the delves of the lower territories… and in many cases created permanent marshes.'

According to this description the river deepened the 'notches' and the water created permanent marshes, i.e. the water could not flow back to the river after the water level in the river had dropped. Nemes (1975) describes in detail the relation between 'notches' and agricultural activities and considers the 'notches' being natural formations:
'In this part of the Tisza river the remains of the 'notches' – according to their former functions and as the result of the river regulation – can only be seen at the outlet of some drainage channels or pumping stations. Thus the original geographic term for the 'notches' is hardly known today: these were the so called rives (openings) in the ridges (dunes) parallel with the rivers through which the rising water could flow from the river to the runoff area (floodplain), filling up the lakes, pits and other lower areas and also empty them in this pattern when the water receded. The shape and size of these rives varied but their threshold were some meters above the mean water level of the given Tisza river section.'

The 'notch' has not only a geographical meaning, but has also an economic and historical meaning. Man, recognising its natural function, intended to make use of it and modified it depending on the needs. So one can conclude that 'notch' management became the basis of the medieval floodplain management.

The water flew through the inlets at the downstream end of the ridges to the floodplains (Andrásfalvi 1975). Thus, the 'notch' is a rive, an opening, a structure through which the water flows to the wider and lower parts of the runoff area. Only those in/outlets through which the runoff areas were filled

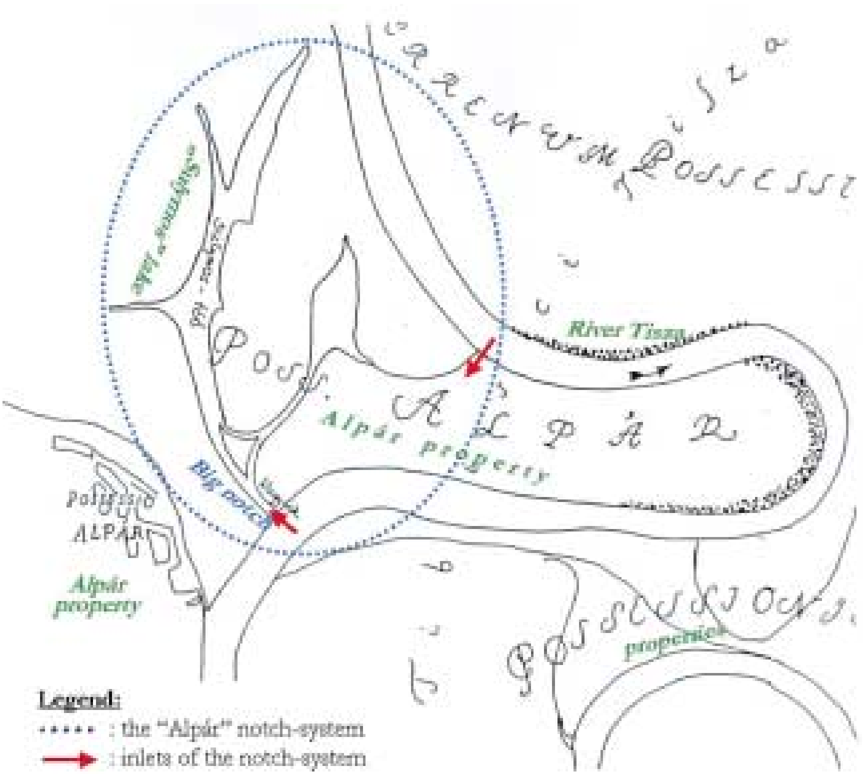

Figure 1. An oxbow by Alpar with a characteristic notch.

with water, at temporary high water levels of the river, for fishing and other uses, can be characterised as 'notches'. The water flowed back to the river at falling water levels in the river, enabling other uses of the same area (e.g. meadows, haying, etc.)

According to the above, 'notches' are those 'channels', made for the use of floodplains, in which the water flows in two directions, towards and backwards the runoff area at rising and falling water level of the river, respectively. The main feature of the water-system is that all still and running water bodies in a given floodplain are connected (one unit). The most important characteristic of this system is the 'filling up from downstream end' (ALRD 1997).
An original map of a characteristic notch system is shown in Figure 1.

The favourable effects of the 'notch'-system were:
- Mitigation of the extent and pace of physical changes in floodplains;
- The 'filling up from the downstream end' made it possible that the water flowed back to the river and made the flood prevention more effective;
- Acting as a buffer zone for the water regime of the river, i.e. lowering the height of the floods (filling up of the floodplain) and delaying a further drop of the water level in the river by the receding water;
- Due to the 'notch'-system the total water balance of the floodplains increased;
- The danger of high floods lessened;
- Less extreme weather conditions inherent to the continental climate;
- The opportunities for agricultural activities on the floodplains (especially fishing) increased.

In the Middle Ages the basis of the agriculture in the Great Plains – since almost two-third of the territory was floodplain – was the 'notch'-system, instead of arable land. At that time, there were two main characteristics of the Great Plains (unfortunately almost extinct by now): forests and water streams. At rising water level in the river, the streams were supplied with water, and at falling water level the streams drained the afforested areas. Spontaneous human intervention started the disintegration of the 'notch'-system. The first step in this process was the creation of dikes to increase the water level necessary for the operation of water mills (local, unnatural water retention). The complete change in the forest areas of the lowlands (decrease forest area) caused the decrease of the water supply at recession, resulting in the complete extinction of the 'notch'-systems.

2. Opportunities for the Rehabilitation of the 'Notch' System

The main reason for the rehabilitation studies was that the rehabilitation of such systems would make it possible to revitalise a (medieval) agricultural pattern that harmonise with nature. The medieval agricultural pattern, besides the different economic benefits, took full account of the natural water regime of the rivers. One great benefit was that fishing and natural spawning and nursery grounds in the floodplains provided income for the population and ensured offspring for the river. This was a typical multipurpose agriculture, where the conditions for safe, permanent activities were created by using the minimum natural resources and at the same time producing the maximum range of products. In this way the people could on one hand completely cover their needs, and on the other hand – due to the diversity of the products – they were hardly dependent on the market. If the highest possible number and amount of output is produced with a unit input, the producers price for one unit will be the lowest possible, and there will most likely be one or more product that can be sold on the market for high price. This way the production can be profitable despite some products can not be sold or sold with deficit. In some cases the production of several products requires (partly) the similar process: fish propagation, growing of forests and orchards, creating favourable conditions for crop and livestock. When one or more products is overproduced, the harvesting was cancelled. This, in the specialised agriculture of today would surely cause bankruptcy but it did not cause even the slightest economic disadvantage, being the production cost almost equal to the cost of harvesting that time. The essence of the production that all the benefits described above relied on the ‘notch’-system, so the agricultural production regarding both structure and methodology were integrated with the management of the system.

After the recent catastrophic Szamos-Tisza pollution, it is obvious that the rehabilitation of the ‘notch’-systems is very important. These areas were not affected by the cyanide pollution, and 6-8 functioning ‘notch’-systems would be extremely effective in the fast recruitment of the fish fauna of the river.

Medieval and modern maps, and satellite images were used to locate the areas with traces and remains of the ancient ‘notch’-systems. These areas were visited. Some areas were neglected because of the significant human interference (channels, structures, etc.), or the size being too large to handle.

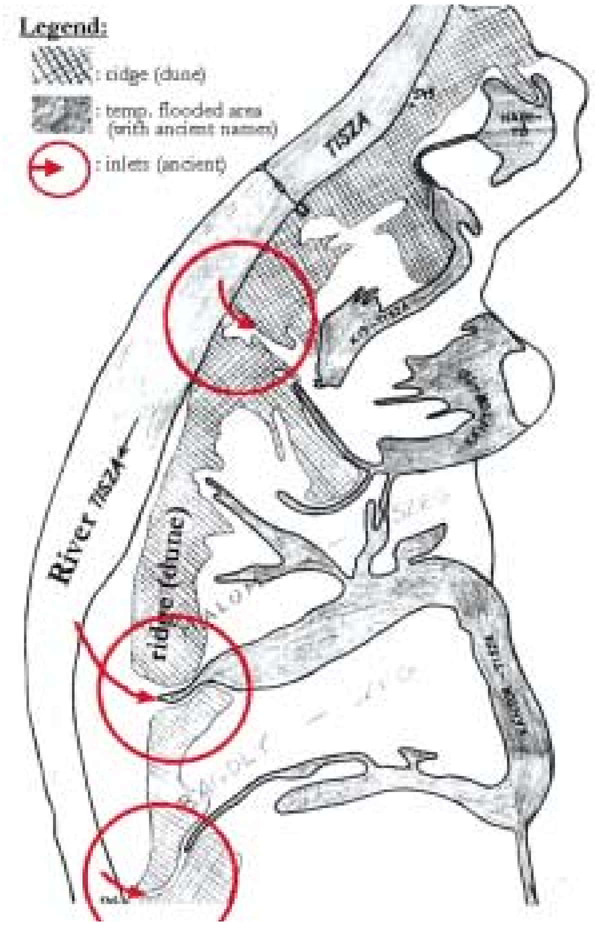

Figure 2. The Timar ‘notch’-system.

Those areas where the opportunity for rehabilitation is fair, and which can easily be managed as one unit have the highest priority.
The approximately 240 hectares large area of Timar 'notch'-system, situated between the river stations 546-549.4 is one of those areas. 48% of the area (approximately 115 hectares) is the property of the village. The ridge around the in/outlet (the elevation is more than 97 meters above Baltic Mean Sea Level) makes the area suitable for a pilot project. A connected water-system can also be realised in the 115 hectare area belonging to the village. In the latter case we can formulate the terms of reference for the adjustments necessary for the creation of a 'notch'-system, and it can act as model area for the multipurpose floodplain management. Figure 2 shows the flooded areas that were connected to each other and to the Tisza river by several 'notches'. The location of the former rives (in/outlets) can also be seen.

The water inlet can be created if the threshold of the 'notch' at the river is 0.3 meters lower than the area to be filled, creating a multipurpose management pattern similarly to the ancient heydays. The presence of the water will have positive effect on the meadows and pastures, as well as on the forests and orchards still present in the area. Fishing will mean the retention of the water until spawning, and the selective capture of adult fish (after spawning). The juveniles will all return to the river due to the larger mesh size of closing structures.

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LITHUANIAN RIVERS: ON THE WAY FROM DEGRADATION TO RESTORATION

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Abstract

Average density of the river network in Lithuania is 0.99 km of river length per km². The total length of 29 000 rivers, streams and rivulets is 64 000 km. 97% of all rivers are not longer than 10 km, and nine rivers are longer than 200 km. There are 30 transboundary rivers with a mean annual flow over 5 m^3 s^{-1}: on the borders with Latvia 11, Russia 5, Belarus 10 and Poland 1.

Surface waters are used to meet the needs of industry, power plants, agriculture, fisheries, shipping and tourism. Rivers play an essential role in fisheries, biodiversity conservation and Baltic Sea pollution control.

Because of land reclamation over 75% of the country's rivers were canalised, causing degradation of their biodiversity. Water pollution caused by agriculture, industry and sewage has a strong negative impact on the rivers. The main problem concerning water quality is the lack of wastewater treatment plants. An extensive part of the pollution of the major rivers, affluent into the Baltic Sea, is coming from Russia and Belarus.

Therefore the basic task to handle is the restoration of transboundary rivers through joint projects (joint policies, plans and implementation). Dams for generation of hydropower without fish-ladders are the main threats for recently recovering of valuable migrating salmon fish species in Lithuania and their stocks in the Baltic Sea. State environmental protection strategies are aimed at restoration of rivers. However, in reality strategic issues, goals and actions are not implemented. Therefore raising of public awareness in the region is essential to get results.

1. National Features of River Network

The average density of the Lithuanian river network is 0.99 km per km^2. The total length of 29 000 rivers, streams and rivulets is 64 000 km. 97% of all rivers are shorter than 10 km, and 9 rivers are longer than 200 km. There are 155 rivers in Lithuania with average annual discharges of 1 m^3/s and 14 rivers with an average annual discharge of 10 m^3/s. The Nemunas is the longest Lithuanian river (937 km). The source of the river is in Belarus. Lithuania's territory accounts for 47.5% of its basin. The Nemunas is also a tributary of the largest Lithuanian inland water body, the Curonian Lagoon. There are 30 transboundary rivers in Lithuania with average annual discharges of 5 m^3/s. They cross the borders with Latvia (12 rivers), Russia (6), Belarus (9) and Poland (1). Surface waters are used to meet the needs of industry, energy, agriculture, fishery, shipping and tourism. The average discharge from the country's territory amounts to 15.3 billion m^3. Lithuanian rivers play an important role in fishery, biodiversity conservation and the Baltic Sea pollution control. Figure 1 show the rivers in Lithuania.

In 1993, 5 wetlands were designated as national Ramsar sites. One of them is the Nemunas River Delta Regional Park. In addition, there are 10 ichthyological and 36 hydrographical nature reserves in Lithuania. Some rivers are included in the territories of strict nature reserves, landscape reserves, regional parks, etc. There are a lot of laws related to water and wetland protection in Lithuania (Zalakevicius 1998):

Figure 1. Rivers in Lithuania.

- Law on Water;
- Ramsar Convention (ratified by Lithuania);
- Law on Environmental Protection;
- Special Conditions for Land and Forest Use;
- Decree of the Government of the Republic of Lithuania 'On Establishment of New Reserves and Approval of the Lists of Reserves';
- Law on Land of the Republic of Lithuania;
- Law on Land Reclamation;
- Law on Wildlife;
- Law on Environmental Impact Assessment of the Republic of Lithuania;
- Law on Protected Areas of the Republic of Lithuania;
- National Strategies of Environmental Protection;
- Biological Diversity Conservation and Implementation of the UN Framework Convention on Climate Change.

Several state environmental protection strategies and action programmes are aimed at the restoration of rivers. However, these strategic issues, goals and actions have not been implemented in reality due to the lack of finances caused by the financial and economical crisis in Lithuania.

2. Past, Present and Future Problems

The main human-induced threats to Lithuanian rivers are water pollution, regulatory and control gaps in the governmental policy framework, anthropogenic impact, water regulation, reclamation of water

Threats	Main Causes
Water pollution	• Ageing of waste water treatment facilities; • Increasing water pollution by domestic and municipal waste water and agricultural runoff; • Lack of capacity (staff, financial resources, knowledge and tools, out-dated soviet equipment and technologies).
Regulatory and control gaps in the governmental policy framework	• Frequent changes in environmental policy and strategy due to frequent changes in governing (instability); • Lack of basic information on river restoration and conservation; • Lack of public awareness.
Anthropogenic impact	• Conflicts between local inhabitants and existing legislative system in resource usage; • Insufficient involvement of local community; • Lack of knowledge and public awareness.
Water regulation mistakes	• Regulation of water level of rivers and streams; • Lack of knowledge and special experience, public awareness.
Reclamation of land and water bodies	• Drainage of river basins and the surrounding territories; • Canalisation of streams and rivers; • Lack of knowledge of zoning of productive use activities in buffer zones; • Lack of public awareness.
Loss of valuable migratory fish	• Man-made barriers (dams) on natural migration paths of fish, absence of fish ladders.
Loss of biodiversity	• Degradation of river valleys due to anthropogenic activities; • Lack of information, knowledge and public awareness.

bodies (drainage of river basins, buffer zones and their surroundings), loss of valuable migratory fish and impoverishment of the biodiversity. The main causes of these threats are as follows:

Reclamation of land and water bodies is one of the most serious damages to Lithuanian rivers, river valleys and their biodiversity. During the process of land reclamation, over 75% of Lithuanian rivers were canalised, which caused the degradation of river valleys, biodiversity, and landscape. In addition, we have insufficient experience in river restoration. So far, no such projects have been accomplished in Lithuania.

Another great damage to the Lithuanian rivers is caused by water pollution. Water pollution from agriculture, industry and sewage has a considerable negative impact on rivers. Lithuanian surface waters (70% of the rivers) are mostly contaminated by organic substances. According to calculations, surface water receives 40% of the total amount of pollutants discharged from non-point pollution sources. Riparian zones – river valleys – contain the most valuable habitats for the biodiversity. However, many rivers and lakes do not have special protection zones or they have not been fully established. The main cause of the pollution is aged waste water treatment plants. A large portion of the pollution in the major Lithuanian rivers (Nemunas, Neris) discharging into the Baltic Sea, comes from Russia and Belarus. Surface water quality in Lithuania is measured by the Hydrometeorological Service having their observation points in 88 special stations, 47 rivers, 9 lakes, 2 water bodies (totalling 122 control sites). The natural situation is observed in 6 streams, where the economic effect is the least. A recent decrease in industrial and agricultural activities influenced the cleaning process of Lithuanian rivers. Therefore, the construction and completion of municipal waste water treatment facilities have remained top priority for the Lithuanian environmental protection in recent years. Considerable allocations from the State Budget for the construction of treatment facilities were foreseen in the Public Investment Programme (PIP) for the years 1995-1999, together with loans and grants from Nordic countries and international donors (WB, EBRD, etc.).

Dams without fish ladders are the next, very important, threat to the recovering of valuable migratory salmons and other fish species in Lithuania and their stocks in the Baltic Sea. Every year, new private hydropower stations are being constructed on rivers and streams, rich in biodiversity. At present, 45 hydropower stations are being reconstructed and 15 stations are being operated.

Specialists in energy and businessmen in Lithuania have developed a special strategy to construct up to 350 hydropower stations on the Lithuanian inland rivers. This strategic plan meets the requirements of EU to find alternatives to nuclear energy by building small municipal power stations working on local fuel resources or constructing wind-power or hydro-power stations. New hydropower stations (as a rule without fish ladders) are constructed on private lands (former collective property). They obviously cause a big danger for valuable migratory salmonid resources.

Here we must stress that the Ignalina Nuclear Power Station produces 77% of electricity; thermal power plants produce 18%; and hydropower plants produce only 2.3%. Kruonis hydroaccumulative power station produces 2.7% of electricity.

Thus constant surplus of electricity is perceptible in Lithuania as well as in Europe. It means that new hydropower stations are unnecessary.

The Institute of Ecology has investigated the current situation and made a list of 145 particularly valuable rivers, on which the construction of hydropower stations should be forbidden. Half of these rivers (70) are not suitable for the construction of hydropower stations at all. On 21 December 1999, the Ministry of Environment issued a decree on the basis of a series of legal laws by which only separate segments of rivers were included in the list of protected areas. The segments of rivers outside the territories of nature reserves, in spite of their value for the biodiversity, remained unprotected. Meanwhile, it is widely accepted that restoration of streams must be based on a holistic approach, which considers the whole catchment area. This approach has been adopted following many research programmes dealing with the ecology of running waters, which revealed the importance of interactions along the watercourses in both longitudinal and lateral directions. The river continuum concept (Vannote *et al*., 1980), which introduced the idea that a continuous gradient of physical conditions exists from headwaters to the mouth of rivers and that structural and functional characteristics of biological communities conform to the dynamic physical conditions of a given river reach, is very important here. In addition, the usage of fish ladders is effective only for grown up salmons, while their young are unable to swim back through them. Great damage is also done for other fish species.

Apart from the human induced direct threats to the rivers, there are other indirect or natural threats. For example, due to the global climate change, evident changes occurred in the ecosystems of Lithuanian rivers and their biodiversity. They are especially obvious in terrestrial and wetland ecosystems. Unfortunately, a rather sceptical attitude towards this problem is prevailing in my country.

Society lacks special information, research and knowledge on this phenomenon. In my opinion, we need special investigations on that issue. It could be a pilot project. Besides, we have not enough information on the global climate change impact on river ecosystems, their wildlife and biodiversity. This part, in my opinion, is inseparable from river restoration and management problems.
Some sites of Lithuania, especially those at the lower reaches of the Nemunas, are regularly flooded after heavy rains in spring and in autumn. The floods cause a lot of trouble to local people, isolating them from the outer world.

3. Conclusions

To sum it up, we may state that the problems of rivers in Lithuania are the same as in most European countries and they can be solved by common efforts of these countries, which should include co-operation, information gap analysis, joint research and projects, raising of public awareness in the region, restoration of transboundary rivers through joint projects, joint strategies and policies, programmes, plans and their implementations.

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RE-NATURALISATION OF CANALISED BROOKS AND DITCHES IN LITHUANIA

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Abstract

The open drainage channels and brooks, canalised for land reclamation purposes, overgrow after some time with bushes and trees and/or with tall grasses. Thus their self-naturalisation begins. It presents a very cheap and therefore important way for naturalisation of ditches and reconstructed streams. In this way ecological corridors for animals and habitats for water life are created. However, these waterways must also serve their primary goal as collectors of sub-surface drainage water. When planning re-naturalisation, maintenance and/or repair of the open channels, it is necessary to take into account the existing or foreseen effects on the discharge.

The calculations of the discharge, based on the known Chézy-Manning formula, did not estimate the discharge of the re-naturalised waterways exactly enough. Therefore, a special calculation method and a mathematical model have been elaborated. The model enables us to estimate hydraulic resistance of tree stems and grasses and the occurring bed deformation. Thus, a tool was created to evaluate if it is either possible to save the existing vegetation or necessary to remove its redundant part. Maintenance of re-naturalised waterways is cheaper, and the discharge is often large enough to guarantee their drainage purposes.

1. Introduction

In Lithuania, like in many other countries, many brooks were canalised and drainage ditches were excavated to collect drainage water from the land reclamation systems. Thus, the natural brooks were transformed into ditches. Nowadays, however, it is promoted very much to restore the original, natural situation. In this way the availability of biogenic materials in the water would be reduced and the corridors for fauna migration would be developed. However, it is also necessary that the channels can collect and discharge the drainage water properly. Therefore, it was necessary to co-ordinate these sometimes conflicting requirements and to find the most economical maintenance methods and re-naturalisation means. In Lithuania, however, the financial means for naturalisation works are limited. Thus only self-naturalisation is possible. Therefore, only the most urgent corrections of natural processes and measures to ensure the required discharge capacity of channels, can be implemented. The discharge capacity can be maintained easily, as the ditches were excavated deep in Lithuania. Deep open ditches were necessary to collect the drainage water from the large agricultural field drainage systems. Thus these channels have now an over-capacity for discharging the water.

Re-naturalisation of channels in our country is understood as growth of trees, bushes and grasses on the slopes or close to it, the natural changing of channel cross-section and longitudinal slope, as well as the bed meandering. Investigation of this process showed that it was useful not only for the environment, but also for the maintenance of these discharge channels. Young trees, starting to grow on the channel slopes, suppress the channel bed vegetation - thus, they decrease the channel siltation process. Siltation might even not occur at all, when the water velocity in the stream becomes strong enough to keep the stream bed clean and bright. When the brook slope is steep (>1.0‰), the roots of the trees growing on the slope foots prevent the slopes from being washed away. Thus, a natural dynamic balance between the stream washing capacity and bed resistance develops. In natural brooks this balance existed before canalising them, but it was destroyed. Now it is necessary to restore the balance.

About 80% of agricultural area in Lithuania is drained. The total area with sub-surface drainage systems is now 2.6 million hectares, covering 63% of all agricultural area. There are 63 000 km of canalised brooks and ditches, collecting water from the sub-surface drainage systems. The maintenance of these open collector drains was very costly. Economic calculations showed that the maintenance of re-naturalised channels becomes much more simple and cheaper than that existing practice of maintenance, i.e. mowing the channel slopes, de-silting the channel bed, and not allowing trees to grow on the slopes and embankments.

The natural processes occurring in the canalised brooks and ditches are complicated and depend on many factors. The natural process was investigated and the data collected enable us to better understand these processes.

2. Vegetation Growth

The development of the vegetation, growing intensity, in relation to time was investigated. This was necessary for planning the maintenance of the channels. The initial natural overgrowth of channels by young trees occurs slowly and it takes quite some time. In the first phase of this process, i.e. when the slopes are not covered by trees over its entire length, the density, height, and the stem thickness of the trees increase all the time. At the end of this phase the discharge capacity of brooks with a flat slope can become insufficient. Trees or bushes must be thinned, or part of them at the bottom of the side-slopes must be removed.
In the second phase, when the slopes have already been overgrown along its entire length, or in the cases when the cut down trees sprout again, their density decreases rapidly during the first 4 years. Thereafter, the remaining tree tops can get sufficient light, and the further natural thinning goes on slowly.

The investigation on the re-growth processes, after thinning (when the density of the trees was rather high), showed that in shadow of the remaining trees the offshoots were weak. At the bottom of the side-slopes the offshoots disappeared in the second year. In the upper part of the side-slopes the offshoots were growing slowly. Such re-growth of the offshoots is favourable for channel maintenance. The offshoots in the lower part of the side-slope do not develop, and the ones in the upper part cover the spaces between the high tree stems and make a shadow on the channel bottom.

Sometimes the trees were cut down when the channel bottom was being cleaned. In this case the trees would grow again rapidly because of their strong root system and the abundance of light. Therefore, the shoots of the entire cut down trees would grow 3-5 times quicker than the shoots of the thinned out ones. The shoots growing did not decrease even when the cutting process was repeated every year in the course of 4 years.

The channels near the forests are more overgrown with trees. However, the trees and bushes, with an average density of more than 1 per m^2, occur also in 50 % of ditches length, located in fields. Therefore, it is possible to expand the self re-naturalisation of field ditches as well. The circumstances are very favourable when the bed slope is flat and the flow velocity is less than 0.2-0.3 m/s. Under these conditions the channel bottom overgrows with water grasses, which initiate siltation.

The outlets of sub-surface drainage may be clogged by roots of bushes. Therefore, the bushes must be removed near the outlets of the sub-surface drainage system, or the outlet section of the drainage pipe should be unperforated, so that roots can not enter the drain pipe. When the water level in the channels is near the outlets (<5-10 cm), the growing of roots into the pipes is less. Therefore, it is not necessary to clean the channel, when the outlets are still not submerged too much.

When the tree growth on the channel slopes continues for 10 years, the amount of timber can reach 200 m^3/ hectares. Thus, the ditches can serve for timber growth as well.

3. Hydraulic Calculation on Re-naturalised Channels

The conditions for water flow in the re-naturalised channels are more complicated than in channels with a non-vegetated trapezoidal cross-section. The Chézy-Manning formula is usually applied for hydraulic calculation of channels. For hydraulic calculations on re-naturalised (vegetated) channels it is necessary to estimate the influence of tree stems, of under sized bushes and grasses and channel cross-section deformations (i.e. for estimating the discharge of re-naturalised channels).

It was necessary to develop the hydraulic calculation formulas that would enable us to estimate the factors mentioned. Laboratory investigations were conducted to estimate the influence of tree stems. Well known hydrodynamics laws of minor losses and of shear stress forming were applied.

A special calculation method and mathematical model have been elaborated. This model can be used in case:

- Trees grow along the entire slopes;
- One row of trees along the length of the slopes or;
- Trees grow in a scattered pattern on the slopes of the channels.

Formulas to calculate the hydraulic resistance of the tree stems are based on known methods to calculate the flow round the cylindrical stalks. The slopes overgrown by trees decrease the stream velocities. It causes the flow velocities' gradients, the shear stresses, and additional energy is lost at the contact with the adjacent free streams. The hydraulic resistance coefficients at the contacts were estimated according to the data of laboratory investigations.

The discharges of brooks also decrease in case the channel slopes are overgrown by a thick vegetation of grasses. Then, the roughness of the cross-sectional area of flow increases. To estimate the grass influence, the equivalent non-conductive thickness of a grass layer was calculated and the bed level was raised to this thickness. Formulas for these calculations were elaborated by applying the laboratory research data of the Polish scientists. The equivalent thickness of hard-stem non-bent-grass was taken 0.6 of this vegetation height. The influence of grasses was estimated only for the calculations of summer floods. During the spring floods the grasses are already dry and bent by the snow.

The discharge of brooks overgrown with high hard-stem grasses during the summer floods is simply sufficient when their bed slope is greater than 0.3 ‰ and the watershed area is less than 9 km^2. Such ditches do not need to be mowed. When bed slope of ditches is greater than 0.5 ‰ and the watershed area does not exceed 6 km^2, the sub-surface drainage outlets are not submerged during the growing period of the grasses. Therefore, it is not useful to mow such ditches. Moreover, the high and hard grasses growing on the slopes, as well as the trees, suppress the water vegetation and decrease the sedimentation at the bottom of the channels.

The discharges of brooks with large watersheds of 10-30 km^2 where the bed slope is more than 1-2 ‰, are sufficient, even when the brooks are overgrown with trees and bushes of high density. The bottom of such brooks is covered with gravel and the slope foots are strengthened by tree roots. However, the discharge of brooks with a flat bed slope (<0.3 ‰) and large watershed area can be too low. In these cases, it is possible to let grow only one row of trees on the channel slopes. The shadows of these trees cover the bottom of the brooks.

4. Silt Sedimentation

Silt deposits in the channel beds were measured to estimate the flow velocity that prevents sedimentation. The amount of sedimentation depends on the channel bed slope, watershed area, existence of trees and grass vegetation and the way the maintenance equipment is used.

When the watershed area of channel is small (<3 km^2), the water flow can not transport the sediments and they accumulate. If there are no trees on the slopes, deposits increase varying from 1.2-3.5 cm/year in the loamy and sandy soils. These deposits must be removed regularly. The deposits come from the fields during the flood season when there are heavy rains or by wind. Sediments get into the channels also because of slope erosion due to rain and frost. The rotten vegetation accumulates also. When the thickness of deposits reaches 0.2-0.3 m, the deposits are usually excavated. The state of ditches after being cleaned, i.e. re-silting and decrease of channel depth again depends upon the quality of the excavation work. It is very important that the excavator does not tear the sward from the slope foot together with the sediments; in case it does, the deformation of the channel slopes would be accelerated.

In cases where the bushes or trees were pulled out during the channel cleaning, the stability of channel slopes was destroyed. Their lower part of the side-slopes was washed away, the slopes slipped down. Quickly the channel became too shallow. In such case the slopes must be strengthened by sward or in an other way. This is costly. Therefore, cleaning of the channels in this way can not be economically justified. The trees must be saved. Such channels must be re-naturalised. The maintenance means should be used in such a way that the naturalisation process is not disturbed.

The amount of deposits is 6-20 times less, when the channels are overgrown with trees. That is not only because the trees suppress the water vegetation, they also protect the slopes against the rain erosion and deposits of sand brought by strong wind. In the channels overgrown by trees, only a local deposit of sediments can happen; for example, when the water inlet shutters are not in order, or the sand enters from the drainage outlets. These deposits must be removed annually at the end of the spring season, otherwise, the deposits can be outgrown by tree roots and become difficult removable. The trees prevent mechanical desiltation, but the little amount of deposits in naturalised channels can be removed manually by channel maintenance personnel.

There is approximately a balance between deposit accumulation and their washing out when the channel bed slope is more than 1-2 ‰. In this case the flow velocity is strong enough to wash out the occurring local obstacles, for example, the slips of the slopes. When the bed slope is sufficient, such dynamic balance can also be reached in the channels without trees. In such channels the collector outlets can be covered by local deposits and be overgrown with grass. In these cases it is sufficient to clean only the outlet spots. The balance in the channel must be not destroyed.

During the floods, the suspended sediments settle on the inundated channel slopes. Therefore, the slopes become more flat. Then the banks of central bed become higher. This process has not been investigated sufficiently yet.

5. Beaver Activity in the Drainage Channels

The beavers create a problem for the maintenance of the collector drains of land reclamation systems, since they submerge the infrastructure. However, their influence on the environment is positive. 70% of all beaver dams in Lithuania are located in the ditches near the forests and in the forests. Most of the beaver dams are constructed in small ditches with small water discharges. The number of beavers in Lithuania is increasing. Consequently, their activities in the ditches near the forests is also expanding. Around the beaver dams the original flora and fauna are observed. The increasing amount of micro-organisms, zooplankton and amphibia attract water and bog birds, the water-and-cave animals. Water, flowing through the ponds, leaves the part of biogenical materials. Thus, the agricultural non-point water pollution decreases. The beaver activity is important for the variety of environment. Most of the dams are constructed in streams of the watersheds, storing large amount of water. This amount reaches 11-14 million m^3 in Lithuania.

The caves made by beavers in the ditch slopes make them less resistant for erosion. The number of caves in 100 m length of side-slope reach several tens. The volume of soil getting into the ditches from the caves reaches 0.5 m^3 per 1.0 m length of side slope. The slopes of ditches become more steep and the ponds more shallow. Thus the naturalisation of ditches takes place intensively.

The beaver dams have a negative impact on the drainage systems when drainage outlets are located in the ponds created by the dams.

6. Snow Drift in Channels

The observations of snow drift in the channels were made in the winter of 1996. These observations confirmed the results of laboratory investigations of this process made earlier. It was estimated that the trees growing on the channels slopes decreased the snow drift, consequently they improved the discharge capacity of channels during the spring floods, when the snow in the channels has not been yet melted. The snow drift is absent when the trees stand in a certain pattern.

7. Conclusions

1. Re-naturalisation of canalised brooks and ditches and perfection of their functions as collector drains from land reclamation systems can be co-ordinated successfully.
2. Re-naturalisation of collector drains helps to restore the dynamic balance between the washing or silting capacity of the water stream and the stability of the channel. The frequency of maintenance activities decreases.

THE COMPARISON OF DIFFERENT DEGRADATION FORMS OF RIVERS: IMPLICATIONS FOR WATER QUALITY RESTORATION

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Abstract
A vast number of examples show that land development of catchment areas and river management based on a hydro-technical approach have been destructive for biodiversity and spatial complexity of freshwater ecosystems. The human impact on river systems has led to a reduction in water retention, self-purification and biodiversity, thus lowering the cultural and aesthetic values of the river valley landscape and threatening the sustainable use of freshwater resources. Because the causes of degradation factors are very diverse, river restoration practices should be based on a comparative analysis of the efficiency of various restoration techniques for different forms of degradation.
The papers deals with 3 different types of rivers: an urban stream, a lowland river, and a river converted into a sewage collector.
The discussed practices for river rehabilitation should be implemented by 'Adaptive Environmental Assessment and Management', which guarantees optimal results.

1. Introduction

The quality of running waters reflects an interaction between natural and cultural attributes of catchment basins (Stanford 1996).
The acceleration of water cycle through the landscape due to land use changes: (large scale deforestation, agriculture development, urbanisation) and water resources use for irrigation have been intensified dramatically in the last two centuries. In consequence, an enlarged quantity of sediments, nutrients and pollutants has been transported to water bodies (Meybec and Helmer 1989; Boon *et al*. 1992).

One of the major reasons of the inefficiency of recent management measures (preventive and conservation) has been the fact that hydrotechnical approach declines spatial complexity and biodiversity of freshwater ecosystems (Petts 1984; Stanford *et al*. 1996; Zalewski *et al*. 1998). Such forms of human impact result in lowering the cultural and esthetical values of river valley landscape, as well as the sustainable use of freshwater resources (Zalewski and Frankiewicz 1998; Bis *et al*. 2000). However, all these forms of disturbance can, to a certain extent, be compensated by resistance and resilience of freshwater ecosystems (Zalewski *et al*. 1997).

An integrated multi-dimensional approach to river restoration practices is required. In this paper, therefore, we focus on the determination of the hierarchy of degradation factors and cumulative forms of human pressure at the river ecosystem. According to this fundamental component in the definition of river restoration, the strategy is:
1. The recognition of degradation symptoms;
2. Quantification of processes across different spatial and temporal scales;
3. Optimisation of the restoration technique.

2. Materials and Study Area

Three types of degraded rivers were analysed: (1) an urban stream, degraded by storm water pollution, (2) a lowland river, degraded by diffuse pollution from an agricultural catchment, (3) a river converted into a sewage collector (sewage from a city with 1 million inhabitants).

The sources of the three rivers are at the water divide between the Vistula River and the Oder River basin. The rivers are part of the Oder River basin. The hydrological regimes of the 3 rivers are different (Figure 1).

1. A river converted into a sewage collector.
   The Ner River collects the sewage and storm water from the City of Lodz and its suburbs. Recently, a new sewage treatment plant has been constructed. The river valley, however, has been degraded due to deposition of toxic pollutants over the last 100 years. Degradation is caused by the long-term disposal of, only mechanically treated, sewage in the Ner River and the irrigation of meadows in the valley with sewage (Biernacka 1992). The general concept of the construction of the sewage treatment plant assumed that storm water and untreated sewage from the old part of the city (lack of separated sewer system) are discharged, without treatment, via a bypass channel to the river valley.
2. A urban stream.
   The Sokolowka River flows through the northern part of Lodz City and is provided with about 50 storm sewer outlets. The main channel was canalised by concrete cement slabs, to straighten the

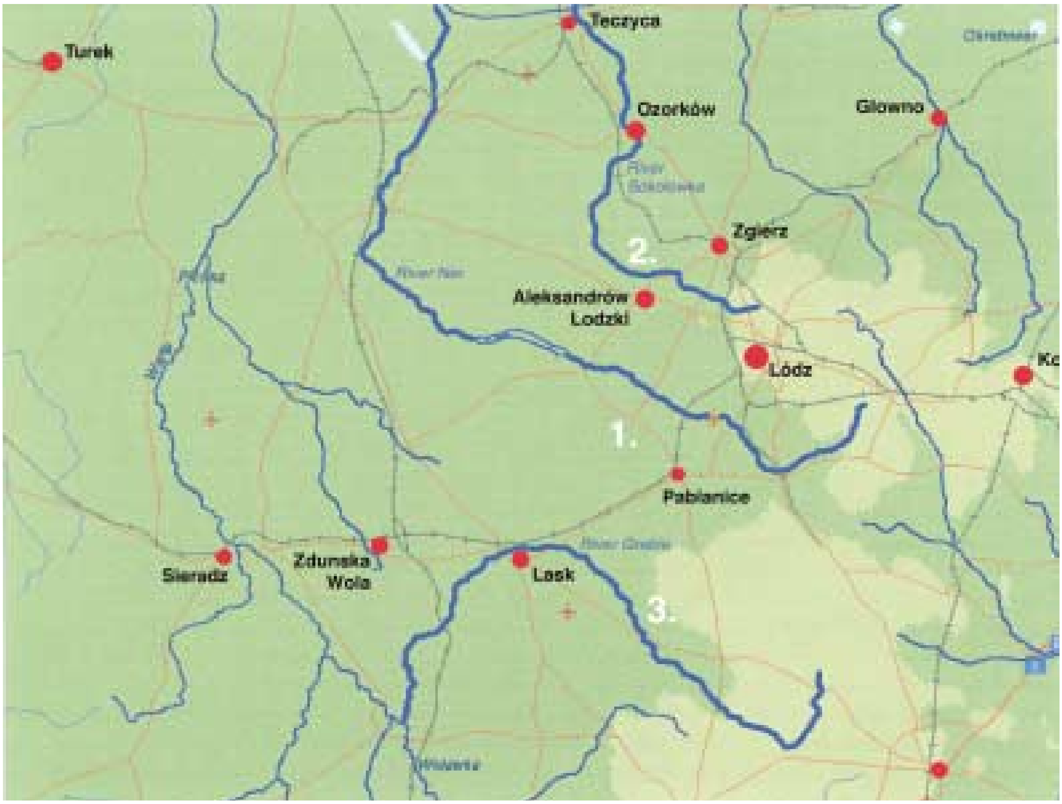

Figure 1. The Rivers Ner, Sokolokwa and Grabia.

course and deepen the bed with the purpose of collecting, containing, and discharging storm water. The middle section of the river valley has maintained semi-natural characteristics, i.e. patches of meadows, wetlands and forests.

2. A lowland river.
   The Grabia River (a semi-natural lowland river is a tributary of the Warta River basin). In the past, some sections of the river and its tributary were regulated for drainage of floodplain meadows. Artificial weirs were build on the river channel for water impoundment. The non-source pollutants, resulting from agriculture and villages, strongly effect water quality, but semi-natural pattern of riparian ecotones modify the water chemistry and biological processes in the river (Bis *et al*. 2000).

Details of the characteristics of the rivers studied is shown in Table 1.

For the canonical analyses (Jongman 1987) all variables were normalised using logarithmic transformation. The statistical analyses were undertaken using the STATISTICA programme (version 5.1 PL; StatSoft. Inc. 1997).

3. Results and Discussion

The canonical analysis is presented in Figure 2.
Total redundancy given for the first two axes (75.43%; 23.08%) indicates, that there is a strong environmental gradient along the first axis, caused by the contrast between highly degraded urban river basin and semi-natural, agricultural catchment characteristics, which are distinctly separated in ordination space.
The first group of catchment properties represents the most degraded river system. It consists of the well-known detrimental effects of heavy organic pollution (BOD; COD; TP) and inorganic pollution (Zn, Cr, Pb, K). The background is highly modified by the hydrological regime (rainfall) and sewage outflow.

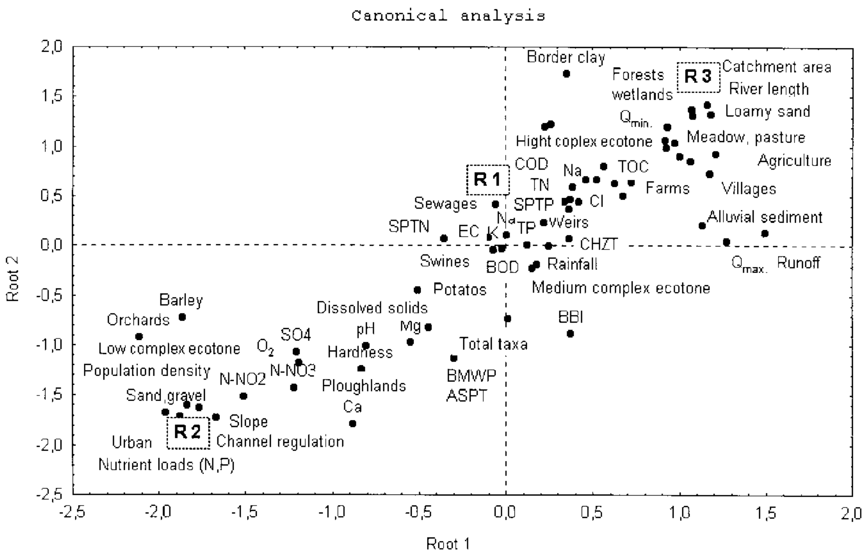

Figure 2. The canonical analysis plot of discrimination of environmental parameters. R 1 - a river converted into the sewage collector, R 2 – a urban stream, R 3 – a lowland river.

Table 1. Landscape properties, physical and chemical features of studied rivers.

	Acronym	The Sokolowka River	The Grabia River	The Ner River
Catchment total area [km²]	CAT	44.5	819.5	1866.5
River length [km]	RL	13.4	81.1	129.5
River channel regulation [%]	REG	100	40	75
Hydrotechnical structures [n]:				
- Sluice	SLA	4	3	20
- Weirs	DE	11	7	19
Gradient [%]	SL	0.55	0.16	0.03
Mean annual rainfall [mm]	RF	535	611	499
Mean annual runoff [mm]	OUT	153	194	168
Mean annual discharge:	Q	0.17 (0.02-2.61)	4.30 (0.92-43.4)	9.98 (0.74-87.0)
Distance from the estuary	ES	4.1	1.6	12.8
Land use [%]:				
- Agricultural	LA	60.1	63.2	71.5
- Forests and wetlands	LFW	7.3	24.7	15.0
- Urban	LU	32.7	12.1	13.5
Structure of agricultural use of total area [%]:				
- Ploughlands	AP	53.2	47.4	55.1
- Orchards	AO	1.0	0.5	0.7
- Meadows and pasture	AMP	5.9	15.3	15.7
Irrigated grasslands in river valley [ha]	IRR	0	9868	4670
Structure of croplands [%]:				
- Wheat	CRW	6.4	9.6	11.6
- Rye	CRR	31.0	38.5	31.5
- Barley	CRB	4.3	3.1	2.9
- Oats	CRO	3.0	3.8	3.0
- Rape	CRA	0	0.3	0.3
- Potato	CRP	15.5	14.4	16.7
- Sugar beet	CRS	0.1	0.4	3.8
- Others	CR	39.1	29.9	30.2
Structure of farms:				
- Average farm area [ha]	FA	3.6	6.2	7.5
- Farms > 15 ha [%]	FB	4.3	16.1	25.4
Population density [n km⁻²]	PD	2759	145	368
Number of towns and cities	CIT	1	2	5
Number of villages	VIL	0	223	276
Human population in the cities [%]	PC	100	46	54
Farm animals per 100 ha of croplands [n]				
- Cattle	CATL	31	43	50
- Swine	SW	68	62	74
Average daily load of source pollution:				
- Sewage [m^3 d^{-1}]	SPS	0	3680	301850
- BZT5 [kg d^{-1}]	BZT	0	14.4	78732
- ChZT [kg d^{-1}]	CHZT	0	166.5	195751
- Total nitrogen [kg d^{-1}]	SPTN	0	116.8	11938
- Total phosphorus [kg d^{-1}]	SPTP	0	50.6	1869

	Acronym	The Sokolowka River	The Grabia River	The Ner River
Nitrogen load from non-source pollution * [kg ha^{-1} y^{-2}]	NNP	4.98	9.86	13.88
Nutrient load * [kg ha^{-1} y^{-2}]:				
- N load	NLE	5.528	0.092	0.112
- P load	PLE	0.378	0.055	0.064
Surficial geology [%]:				
- Alluvial sediment	GAS	5	9	12
- Sand, gravel	GSG	60	9	10
- Loamy sand	GLS	15	45	53
- Boulder clay	GBC	20	35	25
- Chalk	GCH	0	2	0
Water temperature [°C]	TW	10.9 (0.5-24.0)	10.7 (0.2-22)	15.1 (3.0-24.0)
pH	PH	7.8 (7.3-8.7)	7.7 (7.3-8.4)	7.7 (7.0-8.8)
Conductivity [mS cm^{-1}]	EC	579 (360-909)	410 (342-496)	870 (433-1383)
Oxygen concentration [mg l^{-1}]	O2	10.7 (4.4-18.0)	8.9 (5-12)	0.8 (0-7.4)
BOD [mgO_2 l^{-1}]	BOD	2.2 (5.6-10.4)	4.7 (3.8-6.5)	97.5 (19.0-200.0)
COD [mgO_2 l^{-1}]	COD	32.3 (17.2-67.0)	11.3 (9.8-13.7)	243 (59-642)
TOC [mg l^{-1}]	TOC	15.4 (4.4-42.1)	20.3 (4.8-49.6)	62.6 (11.7-164.3)
Cl^- [mg l^{-1}]	CL	53 (28-161)	24 (9.5-42)	100 (34-209)
SO_4^{2-} [mg l^{-1}]	SO4	93 (53-136)	56 (39-101)	88 (36-132)
Dissolved solids [mg l^{-1}]	DS	424 (282-658)	205 (103-228)	548 (314-934)
Suspended solids [mg l^{-1}]	SS	17 (4-70)	25 (18-35)	176 (10-388)
Hardness [mg $CaCO_3$ l^{-1}]	H	274.9 (200.0-400.0)	169 (122-207)	281.0 (135.0-382.5)
Mg [mg l^{-1}]	MG	9.5 (5.4-12.8)	5.5 (4.7-7.1)	10.6 (3.6-93)
Fe [mg l^{-1}]	FE	0.53 (0.35-0.76)	0.41 (0.29-0.66)	2.3 (0.0-34.0)
Ca [mg l^{-1}]	CA	97 (75-145)	71 (57-81)	97 (47-132)
K [mg l^{-1}]	K	4.8 (2.8-7.1)	1.5 (0.7-2.5)	9.9 (5.4-22.8)
Na [mg l^{-1}]	NA	29.9 (19.3-93.0)	8.1 (5.1-9.5)	72.8 (10.0-182.0)
N-NH_4^+ [mg l^{-1}]	NH4	1.1 (0.3-2.9)	0.2 (0.08-0.65)	16.0 (1.2-28.6)
N-NO_2^- [mg l^{-1}]	NO2	0.062 (0.020-0.200)	0.02 (0.0015-0.04)	0.040 (0-0.340)
N-NO_3^- [mg l^{-1}]	NO3	1.68 (0.21-6.60)	1.23 (0.89-3.67)	0.21 (0-2.40)
Ntot [mg l^{-1}]	TN	3.65 (1.31-8.18)	2.87 (1.12-6.22)	22.5 (9.2-43.4)
PO_4^{-3} [mg l^{-1}]	PO4	0.80 (0.29-1.59)	0.08 (0.02-0.16)	6.41 (0.10-17.6)
P_{tot} [mg l^{-1}]	TP	1.73 (0.18-22.30)	0.35 (0.25-0.57)	4.83 (1.58-11.01)
Biological water quality assessment:				
- BMWP [The Biological Monitoring Working Party Score]	BMWP	54.3 (3-116)	70.2 (17-212)	20.2 (0-47)
- ASPT [The Averege Score per Taxon]	ASPT	1.0 (0.8-2.3)	3.8 (2.9-5.5)	0.6 (0-1.4)
- BBI [The Belgian Biological Index]	BBI	3.9 (1.2-5.5)	7 (4-9)	2 (0-3.5)
- Total taxa	TT	9 (1-15)	32 (11-50)	4 (0-7)

*data on the basis Okruszko, H. and W. Dirksen 1999.

Group 2 includes the region situated in the urban areas. Average annual nutrient load (N, P) from storm water runoff, human population density, river slope and channel regulation are the most discriminating factors for this system.
The last cluster provides the most useful descriptors of interactions between the terrestrial and aquatic system. These explanatory factors developed as a number of metrics describing following landscape properties: geomorphology (elevation, soil infiltration coefficients), land use (forests, meadows, pastures) and ecotone complexity. The mentioned factors are valuable for potential responses to restoration and management practices.

The results indicate that proper water quality restoration strategy should be implemented by an ecohydrological approach. The ecohydrological approach integrates abiotic and biotic processes at the catchment scale as well as indicates the use of ecosystem properties as a management tool. (Zalewski *et al*. 1997)

4. Conclusions

It is difficult to apply a multi-scale approach:
I. Understanding of scale depended processes;
II. Hierarchy of linkages across the catchment;
III. Hierarchy of degradation factors.
For this reason, methods of degraded rivers restoration should be implemented by Adaptive Environmental Assessment and Management (Holling 1978). This creates an opportunity to optimise the proposed solution.

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TEREBLE-RIKSKE RESERVOIR: AN EXAMPLE OF MAGNIFICENT ENGINEERING APPROACH WITH CATASTROPHIC ECOLOGICAL CONSEQUENCES

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Abstract
The creation in 1954 of a mountain reservoir in the river Tereblia valley (tributary of the Tisza) was dictated by the necessity to supply the Transcarpathian region of Ukraine with electric power. Its capacity is 29.5 thousand kW per hour. The originality of the engineering approach consists in an effective utilisation of the different altitudes of fluvial valleys of the rivers Tereblia (450–500 m) and Rika (300 m).
Reservoirs markedly influence the environment, causing changes in natural and economic conditions in the nearby territories. The profits of the production of electric power do not counterbalance the economic losses of these adverse effects. Examples are flooding of banks and buildings, undermining of banks, probability of landslides in the reservoirs valleys, decreasing of the water supply and of river water level, summer fish mortality, flowering by blue-green algae excreting carcinogenic substances, climatic changes of the surroundings, loss of valuable natural landscapes and associated flora and fauna.
The Tereble-Rikske Reservoir, because of progressing silting, is also subject to a periodic cleaning every five to seven years, with rather disastrous effects. The average discharge of the river Tereblia has been decreased by a factor 2 and does not exceed 6–7 $m^3 s^{-1}$. This has resulted in a dangerous increase of pollution by the waste of the local population. Thus, the coming 10–15 years there will be a physical necessity to counteract the negative effects of the reservoir and to construct a modern infrastructure to remove litter and liquid waste.
To conclude: hydraulic engineering projects in the Ukrainian Carpathians are only possible when taking care of a number of conditions (only small power stations, no inhabited localities above the reservoir, limited economic activity in the zone of water collection, no reservoirs in zones of extra tectonic activity). Under these conditions the creation of a regional park in the fluvial valley above the reservoir or the restoration of klauzuras (complex of small ponds) would be an expedient option.

1. Introduction

There are over 40 000 reservoirs in the world covering a total area over 600 000 km². This is practically equal to the area of the Ukraine. A reservoir is a basin filled by backwater, behind a dam in a river, with a volume of more than 1 million m³. Conventionally, the creation of reservoirs is closely related to the construction of hydroelectric power stations.

In 1954 of a mountain reservoir (Figure 1) in the valley of the River Tereblia (right tributary of the Tisa) was created to supply the Transcarpathian Region of Ukraine with electricity. Its capacity is 29 500 Kilowatt/hour, the production of the electric power plant is up to 139 millions Kilowatt per year. The reservoir was created by constructing a concrete storage dam (Figure 2). The dam construction included a pressure head water tunnel, a diversion tunnel, and a water power plant. The originality of engineering approach consists of the effective utilisation of the different altitudes of the fluvial valleys of the River Tereblia (450-500 m) and the River Rika (300 m). Water is discharged through the pressure head tunnel, dug through the mountain massif, onto the turbines of the water power plant.

The primary area of the water surface of the constructed reservoir is 180 hectares with maximal depths up to 40 m. By 1958 its area had decreased to 120 hectares (Bilak 1959) and nowadays it continues to decrease. The shallow water area (depth up to 1.5 m) covers only 1% of the whole water surface. In winter the reservoir is covered with a thick layer of ice. Ice-floes can be observed in April.

The phytoplankton of the reservoir is presented mainly by brittle worts and green algae, rarely blue-green algae occur (Vlasova 1958). The free living ciliates were investigated by Kovalchuk (1999) and seemed not be very rich in species. The zooplankton is poor: The small crayfishes of genera *Bosmina, Cyclops, Diaptomus*, wheel animalcules *Asplanchna, Filinia* etc. often occur marked. The number of zooplankton species does not exceed 30. The abundance of zooplankton (mainly *cladoceran crustaceous*) conventionally does not exceed 100-200 specimens per m^3. In the benthopelagic layers the concentration of copepods grows to 12 000 -13 000 per m^3. In the benthos of deep water sites the abundance of copepods (mainly *Cyclops vicinus*) reaches 6000-7000/m^2. From 1958 to 1959 the abundance and ratio of crustaceous zooplankton changed in favour of copepods (Bilak 1959; 1961).

Figure 1. Mountain Reservoir in the River Tereblia.

Figure 2. Concrete Storage Dam.

2. Present Situation and Discussion of the Problem

It seems that there is no danger in the construction of such hydropower stations and reservoirs, being sources of ‘clean’ energy. However, they entail a significant danger to the environment. In the book titled ‘Reservoirs’ (Avak’jan *et al*. 1987), we can read:
‘The Reservoirs markedly, and sometimes essentially influence the environment, causing changes in natural and economic conditions in the nearby territories’.
Could it be that the problems of environment conservation are definitely compensated by high hydropower efficiency of reservoirs? No, for example, the efficiency of the Dnieper cascade hydropower stations is 20-25%.
The profits from the production of electric power will melt into thin air, if we calculate the economic loss from the inundated areas (the valley and inhabited areas), the maintenance costs of the existing engineering constructions, the decreasing water supply in the river, and the moral and ethical losses.

It is also necessary to recollect the effect of flooding the riverside, undermining of banks, summer fish-kill phenomenon, flowering by the blue-green algae, which excrete some carcinogenic substances into the environment. The reservoirs influence the climate of the surrounding areas. In the mountain zone the effect is that the climate is growing cool in summer and warm in winter. Other effects are: the probability of landslides in the reservoirs valleys, redistribution of winds direction, changes in the amount of fall-out, character of soils, plant associations and aggregations of animals, and, hence biocenoses, extermination of valuable natural landscapes, decrease of the water level in the rivers by 10-15%.

The designers have not taken into account several other circumstances, while selecting the site for the Tereble-Rikske Reservoir. This resulted in progressive siltation (this seems to be more than 1% of the useful volume per year) of both bottom and pressure head tunnel and had bad influence on the environment. The tunnel has to be cleaned every 5-7 years, and water level in the reservoir sometimes drops to the ‘dead storage’ level. The author observed this in 1991. The huge mountains of sludge at the bottom of basin were covered by different kinds of rubbish (there are three villages upstream), from old footwear to a huge metal tanks (Figure 3). The transparency of the water in the reservoir did not exceed 1 m. During the catastrophic flood in the autumn of 1999 parts of buildings were washed in the reservoir. Even parts of the museum which used to be situated upstream was washed away. During the early 30 years of existence of the reservoir the area of its surface had decreased from 180 to 150 hectares, the maximum depth from 40 to 27-28 m, and for the last 10 years – up to 120-130 hectares and 20 m accordingly.

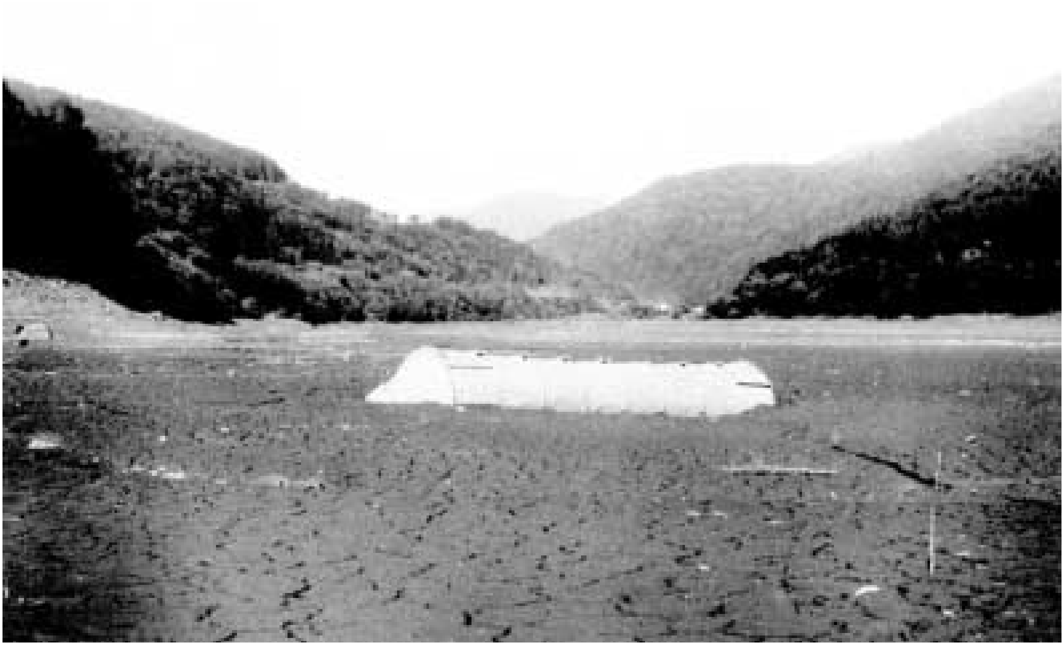

Figure 3. Metal tank at the bottom of the reservoir.

It is natural, that the similar effects of activation of erosive processes in mountains can influence negatively the ecosystem of the reservoir. The vivid example of negative consequences for biota is the extinction of all valuable species of fish, which were introduced into this basin: the blackfin, baikal trout, sterlet and even the brook trout. The financial damage from this particular action is significant. 50 000 berries of spawn of the blackfin, 6.5 millions spawn of the baikal trout, 500 000 pieces of small trout fry of the age of 2 months, and 300 adult males and females of the sterlet were released into the reservoir from 1955 to 1958 (Paliy *et al*. 1965). This has decreased the population of sterlet in the Ukrainian range of the Tisa so seriously, that it could not be restored today. Now this species enters the Red Book of the Ukraine.

Even the ground work on the construction of reservoir influenced negatively the ecosystem of the river. For example, on the River Turets (tributary of the River Vaha in Slovakia) the erosive processes caused by such activity have resulted in an important change of the aquatic ecosystems. The biomass of macrozoobenthos (important food for fish in basins of such type) decreased and biomass of protozoans and microzoobenthos increased (Krno *et al*.1995). Thus anxiety is caused by the condition of ecosystem of the River Tereblia. The flow in the river is actually cut off from the Upper reaches (Figure 4). The average discharge of water in this river has decreased by a factor 2 and does not exceed 6-7 m^3/s (in the lower reaches). It has resulted in a dangerous increase of pollution, as by tradition the local population throws waste into the river. The lack of a flushing releases from the dams' reservoir had a negative impact on the condition of the river.

Figure 4. The Ecosystem Downstream of the Dam.

Thus in the coming 10-15 years there will be a physical necessity in reconstruction of the dam of the Tereble-Rikske reservoir, releases from the dams' reservoirs that flushes the waste, utilisation of huge amounts of sludge in the bottom deposits, anti-erosive measures in the nearby mountains and a lot of educational work among the local population about the necessity to observe the sanitary norms. The latter is possible only in the case of creation of a modern infrastructure to remove the rubbish and utilise, or transport liquid waste.

3. Conclusions

The creation of hydraulic engineering works in the Ukrainian Carpathians is possible when taking into account the following:

- The hydro-electric power stations should be small, and, whenever possible built on the diversion type channel;

- There should not be inhabited localities upstream of the reservoir;
- Limited economic activity in the zone of water collection;
- It is recommended to create a regional, or even national park in the fluvial valley upstream of the reservoir;
- The creation of reservoirs in the zone of extra tectonic activity (Hutin volcanic massif) should be absolutely excluded.

Under such conditions it is recommended to restore the old *klauzuras* (original name of a complex of small ponds, like those on the White Tisa and Chorny Potok in the basin of the River Tereblia) and to create new ones, with small hydroelectric power stations. The volume of these complex of basins should be less than 1 million m^3.

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RELATION OF WATER QUALITY AND AQUATIC ECOSYSTEM CONDITIONS OF THE TURA RIVER BASIN BY CHEMICAL AND HYDROBIOLOGICAL PARAMETERS

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Abstract

The watershed of the Tura River is located in Sverdlovsk Oblast (Ural), where development of an industry and concentration of large enterprises have reached a significant extent. The industrial conurbation has large effects on the river ecosystems. Most obvious are the strong increase of pollutant concentrations in the water and the sharp decline in the biodiversity of aquatic fauna.

In the Russian Federation the assessment of the extent of anthropogenic impact on rivers is based mostly on hydrochemical indicators, comparing parameters actually measured in a river with accepted Maximal Permissible Concentration/MPC standards. This approach does not take into account regional features and does not always adequately reflect real condition of a water body, as safe existence of aquatic ecosystems is observed in waters with considerable excess of MPC standards.

From June to September 1998 seven ecosystems of tributaries of the Tura River have been studied. In particular, water samples for analysis of chemical composition and samples of macro-zoobenthos for assessment of the 'health' of aquatic biocoenose were collected. In total 11 stations were investigated, among which the reference locations with background conditions, and the sites of the river affected by strong pollution, as a rule downstream of industrial towns.

The results of the research have shown that the quality of the water, as calculated by chemical parameters, and the condition of aquatic ecosystems, as assessed by the community of macro-zoobenthos, do not always correspond to each other. In some cases the river ecosystem functioned quite normally even if moderate pollution took place. So the river ecosystem can tolerate certain amounts of polluting substances without adverse effects. Also, for some chemical substances very strict norms for safe water quality are developed.

A number of recommendations may be drawn from the study, e.g. that the norms of water quality for some chemical components (copper, zinc, manganese, colour) need reconsideration.

1. Introduction

In many regions of Russia the anthropogenic pressure on river ecosystems exceeds ecologically permissible limits. Nowadays the degree of anthropogenic impact on rivers is assessed by comparing parameters actually measured in a river with accepted Maximal Permissible Concentration/MPC standards. For natural water flows the fishery MPCs are taken as references. These values have been assessed by commonly accepted test-organisms of three trophic levels: algae, water fleas, and trout. A substance concentration, divided by 10, when at least one of these levels demonstrates negative reaction, is taken as MPC.

As a result of such unified approach the existing MPC standards are characterised by substantial rigidity and are artificially raised for many components. In practice it has been proved in many cases

that such an approach is inadequate. Aquatic ecosystems without any signs of 'sickness' are being classified as 'contaminated' hydrochemical environment, considerably exceeding the MPC standards (up to 10-20 MPCs).
This is the case, for example in the Tura river basin, rather typical for the Urals region, where background concentrations for some metals significantly exceed MPC fishery standards. Beside high background concentrations of natural metals, there are intensive human and economic activities in the whole Tura basin. Ferrous and non-ferrous metallurgy and all related mineral resources preparation and processing activities have specially negative effects on the Tura aquatic ecosystem.

The assessment of the current situation in the Tura basin, using hydrochemical and biological parameters, is presented in this paper.

2. Materials and Methods

In 1998 integrated studies of the rivers in the Tura catchment were conducted to assess the current situation of the water bodies. Eleven stations were installed, spread over 7 rivers, their location is presented on the catchment drawing (Figure 1). Observations were made monthly at all study locations, from June to September 1998.

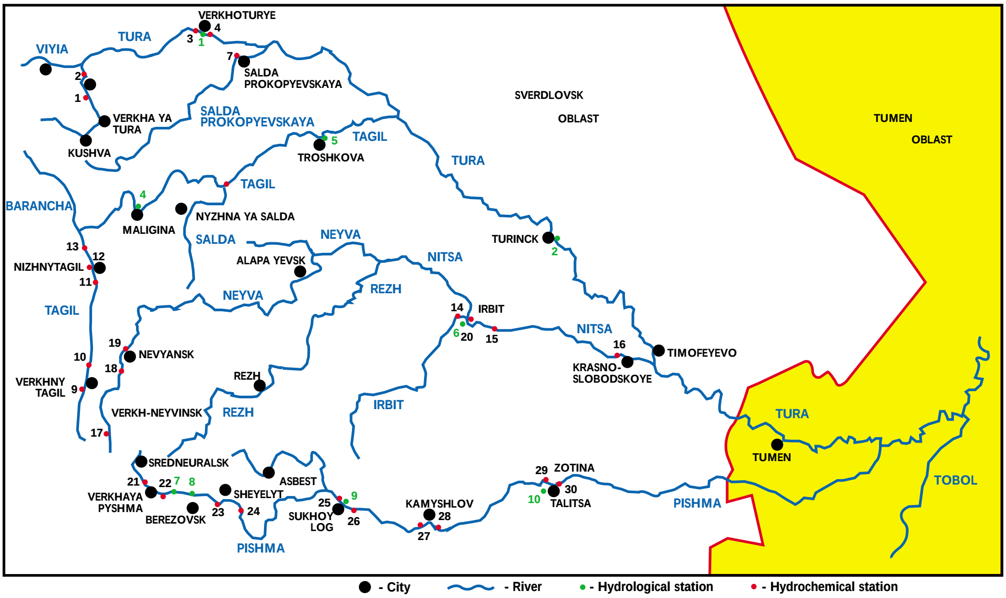

Figure 1. Schematic map of the Tura River Basin with the hydrological and hydrochemical stations

Water hydrochemical composition depends on regional natural factors and anthropogenic activities. Important regional factors are the chemical composition of natural water in the Urals, and in the Tura catchment in particular, the geological structure, the compositions of the mountain rocks and the complex of physical and climatic parameters. The Tura river basin is located within geological zones of the Urals, namely the Tagilo-Magnitogorsk zone and the Eastern-Urals zone. These zones are characterised by large quantities of iron and polymetal ores deposits (copper-zinc-sulphide, titaniummagnetite, etc.). The presence of high concentrations of ore minerals in the mountain rocks determines the natural high background content of a number of heavy metals in natural waters. For many decades mining activities and activities of industrial enterprises contributed to an increase of the heavy metals content in the water bodies. The inundation of relatively high marshes in the Tura river basin increased the discharge of organic matter.

Water samples were taken and put in 3 litres plastic containers to analyse the total chemical composition of the water. A separate container was used to sample water for heavy metal analysis. Prior to the sampling, the container was acidified by adding 1 ml of concentrated HNO_3, expecting pH 2 in the water to be sampled. Determination of cations and anions, organic and mineral forms of nitrogen and phosphorus, heavy metals (Fe, Cd, Pb, Cu, Zn, As, Mn), colour, salinity and other specific physical/chemical parameters was carried out. Sampling for dissolved oxygen content was done by bottle method in glass flasks of certain volume and with immediate fixation in the field.

Determination of total chemical composition and dissolved oxygen content were performed at the chemical laboratory of *RosNIIVKh*. Water tests were performed at the laboratory according to standard methods, 1-4 days after sampling.
During the field investigations a number of physical parameters such as temperature, pH, conductivity and current velocity were measured at the site.
Water discharge was measured with a standard Ott current meter, applying standard hydrometric procedures.

For the sampling of benthic macro-invertebrates we used Dutch artificial substrate (Bij de Vaate, Greijdanus-Klaas 1990). Three baskets were installed in the flow with a flow velocity of at least 0.1 m/sec at the depth of 0.5-2 m, depending on the depth at the observation sites. A representative part of the river was selected as the reference location. After 4 weeks the artificial substrates were collected and washed on an original unit with a 0.7 mm mesh sieve in order to separate benthic animal species from a filling agent (glass or keramzite). The collected invertebrates were fixed into 96% ethyl alcohol solution.

If one of the substrates was lost, animal species from 10 big stones were collected for qualitative analyses. When two or three substrates were lost this qualitative collection was supplemented with quantitative collection of substrate with the modified Dulkate shovel with 0.1 m^2 sampling area. In the last case a hand net was used additionally to the circular shovel. With the hand net we collected benthic animals on the bottom for 3-5 minutes. The contents of the net or shovel were also washed through the sieve (0.7 mm mesh) and the animals were fixed in ethyl alcohol.

3. Results

Hydrochemical assessment of the rivers in the Tura catchment area

The quality of the rivers in the Tura basin is assessed, hydrochemically, by two summarised indices:

- Waters Pollution Index/WPI (Hydrometeorological State Committee of USSR 1988);
- Coefficient of Indicator of Mark Pollution/CIMP (Nossal 1999).

17 hydrochemical parameters were used to calculate the summarised indicators.

Water Pollution Index/WPI is the officially approved criterion, most widely used in Russia. It is based on the relation of mean values of individual pollutants concentrations (C) to Maximal Permissible Concentrations/MPC. A limited number of parameters (6) is selected by ranking from the total list.

Biochemical Oxygen Demand (BOD5) and oxygen contents are always included in the list of parameters which are used to calculate the index. WPI is determined by the formula:

$$WPI = \sum(C/MPC)/6$$

Table 1 presents WPI values and corresponding water quality classes for the summer-autumn period of low water in 1998. According to the MPC-based classification, water quality in the Tura basin ranges from Class 5 (polluted water) to Class 7 (extremely polluted). The WPI indicated also low quality in the control sections located outside the zones of human impact. Critical analysis shows that the main pollutants that causes 'high contamination' in all reference control sections are (in descending order) copper>manganese>zinc>iron, i.e. elements typical for natural hydrochemical background of the given region. On the study locations situated downstream of inhabited locations an increase of pollutants of the nitrogen (nitrites) and phosphorus group has been measured.

Non-parameter Indicator of Mark Pollution (IMP) has been developed in *RosNIIVKh*. This indicator takes into account the background concentrations when determining the water quality class. In general it is a sum of ratios of all controlled indicators to the natural background.

$$IMP = \sum_{i=1}^{N} K_{n\,i} \;/\; K_{ac\,i}\;;\; 1 \leq i \leq N$$

where,

$K_{n\,i}$ = the actual water quality class of the natural background by i-index in accordance with the 'Unified criteria of water quality' of the former Council for Mutual Economic Assistance;

$K_{ac\,i}$ = the actual water quality class by i-index on the study location of the water body section;

N = is the number of the used water quality indicators.

For the background control section the IMP value equals the number of the controlled indicators. Indicator of Mark Pollution characterises the excess of actual contamination over background water quality characteristics.
An integral characteristic of the river conditions is the Coefficient of Indicator of Mark Pollution (CIMP) defined as relation of the IMP value to a number of controlled water quality indicators:

$$CIMP = IMP / N$$

The Tagil river – Polovinniy settlement and the Tura river – Aziatskaya study stations were accepted as background study locations. CIMP values and relevant water quality classes are presented in Table 1. Water quality classes vary from Class 1 (clean water close to the natural background) to Class 4 (highly contaminated). Out of 11 study locations 4 are of Class 1, 2 are of Class 2 (slightly contaminated water), 4 are of Class 3 (moderately contaminated water), 1 is of Class 4. It should be noted that CIMP-based classification is not rigidly dependent on a number of the determined hydrochemical parameters.

Analysis has demonstrated that when taking into consideration the background concentrations of the individual parameters, priorities are changing. Dominant concentrations of copper are observed only on some river locations affected by the copper-melting enterprises (the Salda - the village of Zlygosteva, etc.). The concentrations of pollutants typical for urban discharges (the nitrogen group, phosphorus, and BOD) rises considerably, as well as the concentrations of manganese and lead.

Table 1. The Tura basin rivers water quality assessment by integrated hydrochemical parameters, 1998.

No.	Study location	WPI score	WPI class	CIMP score	CIMP class	Remarks
1	Tagil - Polovinniy (natural background)	6.11	6 (highly contaminated)	1	1	
2	Tagil - Nizhniy Tagil	18.92	7 (extremely contaminated)	1.36 1.36	3 (moderately polluted)	Discharge of production and urban waste water of the Nizhniy Tagil industrial centre
3	Neiva - Byngi	14.78	7	1.39	3	Discharge of waste water of the towns of Nevyansk, Pervouralsk, etc.
4	Neiva- Yamovo	10.04	7	1.32	3	Discharge of waste water of Alapayevsk
5	Neiva - Cheremshanka	9.11	6 (highly contaminated)	1.15 1.15	1 (close to back ground)	Agriculture
6	Salda (Tagil) – Krasnyi Bor	4.8	5 (contaminated)	1.14		
7	Tura – Aziatskaya station (natural background)	7.73	6 (highly contaminated)	1	1	
8	Tura - Nizhnaya Tura	8.49	6	1.25	2 (slightly polluted)	Discharge of waste water of the towns of N. Tura and Lesnoy
9	Salda – highway to Serov	23.14	7 (extremely contaminated)	1.73 1.73	4 (highly polluted)	Discharge of waste water from Kushva
10	Salda - Zlygosteva	43.46	7	1.40	3 (moderately polluted)	Discharge of waste water of Kras nouralsk (copper-melting plant)
11	Viya - Valerianovsk	16.10	7	1.24	2 (slightly polluted)	Discharge of waste water from the towns of Kachkanar and Valerianovsk

Biotic assessment of the Tura basin rivers

The Index of Trophic Completeness /ITC (Pavluk 1998) was used to assess the conditions of the aquatic ecosystem. The index reflects functional connections between trophic groups of benthic invertebrates and other biotic components of an aquatic ecosystem. This is an integral indicator of ecological condition of aquatic ecosystems, depending on a wide range of environmental factors, such as water chemical composition of the water, the hydrological regime of the river, the physical quality of water, etc.

The Belgian Biological Index/BBI (De Pauw, 1988) was used alongside with the ITC, as it operates well on the Urals rivers. Besides, the BBI index has different principles of assessment. This sometimes leads to differences in assessment results of aquatic biocenosis conditions, compared with the ITC.

The assessment was performed on the basis of materials of zoobenthos collected during the summer-autumn period of low water in 1998 (August-September). The results of the rivers ecological conditions assessment by two samplings the stability or dynamics in the environmental conditions can be defined, and, as a consequence, the stability of the aquatic biocenosis trophic structure as a whole. Table 2 gives the results of the Tura basin aquatic ecosystems assessment by ITC and BBI.

Table 2. The Tura basin aquatic ecosystems conditions assessment by biotic indices (August-September 1998).

No.	Study location	Number of ITC trophic groups	ITC class	BBI index	BBI class
1	Tagil - Polovinniy (natural background)	9/11	2/1	10/10	1/1
2	Tagil - Nizhniy Tagil	9/7	2/3	7/5	2/3
3	Neiva - Byngi	11/11	1/1	10/10	1/1
4	Neiva - Yamovo	11/12	1/1	10/10	1/1
5	Neiva - Chermshanka	10/11	2/1	10/10	1/1
6	Salda - Krasniy Bor	10/12	2/1	10/10	1/1
7	Tura- Aziatskaya station (natural background)	10/9	2/2	10/10	1/1
8	Tura - N. Tura	7/9	3/2	9/10	1/1
9	Salda - highway to Serov	8/8	3/3	7/8	2/2
10	Salda - Zlygosteva	7/8	3/3	6/8	3/2
11	Viya – Valerianovsk	10/8	2/3	10/9	1/1

According to the biotic indexes, the situation in the rivers is as follows:

- Portions of the Salda river in the vicinity of the village of Zlygosteva and of the Tagil river downstream of Nizhniy Tagil are classified by both indices as defective;
- The Tura river portions in the vicinity of Nizhnaya Tura, the Salda river in the area of the Serov highway, and the Viya river downstream Valerianovsk are classified by the ITC-index as defective. According to the BBI-index the situation is less critical;
- All other study locations are classified as naturally safe on the basis of the both biotic indices.

4. Discussion

Analysing the research outcomes, it is worthwhile to note, that the hydrobiological assessment of the condition of the rivers in the Tura basin is more representative than the hydrochemical survey.
It signifies that any hydrochemical composition of water is acceptable, when the ITC and BBI indices classify the condition of river biocenoses as sound. For example, the ITC and BBI of study locations 3 and 4 do not indicate any problem of the condition of the ecosystem, while according to the hydrochemical indexes the water is extremely polluted, WPI (7th class from 7), and moderately polluted by CIMP (3rd class from 4). This obvious contradiction perhaps means, that in the particular conditions the environmental factors supplement one another in such a way that the toxicity of the contaminants is neutralised, or the toxicity is compensated by other factors (current, oxygen, organic matter). Using the concept of admissible level of harmful influence, one can say that at locations 3 and 4 the human pressure is within the admissible limits for the normal functioning of the river ecosystem.

The results of the water quality assessment by hydrochemical methods show clearly that the standards used by the WPI for the classification of the water quality are very rigid. According to this index, the water quality at the study locations varies from polluted to extremely polluted (7th class). Making a comparison with other assessment methods, then the lowest classification of water quality (worst) by the WPI should correspond with very pure aquatic biocenose composed of single, or no species of benthic animals. In reality it was found that the benthic biocenoses, marked by WPI score 7 (!), was a sound environment according to the biotic methods survey.

Thus, it is strongly recommended to revise the system of WPI classes in such a way that the WPI classification reflects more adequately the actual condition of river ecosystems.

5. Conclusions

The comparison of the results of hydrochemical and biotic assessments of the current river conditions in the Tura basin proves that the water quality classifications based on the comparison with MPC (WPI) is inadequate. Its discrepancy with the real ecosystem conditions is due to underestimation of the natural background concentrations.

Water quality classes determined by CIMP and quality classes obtained by biotic assessment match rather well with the results of the water body general conditions assessment.

The investigations have proved the supposition that the Federal fishery MPCs accepted in Russia and usually used to evaluate the water body quality, do not reflect the diversity of stability and adaptive abilities of aquatic ecosystems of various natural/climatic zones and biogeochemical provinces of the country to anthropogenic activity.

In reality the toxicological tolerance of hydrobiontes to natural compounds, including those that are components of anthropogenic pollutants, is based on their adaptive ability to components present in a given region. Consequently, hydrobiontes environmental response should reflect regional chemical conditions.

To make an objective assessment, surface waters classification in terms of their ecological safety should be based on regional ecological MPCs that take into account zonal and azonal features of natural hydrochemical background concentrations, causing certain toxicological resistance of aquatic ecosystems.

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DETERMINATION OF THE MAXIMUM ALLOWABLE LOAD FOR WASTE WATER DISCHARGES

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Abstract
Russian legislation of water protection is based on the principle of preservation the background level of chemical contamination, but it does not consider the state of sediments. However, it is well known, that in aquatic environments sediments act as a major sink for pollutants having hydrophobic or complex-forming characteristics. Once settled, contaminated particles may impose a continuous stress on the indigenous benthic fauna. Furthermore, contaminated sediments act as a source of pollution and can have a strong potential environmental impact when the quality of the overlying water is improving. In the absence of sediment standard values in Russia the assessment of sediments is solely based on chemical information of background concentrations. The biological approach concerns only determination of benthic species, assembling density and diversity of the fauna. There is no study of sediment risk assessment in Russia and hence no policy of its rehabilitation.
The approach of validating the maximum allowable load on the water system of Kuybishev reservoir (River Volga) was proposed for improving the ecological situation and functioning of the water body. In this case study quality criteria for water and sediments were derived step by step from the results of the equilibrium partitioning method and the results of aquatic toxicity tests.
The aim of this research is to include normative standards of sediments' quality to the governmental policy of water resource protection and hence to the strategy of the restoration of the River Volga.

1. Introduction

The present Russian water legislation has been based on two main strategies to protect the natural water.

1. The water quality standards based on a principle of preserving and improving, if possible, the background concentrations.
2. Effluent limits, based on the water quality standards observation in the mixing zone.

Russian water quality standards are developed as a result of laboratory toxicological experiments. Hence it does not consider either assimilative capacity of water body or action of pollutant in the water ecosystem. Russian water protection legislation does not take into account the state of the sediment.
However, it is well known, that in aquatic environments sediments act as a major sink for pollutants having hydrophobic or complex-forming characteristics. Once settled, contaminated particles may impose a continuous stress on the indigenous benthic fauna. Furthermore, contaminated sediments act as a source of pollution and can have a strong potential environmental impact when the quality of the overlying water is improving.

The fact that the quality of the water bodies is unsatisfactory, proves that the present Russian system of regulating the anthropogenic activities is not sufficient. This is mostly caused by imperfection (shortcomings) in the environmental regulation policy for the water pollution sources. Effluent limits for all pollutants with similar modes of action are approved accounting the additive effect. Thus, the wider the range of toxic compounds in effluent, the more severe the limits are. In this circumstances water users can not achieve estimated limits because even the modern technologies can't achieve such low concentrations, especially for nutrients. At this time water users solve the problem by diluting the waste waters. That's why the old concept 'the solution to pollution is dilution' prevails.

The central concept of our study is that sediment quality standards must be considered with regional conditions of a water body, and effluent's limits must take into account assimilative capacity of the river-recipient and results of ambient toxicological assessment.

2. Results and Discussion

Quality criteria (standards) for the concentration of toxic substances in waste water, surface water and sediment were derived. The approach takes into account hydrological and hydrochemical conditions of the water body. The main stages of this approach are shown in Figure 1. In the first stage we propose to use equilibrium partitioning method (Kooij 1991) for sediment standards calculation. The second stage is a toxicological testing. The No Observed Effect Concentration (NOEC) is determined through a traditional process of toxic testing with different test-organisms. The main advantage of the submitted scheme is using NOEC values of sediment to find the safe level of water pollution in the mixing zone and correspondingly in effluents (the third stage).
The experimental values of solids-water partition coefficient (Ksw), fraction of organic carbon (foc) and bioconcentration factor (BCF) were calculated from field measurements. The NOEC values for metals were applied more strictly than in comparison with food product standards. All the chemical analyses were performed according to Russian National Standards (Fomin 1995).

The toxicological investigation included acute testing of sediment's water extract with battery testing ➔ chronic testing of the water- sediment system with crustacea ➔ chronic testing of sediment with typical representatives of benthic fauna.

Sediments sampled at mixing zone of two biggest effluents in Kazan (municipal purification plant – discharge A and enterprise of organic compound synthesis – discharge B), were tested with crustacea *Daphnia magna*, algae *Scenedesmus quadricauda*, fishes *Brachydanio rerio*, ciliates *Paramecium caudatum* (Anonymous 1997) and a number of Toxkits – microbiotests with *Thamnocephalus platyurus* (Thamnotoxkit F), Rotifera (*Brachionus calyciflorus*), algae *Selenastrum capricornutum* (Algatoxkit F™) and ciliate *Tetrachymena thermophila* (Protoxkit). Tests were performed according to the manufacturer's instructions (Creasel, Belgium).

The acute toxicity was not observed in the first sediment sample (the first effluent), during all of the above-mentioned tests, except for algae (Algatoxkit). Testing of the second sediment sample has shown the inhibition of *Tetrachymena thermophila's* growth at 22% in comparison with control, algae growth inhibition was 56%. The difference of the algae's growth from the control was not observed when the extract was diluted twice. Mortality for *Daphnia magna* was 73% and for *Thamnocephalus platyurus* was 100%. The dilution of the extract with a factor 2, has eliminated the acute toxicity.

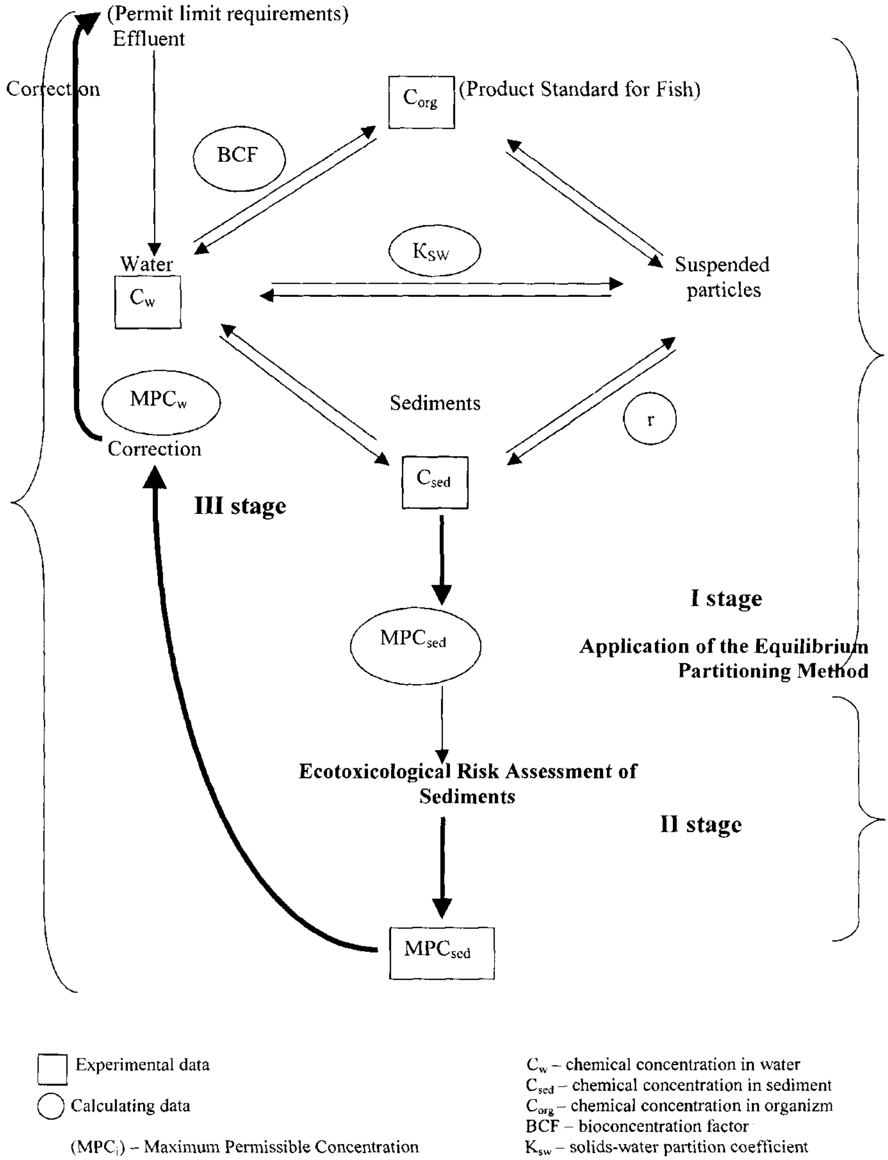

Figure 1. A stepwise application of the equilibrium partitioning method and ecotoxicological risk assessment of sediments for maximum allowable water load calculating.

Chronic testing of the water-sediment system was carried out with *Daphnia magna* according to ASTM procedure (ASTM 1993). In case of survival there were no deviations from the control in both cases. But there was the inhibition of daphnia reproduction on the first sediment sample (29% in comparison with control). Only the 12.5% level of sediment dilution did not give reliable (Significant) deviation of the reproduction from the control. Sediment at the discharge B, unlike the first sample, was characterised by stimulation of daphnia's reproduction.

The next step of the sediment toxicological assessment is concerned with surveys on benthic species (Grootelaar 1996). Chronic bioassay of the first sediment with *Chironomus riparius* has shown that larva's survival was 70% (90% in control) at the end of the testing. The difference from the control was in rate of larva's growth because only 50% of larva had achieved the forth stage (90% in the control) to the end of the experiment. Survival of the larva cultivated at the sediment B had not significant difference from the control.

In accordance with the 3rd stage of the submitted scheme we suggest reverse account of metal concentration in water from their existence in the sediment in safe amount for biota (from the results of the 2nd stage). From the corrected values of metals' concentration in water in the mixing zone it is possible to proceed through the coefficient of dilution at the diffusing discharge to ecologically safe standards for the waste water.

The environment in the mixing zone of the first enterprise is characterised by deterioration of the ecological situation: low Biotic Index (BI=2), acute and chronic toxicity of the sediment. Therefore the computation of maximum load was carried out from the results of toxic experiments. NOEC value for this sediment was 12.5% or TU_c=8 in chronic toxic unit. Correspondingly the content of metals, exceeding calculated standards, must be reduced by 8 times. The concentrations of metals in the waste water were determined through the rate of dilution of the diffusing discharge from the safe metal concentrations in sediment and water. In comparison with present limits of the effluent A the calculated ecological load is much lower for such metals as Fe, Cr, Cu, Pb.

A number of organic compounds found in the mixing zone of the discharge B were compared with calculated standards. Phenol, acetone and benzol did not exceed standards in water. Concentrations of polycyclic aromatic hydrocarbons and polychlorinated biphenyls were significantly lower than the calculated standards both for water and sediment. Mineral oil in sediments was determined by fluorescent method as a sum of hydrocarbons that made it impossible to calculate the threshold values by EP-method. That is why we compared the measured data with standards accepted in The Netherlands (Adriaanse 1995). Despite the fact that at the evacuation discharge site the oil concentration is 13 times more than at the reference point (500 meters upstream), its real value is only a fifth of the Dutch standard.

Four years of observations for diversity of the benthic community have not revealed the acute ecological situation in the mixing zone of the second enterprise. The state of the water ecosystem at this place could be considered satisfactory based on the Biotic Index (BI=4) and the results of the ambient toxicological assessment.

3. Conclusion

Deriving the quality criteria for water and sediment from the results of field measurements and aquatic toxicity tests has permitted us to calculate predicted environmental concentration for waste water discharges of the two biggest Kazan enterprises. Degradation of the ecological situation at the first discharge mixing zone and sediment toxicological assessment has given a reason for further action to decrease the level of some metals' content in the waste waters. Ecotoxicological assessment of the second enterprise discharge indicates that the present level of the waste waters contamination is acceptable for this river.

The method of the ecotoxicological assessment of the waste waters as well as field investigation of the river-recipient at the place of a discharge enables the calculation of ecologically based standards for a number of persistent toxicants in waste water.
This would further create the possibility to deviate from the common approach in policy of the waste water regulation and shift from a fiscal ecological policy to a justified and economically effective one. The all aforesaid enables to make the next important step in policy preparation for waste water regulation: the calculation of permissible ecological load for the whole river, followed by the distribution of the load between the water users, in accordance with their contribution to the river contamination.

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WATER RESERVOIR QUALITY MANAGEMENT

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Abstract
At present, the majority of water reservoirs experience a strong antropogeneous influence, bringing along adverse effects on the environment. One result of the anthropogeneous influence is deterioration of the water quality. Treatment of the water quality is very important for the life and health of the local population.
The quality of the water in reservoirs depends on biotic and abiotic parameters. Also, the requirements of cleaning the water depend on the use of the reservoir: for drinking water supply, fishing, recreation, etc. The higher the requirements to the quality of the water, the more effort is necessary for its treatment.
A management model is used to estimate the water quality in a reservoir and to offer technologies for its treatment. The higher the quality of the water, the less options for water treatment are offered and conversely. The value of the index is calculated in a range and has the following interpretation: if the value of the index is more than 0.6, the condition of the water system is unstable and requires external intervention; if the value of the index is less than 0.4, the condition of the system is stable and aspires to a sustainable development.
So, for the execution of any programme of water reservoir treatment it is necessary to take the following steps: monitoring and collecting the necessary data; analysing and evaluating these data; using the management model to chose the optimal managing strategy; analysing the results of this strategy and finally, based on these results, deciding how to reach a sustainable development of the water ecosystem. Thus, the integrated index makes it possible to define the current water quality of the ecosystem and the necessary managing measurements to achieve a sustainable development.

1. Introduction

At present, the majority of water reservoirs experience a strong antropogeneous influence, bringing along adverse effects on the environment. One result of the anthropogeneous influence is deterioration of the water quality. Treatment of the water quality is very important for the life and health of the local population.
The quality of the water in reservoirs depends on biotic and abiotic parameters. Also, the requirements of cleaning the water depends on the use of the reservoir, i.e. for drinking water supply, fishing, recreation, etc. The higher the requirements to the water quality, the more effort is necessary for its treatment. An integrated index makes it possible to define the current water quality of the ecosystem and the necessary managing measurements to achieve a sustainable development.

2. Estimation of Water Quality of Water Reservoir

The water quality of the Kaban Lakes was estimated. Kaban Lakes consist of three basins: V. Kaban, S. Kaban and N. Kaban. The lakes are located near the city of Kazan with more than a million

inhabitants and experience strong anthropogenic influence. The Kaban Lakes are unstable and characterised by excess of permissible concentrations BOD5, HCO_3^-, NH_4^+, NO_2^-, NO_3^-, iron andanerobic conditions. The destroyed structure of zooplankton, phytoplankton, bentos and ichtiofauna of lakes could not be restored. Some parameters could not be measured due to lack of sufficient funding for the research work.
From 1981 onwards restoration technologies like aeration, creation of running water, removal of sediment were applied in the Lakes of N. Kaban and S. Kaban. On V. Kaban Lake restoration technologies were not implemented. The application of aeration techniques and the creation of running water from1981 to 1983 had a positive effect on the condition of the Lakes of S.Kaban and N. Kaban: saturation of oxygen in the water increased, and nutrients content decreased. In the subsequent years, although sediment was removed, the frequent emergency discharges of waste water into the Lakes had resulted in deterioration of the condition of the Lakes. The integrated estimation of the water quality of the lakes was done on the basis of the ecological classification of the quality of surface water. So, all Kaban Lakes need to be restored. The restoration measures for the Lakes itself should be accompanied by preventive measures for the discharges into the Lakes. For the Kaban Lakes the following measures are required:

- No discharge of untreated waste waters;
- Removal of issues of the storm water drain on clearing structures;
- Cleaning of the lake shores from dust;
- Restoration of springs;
- Improvement water change;
- Creation of a protected zone around the lakes.

3. Recommendations for Improvement of Water Quality of Water Reservoir

The selection of technologies for water ecosystems restoration was based on research, and also on the experience and intuition of the ecologists. As a rule, the decision to be taken to tackle such problems require heuristic methods (in connection with incorrect, incomplete and variable data, which is one of the basic characteristics of the problem area). This requires the application of an management model (ES ÑÒÀÍ). Recommendations, as an outcome of the application of ES ÑÒÀÍ, are used for the selection of a restoration strategy for polluted and eutrophic lakes. ES ÑÒÀÍ presents the results in a tabulated form, indicating the opportunity of application of the different ways of restoration. The estimations cover a range [0,1] and the interpretation is as follows:
0.0-0.2 - the application of this restoration measure is not necessary;
0.2-0.4 - the application of this restoration measure is not essential;
0.4-0.6 - the application of this restoration measure will do not much harm;
0.6-0.8 - the application of this restoration measure is desirable;
0.8-1.0 - the application of this restoration measure is necessary.
Such management model can be used for other fresh water reservoirs of a similar type, located in urban territories (Frolova and Zakirov 1997).

The Management model ES ÑÒÀÍ takes into account the group of the parameters determining the condition of a basin, while selecting a certain way of restoration. For the best account of the influence of a complex of parameters three estimations are entered: minimum, maximum and average. On their basis the management model presents the following decisions for the application of restoration measures: recommended restoration measures, not recommended measures and ranking the restoration measures with respect to the efficiency of their application. Now, the Knowledge base and Database of ES ÑÒÀÍ contain the information on 10 ways of basins restoration. The application of a certain restoration technique depends on 14 parameters indicating the condition of the basin (Frolova 1998). The efficiency of the application of a certain way of water restoration determines the degree of improvement of the water quality. The long-term monitoring will present data on the character and degree of ecosystem changes and the changes in water quality, in time. In Table 1 the recommendations for restoration of Lake N. Kaban are presented.

Table 1 shows that restoration technologies for lake restoration and estimation of its application, as presented by the management model, depend on parameters indicating the condition of a basin, i.e. the water quality. The better the water quality, the less measures for lake restoration are needed, and on the opposite. Depending on the parameters used for the indication of the condition of a basins, the estimations of the application of the way of restoration might change. The most effective from them is given a higher estimate.

The recommendations and estimations given by the management model ES ÑÒÀÍ on the restoration of N. Kaban Lake, which change depending on a its condition, coincide with the opinion of expert-ecologists. ES ÑÒÀÍ also presents additional measures, directed on maintenance and stabilisation of the ecological condition of a fresh water reservoir.

Table 1. Recommended Restoration Technologies for N.Kaban Lake.

Rank/Year/Technologies/Estimate					
6/1981	3/1983	6/1985	5/1988	7/1992	7/1995
Y1/1.00	Y4/1.00	Y10/1.00	Y4/1.00	Y6/1.00	Y10/1.00
Y4/1.00	Y10/1.00	Y4/1.00	Y10/0.89	Y9/1.00	Y4/1.00
Y6/1.00		Y3/0.96	Y5/0.66	Y4/1.00	Y1/0.96
Y9/1.00		Y5/0.73	Y2/0.57	Y1/0.76	Y3/0.92
Y10/0.86		Y2/0.64		Y2/0.85	Y6/0.64
		Y9/0.60		Y5/0.85	Y2/0.64
		Y6/0.59		Y6/0.77	Y9/0.64
					Y5/0.77

Technologies:
Y1 - aeration
Y2 - removal of water from hypolimnion
Y3 - precipitation of phosphorus
Y4 - removal of sediment
Y5 - shielding of sediment
Y6 - creation of running water
Y7 - chemical methods of removal cyanobacterium
Y8 - physical methods of removal cyanobacterium
Y9 - creation bioplato from higher water plants
Y10 - creation bioplato from mollusks

Ranks:
3 - ‘quite clean’
5 - ‘poorly polluted’
6 - ‘moderately polluted’
7 - ‘strongly polluted’

4. Conclusion

This approach for the selection of restoration technology can be used for different fresh water reservoirs, subject to different human activities, varying in character and force.

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THE PROJECT ‘TAKE CARE OF OUR RIVER’

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Abstract
The project ‘Take Care of Our River’ was initiated in 1996 by the NGOs SOSNA (Ko‰ ice, Slovakia) and Holocén (Miskolc, Hungary). Aim of this project is to inform the public in the common watershed of Hornád/Hernád River both in its Slovakian and Hungarian side about environmental conditions of their river and its watershed, and to bring about a positive attitude of the local people towards their own river. To reach this goal a system of monitoring groups was created, built up from schoolchildren of primary schools and students of secondary schools. These monitoring groups measure water quality seek for pollution sources in their neighbourhood and look for illegal dumping along the river, clean up river banks, plant trees and watch animals and plants living in and around the river.
The Hornád/Hernád is polluted, some parts reach the highest levels of pollution rank, especially nitrites and phosphates show high concentrations. Main pollution sources come from household waste, which is not or not adequately treated in most of the villages in the watershed. Another serious part of the pollution comes from industry and agriculture.
Other initiatives of the project are the programme ‘Adopt a River’ (volunteers doing small-scale restoration activities), the revitalisation of an oxbow, and the preparation of models for pollution control in different parts of the watershed.
In 2000 SOSNA will start a similar cross-border citizen's monitoring project on the Latoritsa River together with NGOs in Ukraine. There are already some concrete plans to start river restoration activities on the Latoritsa River. First activities should be starting already in 2000.

1. Introduction

The River Hornád is a 240 km long river, a tributary of the Sajó River (which is a tributary of the Tisza River), so it belongs to the Danube River basin. The source of the River is below the Král’ova hol’a mountain of the Lower Tatra in northern Slovakia, then it flows eastwards and southwards through districts of the towns of Poprad, Spi‰ ská Nová Ves, Ko‰ ice. The last 110 km, the river flows in Hungary, as Hernád.

The project ‘*Take Care of Our River*’ is a project of public participation in Citizens Water - Monitoring through schools, local governments and Non-Governmental Organisations/NGOs. The whole project was initiated by the NGO SOSNA from Ko‰ ice, Slovakia in 1996. Now, it is an international project, involving Hungary (NGO Holocén in Miskolc), the Chech Republic (NGO Veronica in Brno) and Ukraine (NGO Ekosfera in Uzhgorod). The same method of Citizens Water - Monitoring activity was adapted in different watersheds in Slovakia, i.e. Hron, Váh, Ipel’/Ipoly , Danube watershed, by NGOs Slatinka, Dub, Zelená Linka, Ipel’ská Únia/Ipoly Unió. The methodology was provided through practical training by SOSNA. In 2000 SOSNA and Ekosfera started a common monitoring project on the River Latoritsa both in Ukraine and Slovakia.

2. Present Condition of the River Hornád

The present condition of the River Hornád is the following: some parts of the upper, middle, and lower section of the river are still in a well-preserved condition, with good riparian buffer zone and high biodiversity (various fish species, fish-otter, dipper, common sandpiper). Several parts, however, are regulated, and polluted by household waste, mining industry, steel mills, agriculture and illegal waste dumping. Pollution of the surface water is high, some parameters, like nitrates - are usually in the worst, 5th category of pollution and phosphates are in the 3rd - 4th category of water pollution.
The River Hornád is one of the most polluted rivers in Slovakia, with a high nutrient pollution content. Another problem is the pollution by metals from heavy industry. High concentrations of copper, nickel, lead, mercury, zinc and other metals are present in the mud of the middle section of the river and in the sediments of the Rudín water reservoir, where they have settled since the 1950s, when mining industry has its boom in the Central Spi‰ region (towns Krompachy, Rudòany, Smolnícka huta, Slovinky).

In the middle and lower section of the river large areas covered by floodplain-forests for centuries were converted into intensively managed agricultural land and human settlements. Restoration of the river and its watershed requires reduction of pollution, restoration of the remaining oxbows along the river and international (transboundary) co-operation of governments in both countries, institutions managing the watershed (PBH in Slovakia), NGOs and local governments. Water treatment will require adequate funding.

3. The Project

In 1996 SOSNA started a programme of a Citizen Water Monitoring in the watershed of the River Hornád in eastern Slovakia. The project is called '*I Take Care of Our River*'. The project was an international project with a partner organisation in Hungary, called Holocén. The aim of the project is to test the quality in the River Hornád and its tributaries in different parts of its watershed. Most of the monitoring groups are schoolchildren from elementary schools and secondary schools, who do the testing under the leadership of their teachers. Additional activities include river-surveys, counting of water birds, testing of macro-invertebrates, river bank cleanups, and small-scale habitat restoration projects. In 1996, 13 monitoring groups from Hungary were involved, the project is running continuously. In 1997 and 1998 the project was expanded to cover the whole watershed. In 1998 a total of 33 groups were involved (22 in Slovakia, 11 in Hungary), testing the water on 39 sites. The method is being adopted by other NGOs in Slovakia. SOSNA participates in training programmes for other NGOs, maybe also from the neighbouring countries.

SOSNA started in1998 another programme called '*Communities in Action*' to co-operate closely with local governments in the Abov region (Eastern Slovakia, between the town of Ko‰ice and the border with Hungary). This co-operation focuses on environmental issues, and solving problems of water and air pollution. The programme includes training and seminars for the mayors and local citizens, environmental and legal advisory service, discussions with the polluters, and co-operation with Hungary in solving environmental and nature protection issues, etc.
The programme continued in 1999.

Recent activities of SOSNA can be divided into 3 main programmes:

1. Communities in action: includes projects like '*I Take Care of our River*', '*Know Your rights*' (training for mayors in villages and citizens) and '*Adopt a river*' (a programme to encourage volunteer

groups of citizens in the Hornád watershed, who are willing to support their river);

2. Rural Development: includes the project ‘*Healthy Food for Healthy Prices*’, which supports ecological agriculture in practice, creates a distribution network of small farmers producing their crops without chemicals and consumers (families from the city) buying their products;
3. Environmental education programmes: lectures for the public, seminars for teachers, project ‘*Colourful World*’ for schoolchildren in Abov region, summer camps, and field trips.

Restoration activities on the river Hornád. A result of the co-operation of the SOSNA and a private company ENVIRONCENTRUM was the small-scale restoration of the bank of a gravel-lake at Krásna in the southern suburb of Ko‰ ice. The bank of the lake was used to dump concrete waste. One part of the gravel lake was a proposed protected site, because of its unique bird-fauna. The concrete waste on the bank of the lake was covered by soil, and trees were planted. This area now provides home for more then 10 bird and mammal species.
In 1999 a summer-camp was organised by the SOSNA at Kluknava in the middle section of the Hornád River. One parallel tributary of the river was cleaned up from waste and was prepared for the restoration. Further activities will be continued by local citizens in co-operation with the local government in Kluknava and the Environmental Office in Spi‰ ská Nová Ves.

To protect the Tisza River from further environmental damage, future co-operation between watershed management companies, governments, NGOs, local governments and citizens in Slovakia, Hungary and Ukraine on the rivers Hornád, Latoritsa, Laborec and Bodrog will be very important. All these rivers belong to the Tisza watershed and they all contain in their watersheds potentially threatening sources of pollution by toxic metals, sulphuric acid and other chemical substances. These sources should be supervised and monitored to prevent further environmental disasters in the future.

RESTORATION OF THE VOLGA RIVER AND RIVERS OF THE DON BASIN

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Abstract

The Volga and Don rivers are representative for the analysis of the river restoration problems in south-east Europe. The hierarchy of river dimensions from Volga to numerous minor rivers, the multifunctional use, and the different kinds and extents of degradation determine the hierarchical system of the aims in policy, planning and implementation of river restoration.

The main problems of degradation of the Volga River are closely connected with dams, sewage and irrigation, and lead to a reduction in potable water supply, fisheries and biodiversity. The main problem of the minor rivers of the Don basin is water shortage. Therefore the aims and methods of river restoration for large and minor rivers are different. However, they have to be achieved through a common complex of co-ordinated arrangements. This complex is based on system and target-programmed approaches and includes, from the one side, the elimination of some dams, reduction of pollution, restoring of water content and biodiversity, and from the other side, the settlement of conflict situations through negotiated agreements and involvement of the public opinion.

The target programming of river restoration is a process of some well defined procedures, including: analysis of the situation, goal setting, evaluation of problems, settlement of conflicts, and planning. This sequence of operations is realised in the concept of the Federal Target Program 'Volga Reviva' and in some measures of the restoration of the minor rivers of the Don basin.

THE THEORETICAL AND PRACTICAL APPROACHES TO RESTORATION OF WATER ECOSYSTEMS IN THE MIDDLE OF THE VOLGA REGION

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Abstract

The theoretical basis of ecological restoration, the definition and essence of restoration processes, the results of practical experiments and the methodical approaches to the restoration of water ecosystems are considered.

In the author's opinion, the restoration of a water ecosystem implies the rehabilitation of its natural values by means of special measures. Those measures are aimed at activating the process of self-restoration into the sustainable ecological condition, closely resembling the initial condition. The biocoenosis and ecosystem can not fully be restored on this condition. The ecological laws and principles responsible for restoration are the law of evolution-ecological unbacking, the principle of 'genetic memory', and the principle of partial backing, which was especially proposed for the explanation of water ecosystem restoration processes.

Besides, the results of experiments on the ecological restoration of lakes and rivers in the middle Volga region are considered here. One of the largest experiments was the restoration of the Sviaga River (the main tributary of the Volga River, more than 300 km in length). Here the water quality was enhanced by the creation of waste water reservoirs in the basin and the installation of macrophytos-biofilters. These measures proved to give good results in the city of Ulyanovsk (500 000 inhabitants). In other experiments many different restoration methods were tried out, such as aeration, and elimination of sediments.

In order to tackle the problem of lake and river rehabilitation in a more systematic way a special databank of all of these restoration methods was created. This databank allows to chose the optimal set of methods, taking into account the condition of the water ecosystem and the special qualities of each method.

CONSERVATION MEASURES, ECOLOGICAL NETWORKS AND INSTITUTIONAL DEVELOPMENT IN THE CENTRAL BORDER REGION BETWEEN SLOVAKIA AND HUNGARY

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Abstract
The region concerned has a tradition of an extensive cultivation culture and the local people owned traditional farming skills, that enhanced the quality of the landscape. Nowadays there are not enough of these traditionally farming people left in the region and consequently, as a result of the current land use activities, the landscape is degrading. The big challenge is to preserve the existing landscape, and stimulate the traditional rural employment by increasing the rewards for these ancient farming skills.

The region is the junction of some major landscapes (mountains, rivers and plains), each with its own geological characteristics, giving rise to many habitat types with a rich flora and fauna. Although specific sites have been given a protected status, there is an overall lack of knowledge of the biodiversity and ecological stability in the project's land corridor.

There is an urgent need for an integrated biological, ecological and landscape database, that will strengthen the protection and improvement of the region's biodiversity and ensure the maintenance of ecological stability. There is a also need to develop a catchment management plan for protection and revitalisation of the River Ipel.

The 'Pan-European Biological and Landscape Diversity Strategy' in the central border region of Slovakia and Hungary is based on four action themes:
- *Habitat conservation measures;*
- *Transboundary ecological networks;*
- *Biological and landscape diversity;*
- *Institutional strengthening.*

The first practical steps to facilitate the implementation will be taken soon, among which are field inventories of biodiversity, development of conservation plans, agreements concerning transboundary responsibilities, enhancing the awareness of the public, and participating in policy development and institutional planning.

WESTERN EUROPE

NATURE REHABILITATION ALONG RHINE RIVER BRANCHES: DILEMMAS AND STRATEGIES FOR THE LONG TERM

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Abstract

The three branches of the Rhine River in The Netherlands have been diked to prevent flooding and normalised to enhance shipping. Consequently, only a relatively confined floodplain area remains, which is frequently flooded. The River responded morphologically by eroding the channel whereas the floodplains keep rising through sedimentation. Consequently, the diversity in environmental conditions declined and nature is impoverished.
Since the large floods in 1993 and 1995 it became clear that there is a limit to the safety dikes can provide. Moreover, it is foreseen that the discharge of the river may increase in this century due to climatic change. Sufficient reasons to rethink the strategy of flood risk management. Nowadays, any such a strategy must take into account nature rehabilitation goals.
From a river restoration point of view, the river manager is confronted with two dilemma's. Firstly, can flood management and nature rehabilitation be combined in a sustainable way? And secondly, what level of river restoration is possible along a normalised channel? In this context, two different strategies for future river management are presently being investigated. The first relies on the recurrent excavation of the floodplain and is called 'cyclic rejuvenation'. The second enlarges the floodplain area thus allowing the river much more room, but also requiring the adaptation of land use to new temporary hydraulic functions; this strategy will be addressed as 'living with floods'.
This paper briefly examines these two approaches, illustrated with a possible long -term solution for the three Rhine River branches in The Netherlands.

1. Introduction

History of river management

The present dike system along the Rhine River branches in The Netherlands (Figure 1) dates from about 1400 AD, when the dikes were connected into a comprehensive system of closed dike-rings. Flooding is since then confined to the 'actual floodplain' area, which is primarily used as pasture.

Also, for centuries, The Netherlands economically benefited from its being situated in the Delta of the River Rhine (Figure 1). The port of Rotterdam is considered the gateway to Europe thanks to its being located at the mouth of the Rhine River, which is navigable for about 1000 km. The navigability of all three Rhine branches relies on 'normalisation' to uniform depth and width by means of groynes. In three phases the channel has been narrowed, first to 360 m width and finally to only 260 m in the Upper-Rhine. Sand and gravel banks were removed already in the first phase and lateral channels were cut off from the river. Finally, the Lower-Rhine branch has also been regulated by weirs, both to control the discharge distribution over the three branches and to enhance the navigability even further.

Figure 1. The Rhine branches in the Netherlands.

Obviously, for centuries the main objectives of river management have been protection against flooding and maintaining the navigability of the rivers. This relatively narrow approach to river management has lead to a continuous deterioration of the river's nature value in terms of naturalness of processes, diversity of environments, biodiversity (species richness) and ecological carrying capacity.

Ecological consequences

The diking of the floodplains bounded the surface area for flooding and flood-related processes. This causes an increase in hydrodynamics in the sense that during floods water cannot spread over vast areas but rises rapidly while flooding (almost) the entire 'actual floodplain' area. No places remain dry, so no refugia for plants and animals remain. Behind the dikes, intensive land use offers no room for floodplain plant and animal species to temporarily reside either, because it is all intensely used agricultural land. Especially the ecosystem types which require seldom or infrequent flooding are now scarce; only the very flood-resistant types remain, but these are impoverished in species richness.

The normalisation of the channel had quite a different impact. The groynes and other structures prevent any lateral morphological development, whereas vertical morphological developments were speeded up. The normalisation thus evoked accelerated erosion in the channel and sedimentation in the active floodplains. Through the narrowing of the channel the bed level has sunk substantially, whereas the floodplains have risen with approximately 1 cm/year during the last century. Because the floodplains are bounded by dikes, this accretion was accelerated in comparison to an undisturbed reference.

Summarising, in contrast to the increased hydrodynamics, morphodynamics have declined to almost zero lateral development, whilst the channel has sunk and the floodplain has risen. Instead of a diversity of environments with different flooding frequency, only a deep channel and relatively flattened floodplains remain. These are mainly used for agriculture. As a consequence, characteristic riverine and floodplain ecosystems disappeared and the quality of the remaining ecosystems deteriorated.

Response of nature policy

The national policy plan for nature management regards the floodplains along the Rhine branches to be a keystone in its Ecological Main Structure; a network of connected core-areas, corridors and stepping stones of nature reserves. The prime reason for this focus on river corridors is the ecological potential to rapidly enhance the nature values in floodplains in comparison to that in other areas: the abiotic environment is relatively favourable, rare species appear frequently as they are brought in by the river, and vegetation development is fast. Moreover, the Rhine and its floodplains are a very characteristic landscape from a national point of view.

Presently, this Ecological Main Structure is being realised by reclaiming agricultural lands and turning them into so-called 'nature development areas'. This implies the buying of land and the functional change of agricultural land into nature reserves, also in the floodplains.

However, as vegetation development, especially of reeds and forest which take the place of agricultural pasture, implies a decline in the discharge capacity of the river because of the increasing hydraulic roughness, the allowable nature development must constantly be tuned to the required discharge function of the river. So-far, it seemed that the matching of nature restoration with flood protection might succeed, but presently the discussion is being troubled by the two latest floods in the Rhine River as well as by the increased awareness of the possible impact of climatic change on the river's discharge regime.

Changes in river discharge

The 1993 and 1995 floods in the Rhine and Meuse Rivers affected the statistics of flood frequencies, in such an way that for the Rhine River in The Netherlands the safety standards for flood protection will have to relate to a (1:1250) discharge of about 16 000 m^3/s instead of 15 000. In the near future a further increase of the discharge is expected due to climatic change. It is commonly assumed that the peak discharge will increase with 5-10% on the medium term (25 years) and with 10-20% before the end of 21st century.

Changes in view to flood risk management
After the 1993 and 1995 floods the decades-old plans for dike reinforcements were rapidly revised and implemented. But the floods were also an incentive for revising the centuries-old view to flood control and flood risk management. Raising the dikes is no longer regarded the one and only answer to flood hazards. It is argued that however high the dikes are, they can only provide protection against flooding to a certain level. In addition, records of physical planning in The Netherlands over the last decades reveal that land use quickly changes in response to enhanced safety levels. A lowering of the probability of flooding is soon counteracted by larger potential damage of flooding due to an increase of investments in housing, industry, infrastructure and agriculture.

Also, the societal acceptance of a further reinforcement of the dikes is very low, because raising and strengthening of the dikes would result in a considerable loss of natural values and cultural heritage. Therefore, large efforts are now being put into the design of alternative strategies and measures which minimise flood risks and at the same time enhance the nature values of the river and its floodplains. The current management adagium is: ‘Room for Rivers’.

2. Two Dilemmas

The historic record of changing facts, goals, views on how to achieve these goals, and the related concrete structures (dikes and groynes) sets the stage on which the current river manager has to act. Just as a reminder, we emphasise that river management nowadays should comply with rules of integrated water management, fully incorporating ecological rehabilitation as objective of river management along with flood protection and ensuring the channel’s navigability.

Consequently, the river manager is confronted with many dilemmas, related to the question of how to match the many different functions of a river and its floodplains in a sustainable way. In this paper, we focus on only two:

- Can the discharge capacity of the river be sufficiently enlarged and maintained in combination with the desired rehabilitation of riverine and floodplain nature? This relates to the potential conflict between flood protection and nature conservation.
- What river restoration can be achieved without undoing the normalisation of (one or all) the Rhine’s branches? This relates to the conflict between the requirements of a navigable channel and morphological rejuvenation as prerequisite for river restoration.

3. Alternative management Strategies

Two alternative strategies have been proposed, which both have to tackle the two dilemmas. The strategies are very different, however, and the possible consequences not yet fully explored. A sound ex-ante assessment of the advantages and disadvantages of the strategies from a sustainability point of view is programmed by The Netherlands’ Centre for River Research/NCR. This includes nature values, cultural values, etc. We shall briefly introduce the two strategies, ‘cyclic rejuvenation’ respectively 'living with floods', with emphasis on the river restoration aspects.

'Cyclic rejuvenation'

So-far, the adagium 'Room for Rivers' translates into very strict regulations for building in the floodplains. This prevents a further decline of the river's discharge capacity. For the future, however, the flood risk management policy is oriented towards safely discharging larger amounts of water without having to raise the dikes. The solution is sought primarily between the dikes, i.e. in the channel and the floodplains. In this context, a wide variety of measures is available (Pedroli and Dijkman 1998; Duel *et al.*1998; see Figure 2). Presently, a strategy is favoured which relies on 'building nature', i.e. with emphasis on:

- Lowering (parts of) the floodplain;
- (Re)constructing lateral channels and floodplain lakes;
- Removing artificial levees in the floodplains.

Civil engineers might regard some of these measures to be merely delayed maintenance, as the post-normalisation sediments will be removed. The measures may also be economically interesting, because the sand and clay, which become available by lowering the floodplains, may be used for construction purposes or the brick industry. In policy analyses it was found that an important reduction of the water levels during floods can be achieved by such measures (*Rijkswaterstaat* 1999; *RIZA* and *WL* 1999).

From an ecological point of view this lowering of the floodplains is, of course, wholly unnatural and contradicts with the desire to let the river be a 'self-organising' system. Alternatively, when one realises

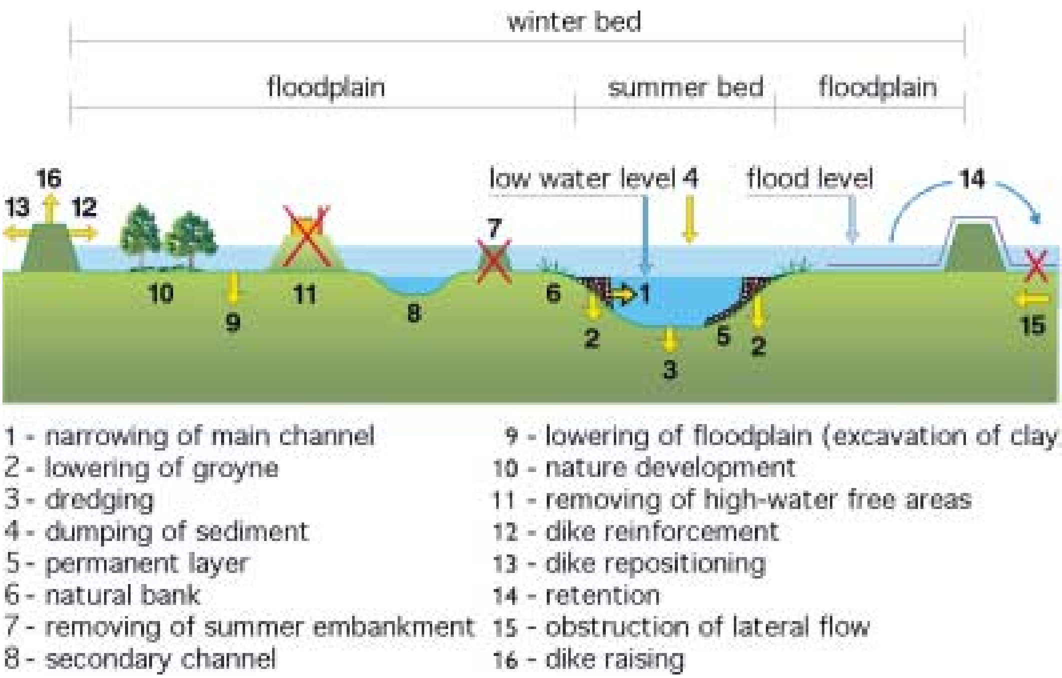

Figure 2. Possible measures to reduce flooding risks.

that floodplains along the Rhine are the mere margins of the shipping highway constituted by the channel, the lowering may be regarded as a 'resetting' of succession on a smaller spatial scale. More specifically, as a resetting of the man-induced accelerated floodplain sedimentation in a way which distantly resembles the natural rejuvenation of floodplain morphology and vegetation succession. In this strategy, human interference is considered as alternative to natural rejuvenation by lateral morphological development. In other words: morphodynamics are substituted by 'anthropogenically added dynamics'/AAD (after Westhoff 1976). This explains the term 'cyclic rejuvenation', which is a process known from natural rivers, but which is now imitated with bulldozers.

To maintain a safety level of a 1:1250 years probability while facilitating a higher peak discharge requires that large areas be excavated. A very important question, then, concerns the sustainability of this strategy.

Firstly, this concerns the flood protection objective. Without enlarging the surface area of the floodplain, the sedimentation process will be speeded up by the excavations. After all: the lower the floodplain, the higher the sedimentation rate. In lateral channels it may even amount 5-10 cm/year. Thus, the discharge capacity decreases again, but we do not know precisely yet at what rate. Moreover, vegetation development will cause an increase of the hydraulic roughness of the floodplains, diminishing the discharge capacity by itself, but also interfering with the morphological development. How much natural vegetation succession can be allowed without conflicting with flood protection objectives?

Secondly, from the nature rehabilitation point of view, it is questionable whether the desired ecosystem types can develop on extremely lowered floodplains, whether a sufficient number of lateral channels can be allowed to develop, whether these channels are sustainable when the main channel is – and must be – fully regulated for navigation purposes, whether sufficient time is allowed for forest stages to fully develop before renewed lowering of the floodplain is required, etc.

'Living with floods' strategy
Many of the measures of the former strategy may prove to be only temporarily effective, unless intensive 'maintenance' is carried out to counteract the accelerated sedimentation. Moreover, the present floodplain areas of the rivers Rhine and Meuse may prove to be too narrow when peak discharges increase with more than 10%. In the long run 'room for rivers' may therefore require room in width instead of room in depth, or in other words, that large areas of former floodplains which were protected from flooding centuries ago are given back to the river.

The second strategy is illustrated by referring to the proposal for long-term river management by *WL*/ Delft Hydraulics in the study 'The Rhine on the long term' (*WL* 1998; Baan and Klijn 1998; Opdam 1998). This strategy focuses on dike relocation or (where possible) the removal of dikes to provide additional discharge and storage capacity to the river with the effect that the flood levels are lowered.

Because large tracts of land which are currently protected by dikes may become flooded, the land use should be adapted to the newly required temporary 'hydraulic function'. In other words, the strategy implies a change from flood protection to flood risk control by also delimiting the potential flood damage to economic goods, i.e. by 'living with floods'. It implies that land use and physical planning must be tailored to the dynamics of the river. By doing so, the river can behave in a hydrologically more natural and at the same time easier to manage and maintain way. Also it will make society less vulnerable to flooding. From a nature rehabilitation point of view it may be welcomed that the natural hydrological and morphological behaviour of the river may be tolerated again, whereas the land use along the river should become as flexible as necessary with a view to flooding.

The ‘Rhine on the long term’ proposal started with a separation of functions over the three Rhine branches. Navigation is concentrated on one branch, the Waal, only, which would allow lateral morphological developments along the other two branches. A bypass (‘green river’) is used to divert the extra discharge to the north through the IJssel branch. The two branches running to the west will receive no higher peak discharges than in the present situation.

Along the IJssel the active floodplain area is almost doubled in comparison to the present total floodplain area along the three branches, adding some 300 km². To create room for the excess water, 50 km of dikes have to be moved outwards, and to enhance natural behaviour of the river a further 30 km is eliminated completely. The IJssel partly runs through a natural valley, which limits the flood depths. Flood simulation using *Delft FLS* shows that a large area of the IJssel valley will indeed be flooded frequently (see Figure 3). However, the flooding depth remains less than 2 m, even at the deepest point. This means that many land use functions can still be permitted in the IJssel valley, for example agriculture and housing (Figures 4 and 5). In other parts, a natural and undisturbed succession of riverine and floodplain ecosystems can be allowed. Morphodynamics increase and hydrodynamics decrease, thus leading to an increase of the diversity in environments (Figure 3).

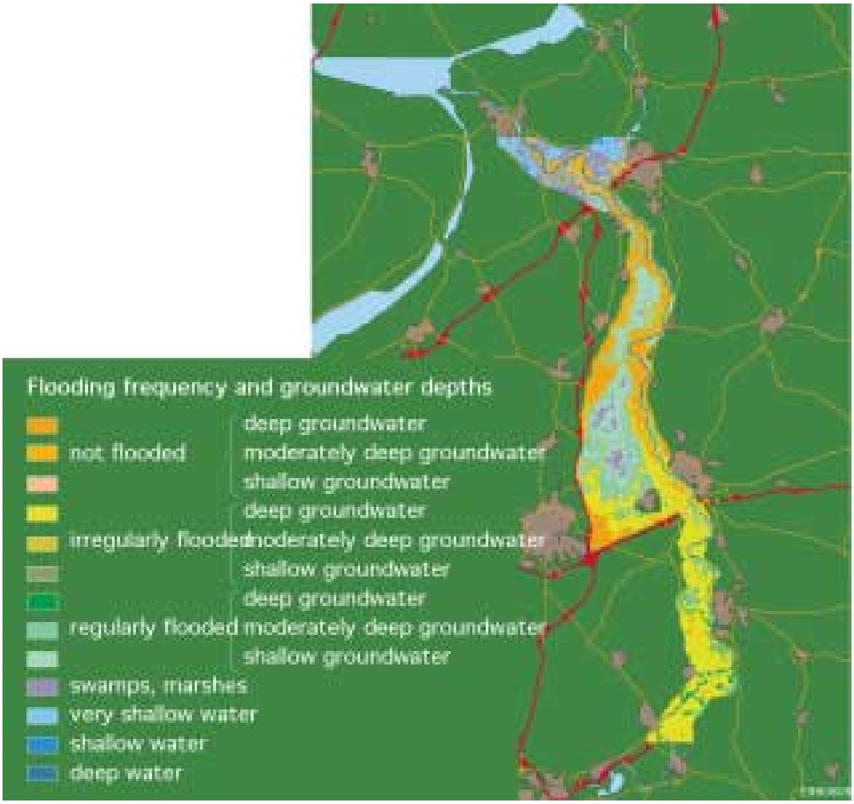

Figure 3. Ecological zoning (‘environments’) in the IJssel Valley in the ‘living with floods’ strategy.

The Waal branch of the River Rhine will retain its primary transport function. Moreover, the shipping capacity of the Waal can be increased to meet growing demands, but this requires that morphological processes are controlled even further. The third branch of the Rhine River, the Lower-Rhine, offers excellent opportunities for ecological rehabilitation of floodplains and recreation. To this end, the weirs and groynes are removed, shipping should be given up, but the dikes may remain.

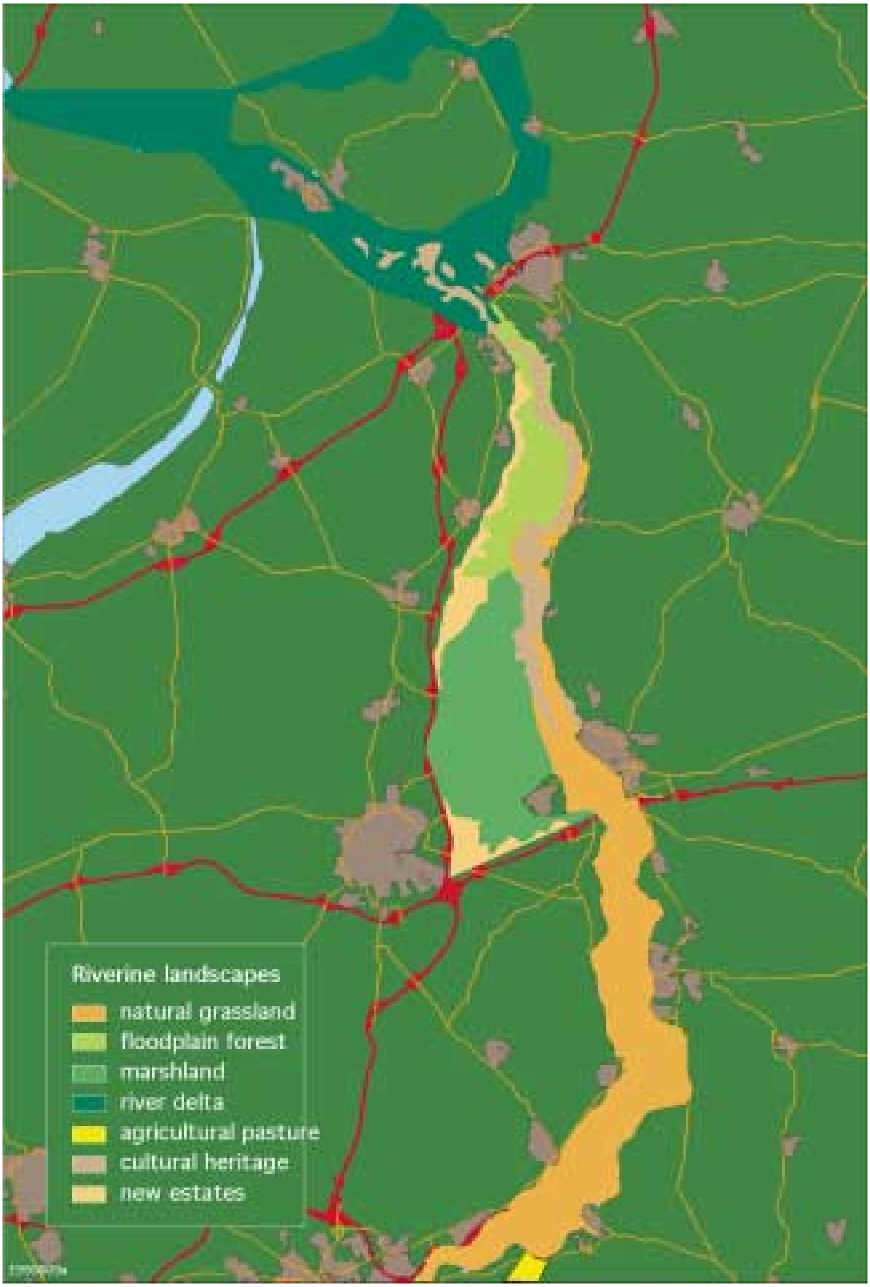

Figure 4. Proposed land use and ecosystem development in the IJssel valley in the 'living with floods' strategy.

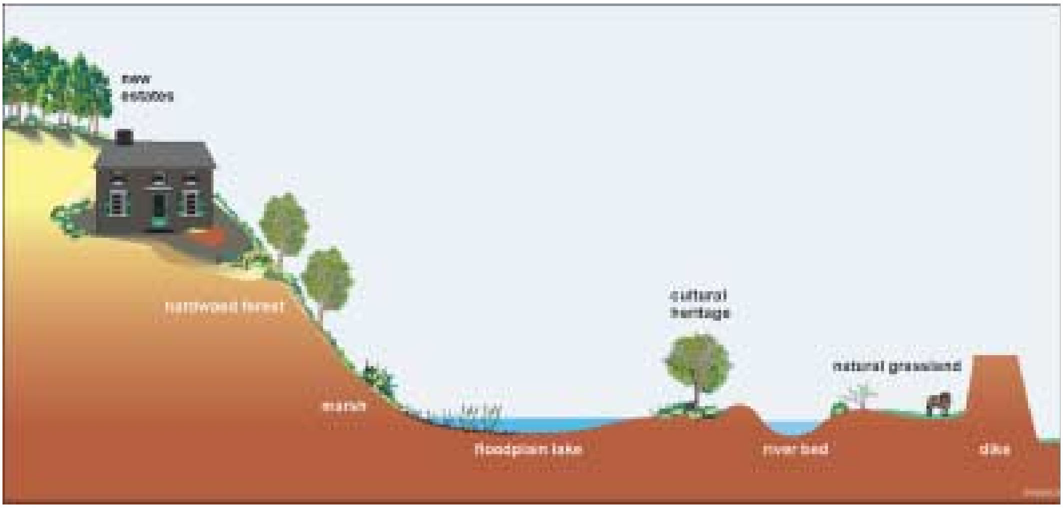

Figure 5. A cross section of the IJssel valley in the ‘living with floods’ strategy.

Key research questions

The two strategies introduced above were developed from very different starting points, through different processes, with different objectives and with different priorities. The first strategy was developed by the responsible authorities for the immanent problem of higher peak discharges: a real-life problem and a real-life strategy with inputs from all stakeholders. The second strategy was developed by an independent research institute, primarily in order to provoke discussions about the future of our river landscape at large. Both strategies are new, however, and there is no sufficient long-term experience with the measures proposed. Because the measures have large and very long-lasting impacts on the landscape and (a large) society’s appreciation of it, a sound *ex-ante* evaluation is needed before any action is taken. Particularly concerning the cyclic rejuvenation, we need to:

- investigate whether a sustainable safety level can be achieved, but also whether an ecosystem development can be induced which may satisfy the desires of future generations. To this end, we need to fully understand the interrelated development of morphology and vegetation succession in lowered floodplains and lateral channels.

As for the ‘living with floods’ strategy, it is necessary to:

- carry out a full policy analysis in which the ‘living with floods’ strategy is compared with more traditional alternatives for coping with increasing discharges. The assessment should, of course, include flood protection of economic land use functions and natural and cultural landscape values, but it should also take into account criteria such as flexibility and robustness.

These key questions are presently being investigated (see the acknowledgements).

Acknowledgements

This paper is based on various studies by *WL*/Delft Hydraulics and by its partners in The Netherlands Centre for River Research (NCR), as well as on experiences in policy analyses commissioned by the river management authorities. Financial support to further explore the two strategies discussed in this paper is received from the EC Interreg Rhine Meuse Activities Programme (IRMA).

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SPACE FOR THE RIVER IN COHERENCE WITH LANDSCAPE PLANNING IN THE RHINE-MEUSE DELTA

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1. Introduction

The Netherlands, once described by Napoleon as 'a silty delta formed by the great rivers of my empire', consist to a large extend of sediments deposited by the River Rhine, Meuse and Scheldt. In the decennia ahead this low lying country will have to face several crucial developments with respect to water management and land use changes. Effects of climate change point towards sea level rise and larger variations in river discharges, putting safety against flooding from both sea and rivers at risk. Moreover, behind the dikes, the soil subsides.
The current policy for the major rivers 'Space for the River', aims to maintain flood protection in the face of larger design discharges while at the same time conserving landscape, ecological and historical features. Because dike heightening will no longer be a feasible option for future risks, this policy implies that the rivers must be given more physical space to facilitate the larger variations in discharge capacity. Close co-operation with other countries along the Rivers Rhine, Meuse and Scheldt will be essential. For the Rhine an international flood action plan has been accepted (ICPR, 1998) and the EU-Interreg subsidises the Rhine and Meuse flood risk reduction programme IRMA.
In a series of exploratory studies opportunities are being examined for improving the river discharge capacity for the major rivers in The Netherlands. This paper deals with the spatial planning aspects of one of these studies i.e. the 'Integrated Survey on the Dutch River Delta'.

In The Netherlands, the low lying delta with tidal rivers in the western part of the country, may be facing great future problems. This is due to the fact that the delta area not only will have to deal with increased river design discharges but also with sea level rise. And it concerns an intensively used region. Not only the metropolis Rotterdam, but also smaller cities and large areas of agricultural land are being threatened. Far-reaching measures will be necessary to prevent problems in this river area.

For the longer term it proves rather difficult to find adequate and feasible solutions for the areas between the existing winter dikes in the delta. Over the centuries, dikes and land reclamation operations have constrained the riverbed within a narrow strip. Therefor, solutions also must be sought in measures behind the dikes. Many optional measures may result in spatial changes, such as the change in land use and landscape scenery. This needs very careful consideration. In the longer term, safety for rivers in The Netherlands will not only mean a change in the river or the river-bed, but also a change in the entire river landscape. Therefor a study called 'Space for the future' was carried out as part of the survey. The characteristics of the landscape were extensively explored. With the help of 'design-orientated research', directions for solutions were initiated in which feasible river expansion measures in the river landscape are being sought. These will be discussed.

The spatial impact of measures may be huge. To increase river discharge capacity is not only a hydraulic matter but also and mainly a spatial one in which social requirements and the public opinion

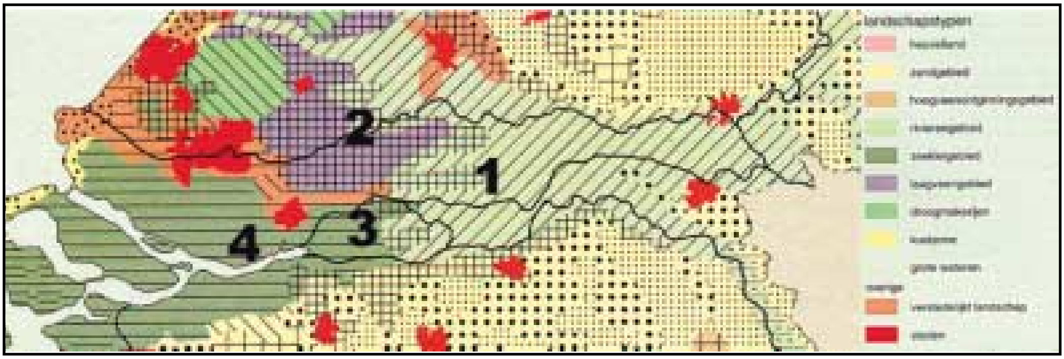

Figure 1. Study area with the various types of landscape (from Landscape Policy Document 1992):
1. River landscape, 2. Peat land, 3. *Biesbosch,* 4. Estuary.

Figure 2. Impression of the River landscape.

play an important role. Knowledge about the landscape in its widest sense places river expansion in a wider perspective. In addition, with the help of a 'design-orientated research', coherent spatial solutions could be formulated. Key aspects in formulating solutions are the coherent landscape structures of both the tidal river area as a whole, and the range of sub-areas. They offer opportunities to enhance both safety and spatial quality. Measures can be used to strengthen the individual identity of the river landscape, to stimulate existing or new functions, to restore lost spatial and ecological coherence, or to realise new coherence.

2. The Rich Palette of the River Area

The Rhine Meuse Delta shows a very varied landscape. In the transitional area from land to sea, the river has left rough patterns of various formations. Human activities and settlements have influenced these patterns. The design-oriented study is based on the landscape characteristics and the human habitation pattern.

The eastern part of the study area, called the *River landscape,* is characterised by natural, sandy river levees near and parallel to the river bed. Behind the sandy levees, clayey sediments were deposited as a result of low stream velocities after floods. Over the centuries, settlements developed on the drier soil of the natural levees. And some of them developed into towns and cities. The recently cultivated wet clayey flood plain areas now are being used as large open grasslands. They form a clear contrast to the more intensively used natural levees.

Further north-west, the river landscape changes gradually into the *Peat landscape.* Here natural water stagnation resulted in extensive peat land areas. Systematic ditch digging gradually transformed it into an open landscape with peat grassland parcels in a regular pattern. On the dikes and narrow natural levees, settlements appeared in a characteristic ribbon pattern.

The Peat and River landscape rather abruptly changes into a landscape of young marine clayey polders. These are situated in the area where the sea, through massive flooding, has washed away the peat and deposited clay. We hereby distinguish between the *Biesbosch* and the *Estuary*.

Figure 3. Impression of the Peat landscape.

The *Biesbosch* has a rather unusual origin. The area used to be part of the Peat landscape, but as a result of sea level rise, soil subsidence and concurrent floods, the peat was washed away and covered or replaced by thick layers of clay deposits. It now is a natural inter-tidal area of creeks and (partly reclaimed) banks in the transition zone between the River landscape and the Estuary.

The Estuary landscape originates from small islands that were diked and a continuous reclamation of accretions between sea inlets, coastal plains, systems of creeks and salt marshes. This continuous process of land reclamation with dikes and the old creek structures can still be recognised in the small-scale landscape pattern of dikes and small elongated polders.

All distinguished sub-areas have their specific origin and characteristic landscape structures. These characteristics are a decisive factor to judge whether hydraulic measures serve spatial qualities. In one area a measure may be feasible, whilst the same measure could be entirely undesirable in another.

3. Space for the River: Opportunities

River enlargement options have been looked for at the scale of the entire Delta and at the level of the distinguished sub areas (i.e. the landscape types).

Figure 4. The landscape of the Biesbosch.

Figure 5. Impression of the estuary landscape.

At the Delta level, measures were examined in terms of their effect to increase either storage or discharge capacity. Figure 6 gives an idea of the effect of these types of measures.

Per sub area, the feasibility of measures was first of all studied from the viewpoint of specific landscape characteristics. Besides, measures were also classified in terms of their effect on the storage and discharge capacity.

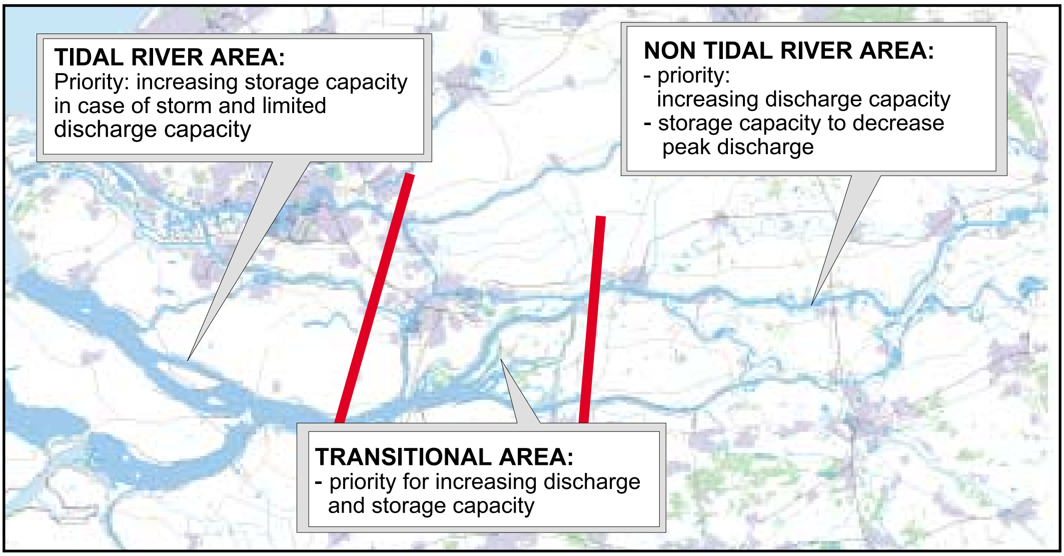

Figure 6. River enlargement in the delta as a whole.

Figure 7 shows the result of the designed oriented approach towards potential areas in the landscape types where effective and feasible measures could be applied in the Delta. On this map, a distinction was made between areas for increased discharge capacity, areas for increased storage capacity that directly influence river water levels, and potential areas for new river bypasses. The model doesn't reflect the ultimate design, but indicates where particular types of measures could be feasible.
The map again clearly shows the differences between the various sub-areas.

The *River landscape* has very limited opportunity for measures directly along the river; this due to the narrow winter bed and the adjacent settlement pattern Because of the scale of measures necessary to increase discharge capacity effectively, no sustainable solution can be found here within the existing spatial structure. Only new structures can offer opportunities.

Therefor, in the river landscape area mainly the large elongated river flood plain areas behind the natural levees are the potential areas for measures to increase discharge capacity. The creation of new bypasses, which are hydraulically very effective, is a possibility. However, their spatial impact is enormous and therefore need to be carefully designed and considered. Moreover, there is a relatively large amount of space along the river Meuse. The possibilities for retention in the river landscape are limited and not very effective.

The *Peat landscape* area doesn't offer many opportunities because of its highly vulnerable and small-scale structure. This is not surprising, as the water in the peat lands originally didn't flow but stagnated. At local scale there are possibilities for improving the local rainwater storage in case of heavy rainfall and limited pumping possibilities into the river.

In the *Biesbosch* there is a lot of space, both to expand the discharge and storage capacity. Here, the existing characteristics can be enhanced and lost ones restored.

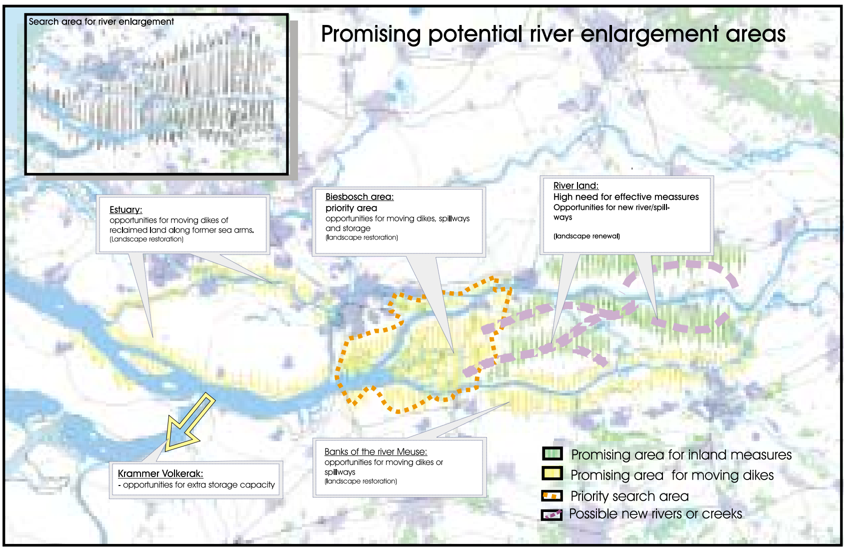

Figure 7. Potential areas and feasible measures are related to landscape characteristics existing qualities or structures are enhanced or new ones added.

A good measure in the *Estuary* is the diversion of water to the south, to the Lake Krammer-Volkerak and the Eastern Scheldt. This would greatly expand the storage capacity in times of a storm surge. This offers also possibilities for ecological restoration, such as fresh-salt water transition zones. Moreover, the most recently reclaimed polders in the lower Delta offer plenty of opportunities to increase storage capacity. Within the framework of 'Space for the River', and in combination with nature development, here riverbank zones can be created or restored, without damaging too many of the existing landscape qualities.

The, inner dike, reclaimed tidal creeks offer a very limited storage capacity, unless adjustments are made to them. However, from the scenic and cultural-historical value point of view, dike changes here are regarded undesirable. They are far better suited to playing a role in the regional water management.

4. Conclusion

The primary issue of 'Space for the River' is the maintaining of safety in the river area, also in the longer term. However, it concerns large-scale measures with great impact. It will sharply change the landscape, our living environment, both in the functional sense and in appearance. This implies that 'Space for the River' is not only a question of water management, but also a spatial planning issue, and should be dealt with accordingly.

Only too often water issues are worked out in a technical way. The effects on other functions and the landscape, for instance, are determined afterwards. Only integration of these aspects from the beginning on a mutually coherent basis, will result in better, integrated planning and design. This approach will do justice to both the safety issue in relation to the river, and the wider spatial and social issues in relation to the development and the functioning of our living space and its beauty.

The study 'Space for the future' has had important spin off. By putting the technical safety issue into a wider, spatial context, it has offered solutions in which both the primary safety issue has been solved, and the spatial quality and coherence of the Delta enhanced. Landscape characteristics have provided strong leads and a direction for the proper spatial structuring of river enlargement measures. They have dominantly determined which types of measures are feasible and in which areas.

The fact that, with this study, a number of potential areas have been identified where a particular type of measures could be feasible, does not mean that they **are** feasible. This will also depend on their tailor-made design for a particular area. The spatial characteristics of a specific location offer access here also.

The integration of landscape characteristics and spatial planning aspects at all project levels, can result in realising sustainable safety in close coherence with the conservation and enhancement of the spatial quality of our living environment. This not only applies to the Delta, but also to any other project in the river area.

RESTORATION OF FLOODPLAIN MEADOWS AND FORESTS

Results of 15 years of monitoring in natural and controlled succession on re-flooded areas in the Nature Reserve Kühkopf/Knoblochsaue/Upper Rhine

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1. Introduction

The 'Kühkopf' (northern Upper Rhine/Hessen) represents, together with the adjacent 'Knoblochsaue', one of Germany's broadest protected floodplain areas (Figure 1 and Figure 2). The central part of the Kühkopf, about 700 hectares (400 hectares of arable land and 300 hectares of forests), which had been protected against floods by summer-dikes until 1983, have been reconnected (dam breaking after the big flood of 1983) to the natural hydrological regime of the Rhine river and agricultural use came to an end. It was the beginning, for the first time in Europe, of large-scale floodplain restoration. To improve the knowledge in this field, permanent experimental plots for natural succession (without the influence of man) and controlled succession characterised by different soil conditions (i.e. different sand content) and their micro-relief have been established. To document the influence of game (wild boar, deer) on the course of succession, fenced and non-fenced areas have been established for each experimental plot. The network of experimental variants has been scientifically followed from 1986 onwards.

Figure 1. Rhine River.

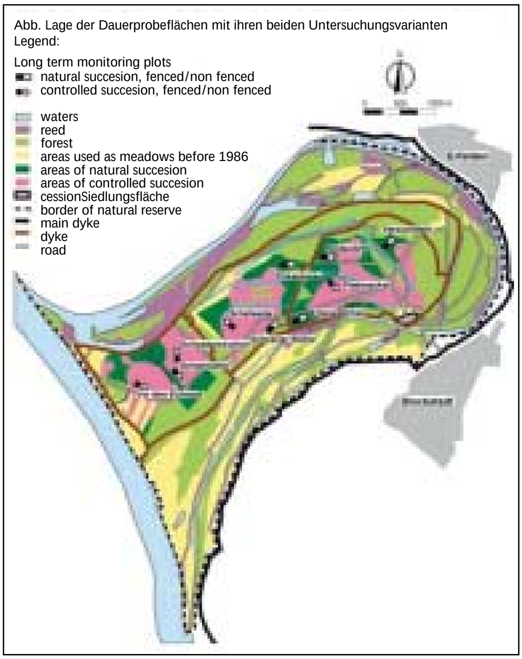

Figure 2. Study area.

2. Results

Succession went through various, distinct stages if one compares controlled to natural succession. Controlled succession (mowing once or twice a year to extract nutrients) developed from the stage of annual therophytes (in the first and the second year of succession) to the ruderal hemicryptophytes stage (in the third, fourth, fifth year) dominated by thistle *(Cirsium arvense)* and eventually to the grass-stage with herbs, the development of which began in the fifth and sixth year and is still enduring with different aspects in dependence of time, duration, height and frequency of flood. After the long summer flood of 1987 the thistle has thus rapidly declined (Figure 3). It was followed by the grass-stage with herbs (in particular different species of *Trifolium, Vicia, Medicago, Lathyrus* and *Chrysanthemum leucanthemum*) which develops micro-facial structures showing 'flowerbed' aspects. These structures existed in every scarcely changing area, with a domination of different grass-species. Regular mowing activities altered this micro-facial structures and the area's aspect became comparable to that of natural floodplain meadows. In the eighth and ninth year, the grasslands growing in more elevated places turned into *Arrhenatherum elatius*-like meadows (Figure 4). Next to the *Arrhenatherum*-meadows, but on the lower spots, the floodplain meadows are dominated by *Alopecurus pratensis*. In the lowest places, i.e. the more or less regularly longer flooded channels, one finds wet meadows with *Poa palustris*.

In contrast to the areas of controlled succession one may observe a slower although more continuous development on the natural plots. From the very beginning, willows (*Salix alba, S. rubens, S. viminalis*) and black poplar (*Populus nigra*) settled along with other herbaceous pioneer plants on open virgin

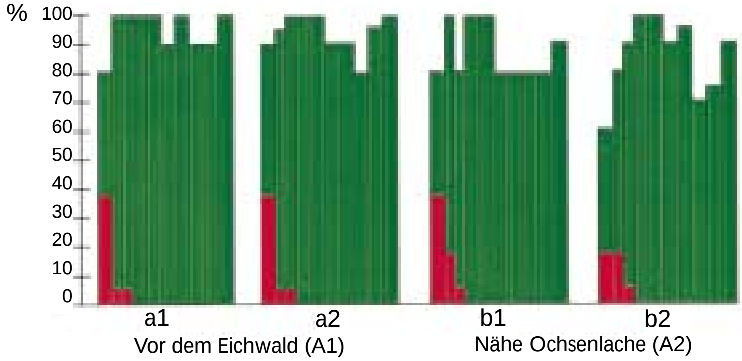

Figure 3.

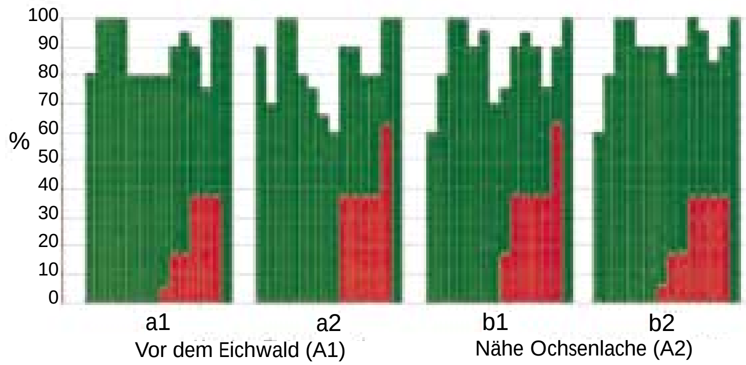

Figure 4.

soils. In the following years they were completed by species of the hardwood forest. The first plants of hardwood floodplain forests were *Cornus sanguinea, Crataegus monogyna, Ulmus minor, Fraxinus excelsior* and the oak *Quercus robur*. The present stage of natural succession on abandoned agricultural lands is a mixture of tall-herbaceous vegetation with different shrubs and trees, characteristic of soft- and hardwood forests. In the area of the dike breaking, on about 4 hectares, the soil was covered with sand. This is where, unique in Europe, the natural development of a softwood floodplain forest from the pioneer stage with *Salix alba* and *Populus nigra* and the transition to a hardwood forests with oak, elm and ash may be observed.

Because of the former high deer density, oak regeneration revealed to be extremely restricted. The regulation of game stocks through hunting management, however, has considerably improved the situation.

3. Conclusions

- It clearly showed particularities of floodplain succession differing from the development in humid fallow lands outside the floodplain. This difference is caused by the coincidence of the flooding factor with the other ecological conditions;
- Succession progresses very rapidly in the former floodplain zones and follows different stages from the initial pioneer therophytes to different structured stages of herbs and grasses;
- After about 15 years, the structure of the grasslands became more and more comparable to the aspect of typical meadows, but the stability and structure of typical floodplain meadows is still not reached;
- The evolution of the meadows is also conditioned by regular mowing. This measures are important for the extraction of nutrients from the former agricultural lands. Seeding accelerates the transition to the initial phase so that there is no ruderal stage. After 6-7 years the evolution of seeded and unseeded plots is the same;
- The diaspore bank of the soil plays an important role in the evolution of the area. A considerable genetic potential, with numerous rare and endangered species, can be activated under certain circumstances. Species like *Verbascum blattaria* (threatened by extinction in Hessen) and other rare species such as *Potentilla supina* and *Hyoscyamus niger* have been observed in the plots. The orchid *Anacamptis pyramidalis* occurred as well;
- The deciding factor is the restoration of a flooding regime being as near-natural as possible. As regards a succession towards a floodplain habitat, the importance attached to the more frequent small floods is just the same as for the more rare but significant floods. If the shorter and more frequent floods are eliminated, the succession development may temporarily be inverted and lead to communities which are untypical for floodplains.

The experience from the restoration project on Kühkopf is very useful and constitutes an important base for floodplain restoration projects on other European rivers, like the Rivers Elbe and Danube.

'ZONING PLANS' A NEW POLICY TOOL FOR INTEGRATED WATER MANAGEMENT OF FLEMISH WATERWAYS

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Abstract

'Zoning plans' are a new strategic policy instrument for the Flemish Waterways and Maritime Affairs Administration (AWZ) to develop and record a vision on the multiple functions of waterways. This initiative fits into the aims of integrated water management. Amongst other strategic objectives, AWZ wishes to play a key role in co-ordinating the management of freshwater reserves in Flanders and in promoting nature conservation and nature restoration along waterways.

The Institute of Nature Conservation was contracted in 1998 to elaborate an ecosystem vision and nature rehabilitation scenario's for the future of four large river-valley systems: Bovenschelde, Durme, Grensmaas and IJzer. The aim of the studies is to designate zones where nature conservation should become the primary function, zones where nature is equally important as other functions (for instance interwoven with agriculture) and zones where nature has a low priority. In this paper, the methodology and the results are discussed for the River IJzer.

On the basis of such 'zoning maps' for the most important functions of waterways, finally AWZ wishes to develop and execute a global policy and management plan for all Flemish waterways with much more attention for nature conservation and nature restoration than at present.

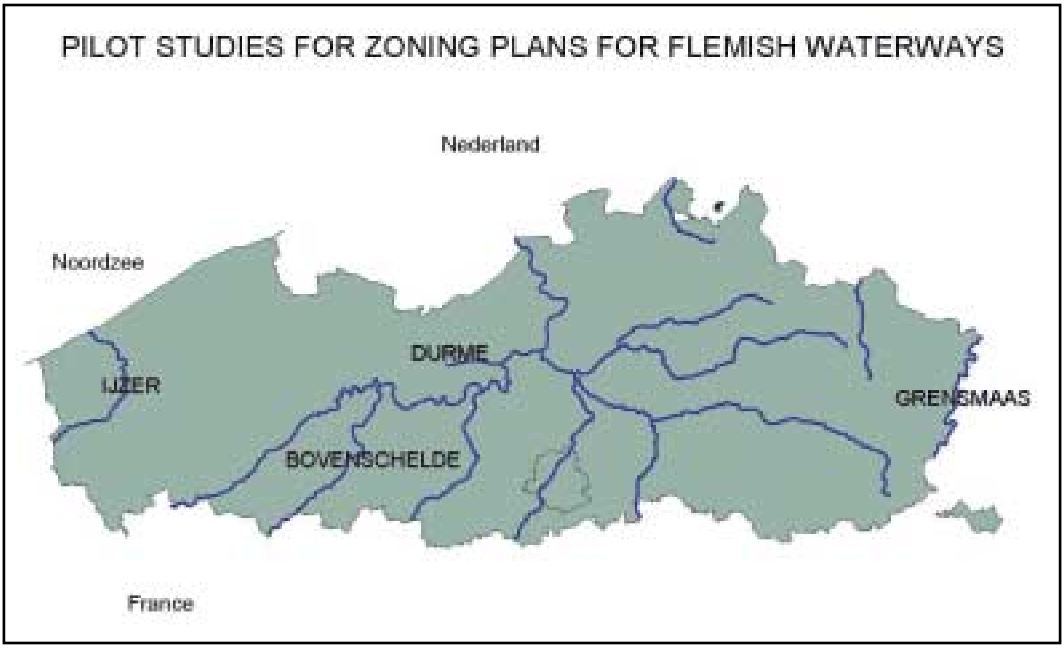

Figure 1. Pilot studies for zoning plans for Flemish Waterways.

1. Introduction

The human influence on river systems in Western Europe is enormous. Also in Flanders, rivers were straightened and embanked and floodplains were cultivated or build-over. Consequently the ecological value of our river ecosystems declined. The need for an integrated water management approach was enhanced by problems with large floods during the last decade and the need for larger fresh water reserves in demand of several branches of society: industry, agriculture, drinking water, recreation and last but not least nature.

An integrated water management needs to establish a multi-functional approach. Functions such as water supply, nature, economy (shipping, industry, agriculture), recreation, space and landscape should be considered. A ‘zoning plan’ should be the result of a careful balance of these different functions, with an optimal spatial and functional interweaving within the planning framework of the Flanders Spatial Structure Plan (Strubbe 1999) and without exceeding the natural carrying capacity of a river system or waterway and its surroundings.

In order to provide substantial knowledge for these zoning plans, the Institute of Nature Conservation is elaborating ecosystem analyses and future visions for the nature function. Questions to answer in these studies can be summarised as follows :

- Where are opportunities for nature conservation and restoration along the river/waterway ?
- To which extend is spatial and functional compatibility with other functions possible ?
- Where should nature become the primary function, where can nature be indicated as equally important as other functions and where is nature only of basic importance ?

2. Methodology and Results for the River IJzer

Ecosystem analysis

The River IJzer is a small lowland stream which rises in France with a total length of only 76 km, of which 45 km lies in Flanders. It runs through two cities: Diksmuide and Nieuwpoort where it enters the North Sea. Morphological and hydrological characteristics divide the river into four parts:

1) A narrow, natural valley of about 500 m width until Lo-Fintele;
2) A part, straightened in the Middle Ages, with a large flood plain on the right side up to Diksmuide;
3) A meandering and embanked zone without valley until Nieuwpoort;
4) A maritime zone with salt marshes at Nieuwpoort.

Figure 2. The IJzer in normal conditions and during winter floods.

Hydrological conditions are as follows:

- The water level is artificially kept at 3.14 m TAW (shipping) (AWZ 1999);
- Large changes in flow rate occur corresponding to precipitation;
- Annual winter floods cover up to 3000 hectares of the valley, while in exceptional conditions this can rise up to 5000 hectares (winter of 1993-1994) (Figure 2);
- The River IJzer has a medium water quality with high levels of N and P mainly originating from agricultural run-off which are resulting in eutrophication problems.

Agricultural intensification is the main cause for fragmentation, desiccation and pollution resulting in a large ecological degradation and disappearing of natural river habitats such as species-rich meadows and marshes. 74 % of the surface of the IJzer valley consists of meadows, of which only 2 % still belongs to the typical *Calthion-* or *Alopecurus* type with high ecological value. The remaining part

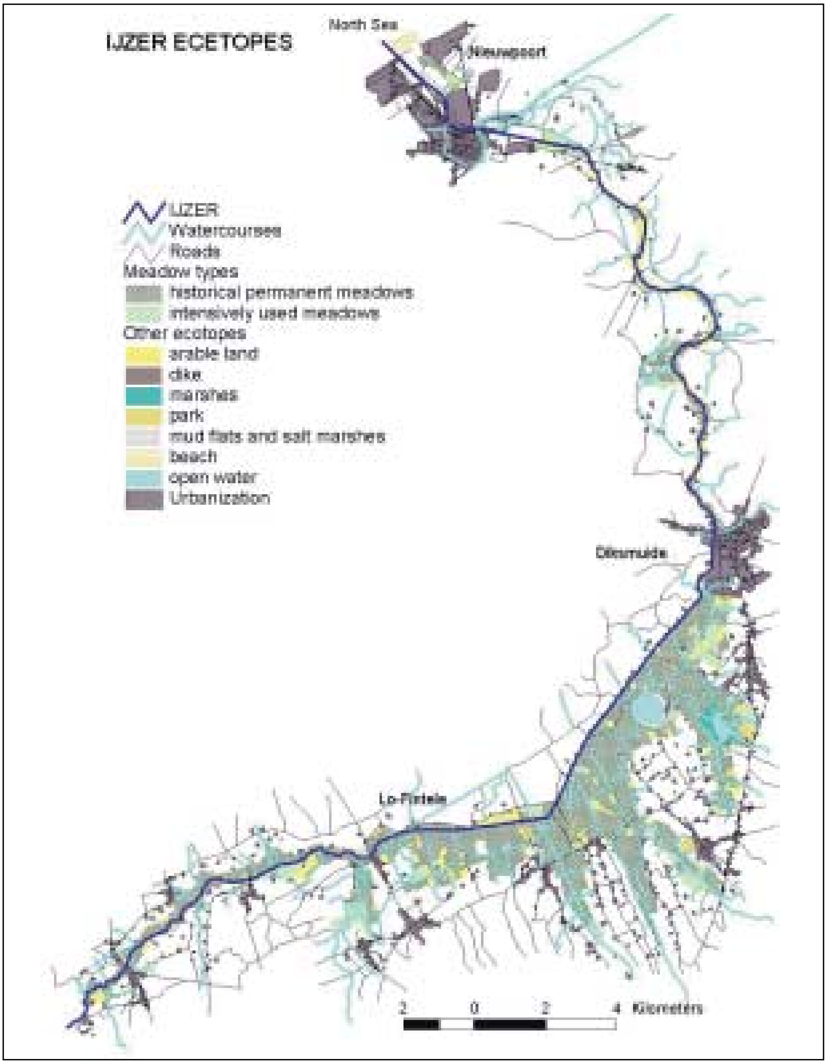

Figure 3. IJzer ecotopes.

includes only relicts of these types. Marshes and open water occupy only 1.4 % and 3 % respectively of the total valley surface.
Although the botanical value of the area has seriously degraded, the IJzer valley remains of great ornithological importance. The number of waterfowl and breeding birds justifies the designation as Special Protection Area under the EU Bird Directive and as Ramsar Site (Devos 1998).

Ecological objectives and preconditions

The objectives for nature conservation and restoration (Demarest 1993; Decleer *et al.* 1995 and Devos *et al.* 1997) can be outlined as :

1. More space for water and nature with the conservation of floodplains and the restoration of natural wetland habitats such as marshes, wetland meadows and wooded marshes;
2. Optimal development of ecological characteristics of the river ecosystem with the restoration of dynamic processes such as erosion/sedimentation of riparian zones and meandering;
3. Amelioration of corridor functions between nature areas;
4. Sustainable nature management.

Preconditions are:

1. Protection of urban zones against floods;
2. Maintenance of the existing sluice-valves to the North Sea at Nieuwpoort;

Figure 4. Target meadow vegetation with *Lychnis flos-cuculi* and *Rhinanthus augustifolius*, for some parts of the river plain.

3. Possibility for navigation (300-600 ton ships);
4. Implementation of international (EU Habitat and Bird Directives, Ramsar convention) and national (water quality, nature decree) legislation.



Figure 5. Restoration of natural riparian zones is proposed.

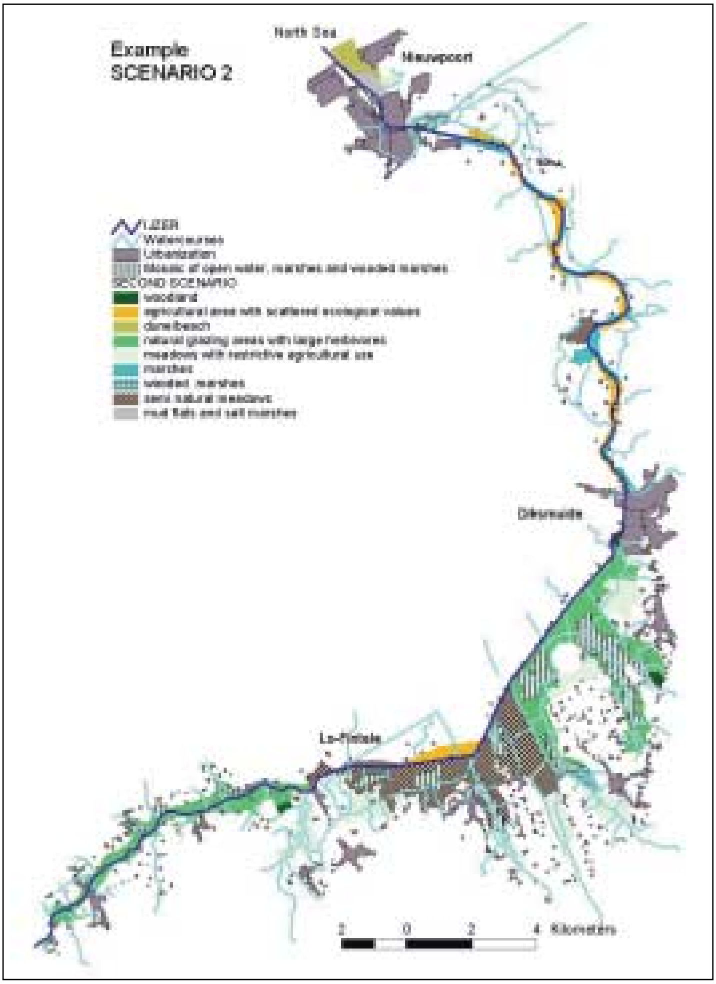

Figure 6. Example scenario 2.

Nature restoration scenario's

These ecological objectives were translated in three nature restoration scenario's with each a different level of ambition. Figure 6 illustrates the second scenario.

Each scenario was then transformed into a plan with indication of the zones where nature conservation should become the primary function, zones where nature is equally important as other functions (for instance interwoven with agriculture) and zones where nature has a low priority (see Figure 7).

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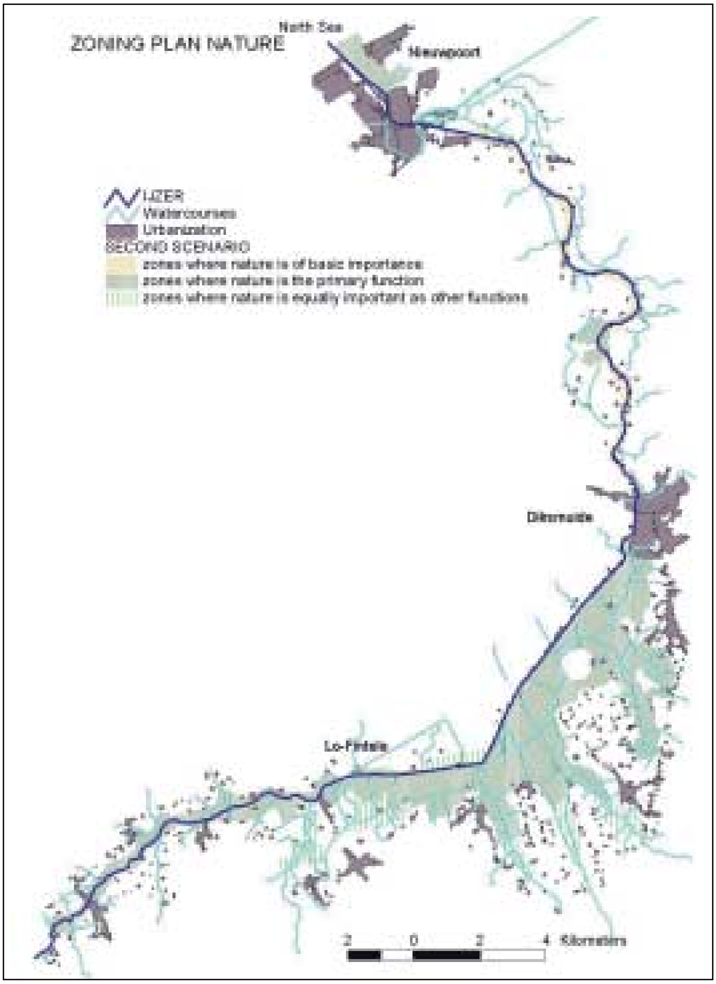

Figure 7. Zoning plan nature for scenario 2.

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SKJERN RIVER RESTORATION PROJECT

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Abstract
The 'Skjern River Restoration Project' is the largest river restoration project in Northern Europe. The lower reach of Skjern River was completely drained and converted into farmlands 40 years ago, and the river was dammed. The restoration project has been under consideration for 12 years due to concerns about the environmental impacts of the drainage scheme. In June 1999 the restoration works were initiated with a budget of approximately 35 million US$, including land acquisition and all work to be done on soil, water and roads.
The design was based on the principle of authenticity, which required extensive historical and geomorphological investigations and analyses of the river and the bordering landscape. As the river has a high sediment load and a low gradient, it formed a characteristic 'inland delta' before the regulation. This dynamic system is being re-established in about half of the valley.
Furthermore, the design had to account for protection of sensitive flora and fauna, in particular for the natural stock of Atlantic Salmon Salmon salar, which is the only remaining wild stock of salmon in this part of Europe.

1. Introduction

The Skjern River Restoration Project is the largest river restoration project in Denmark. It includes the lower 19 km stretch of the river and a floodplain area of 2200 hectares. Implementation of the project has been in progress since June 1999, after a twelve year period of planning, stakeholder hearings and land acquisition.
Skjern River is the largest river in Denmark by volume, having a catchment area of 2500 km^2 and a mean flow of about 35 m^3/sec. It is located in Western Jutland (Figure 1), in a humid temperate climate. The catchment is a lowland area, most of which consists of intensively cultivated farmlands. The estimated sediment transport of the river is 30 000 tonnes/year, and nutrient transports are about 5000 tonnes N/year and 100 tonnes P/year.

The river discharges into Ringkøbing Fjord, a shallow coastal lagoon, connected with the North Sea by a gate, which eliminates tidal influence.
The floodplain was systematically drained and the river enclosed between dikes between 1962 and 1968. Until that time the floodplain had been managed as meadows, used mainly as hay-fields.
The floodplain had been formed partly by marine deposits and partly as an inland delta created by the sediment transport. Through the 19th and early 20th century, some minor regulation schemes were performed in order to secure hay production and grazing.
The main regulation and drainage scheme in 1962-1968 effectively regulated the course of the river and developed the lands for intensive farming, reducing the meadows and wetlands to small, mostly marginal sites (Figure 2). The total area included in the drainage scheme was 4000 hectares.

In order to control the sediment transport of the river, its longitudinal profile was adjusted with a constant slope. Therefore the regulated river runs at a high level in the floodplain, and it was found

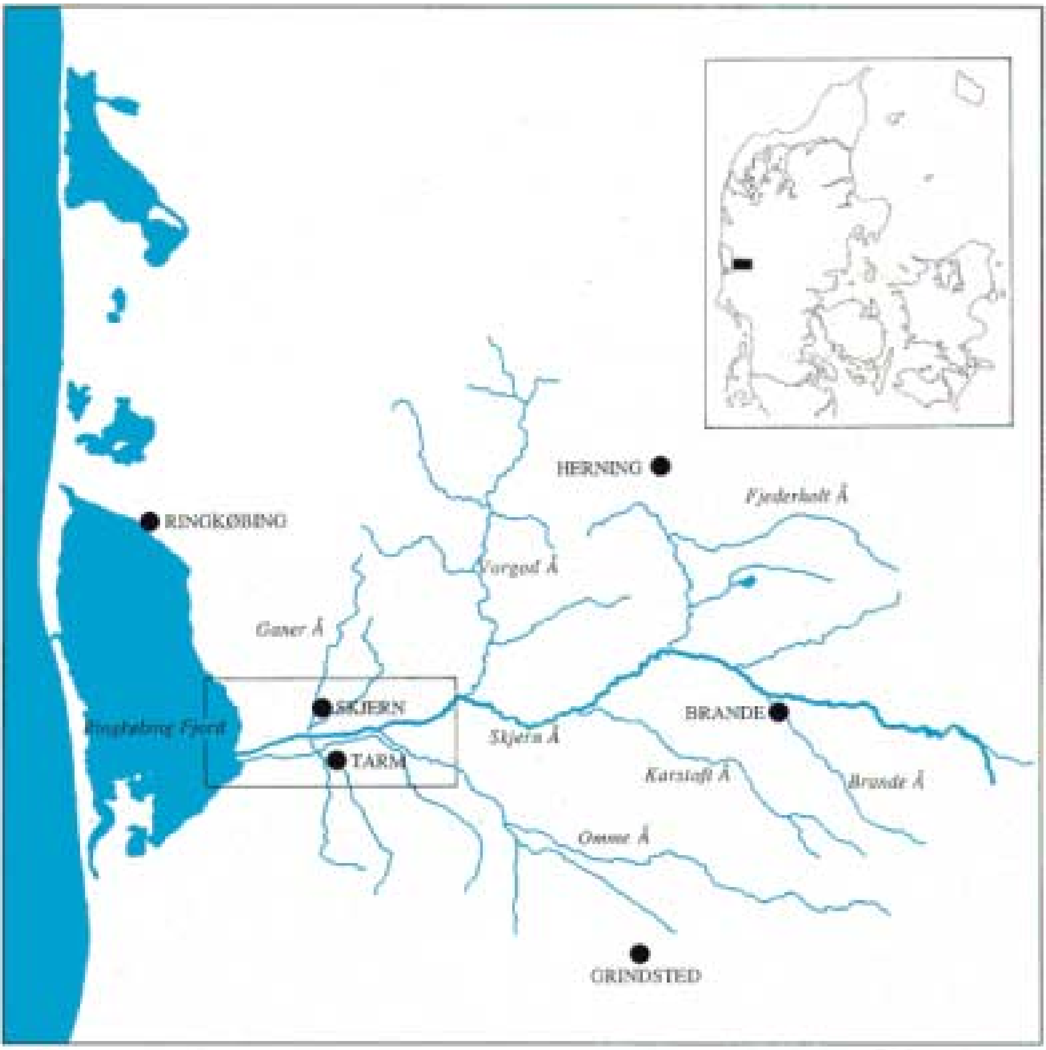

Figure 1. Skjern River. The project area is indicated by a rectangle.

favourable to collect local tributaries in a parallel channel at a lower level. Still the drainage water from the lower level of the floodplain has to be pumped to the channel (Figure 3). Several crossovers have been constructed for drainage channels and tributaries to the Parallel channel.

2. Restoration

This fairly complicated infrastructure has influenced design of the restoration in various ways and has put certain constraints on the delimitation of the project area.
The idea of the restoration project was based on an increasing environmental concern, which had started already before the regulation and grew from the experience of the actual impacts of the regulation.

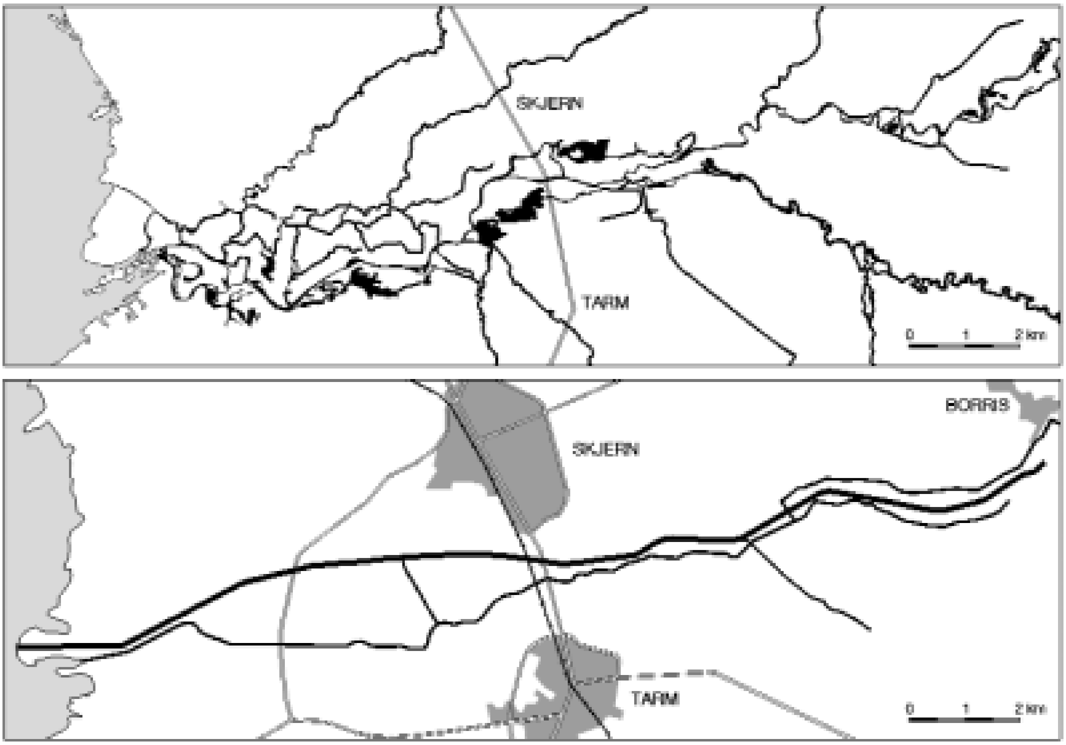

Figure 2. The floodplain before and after the regulation.

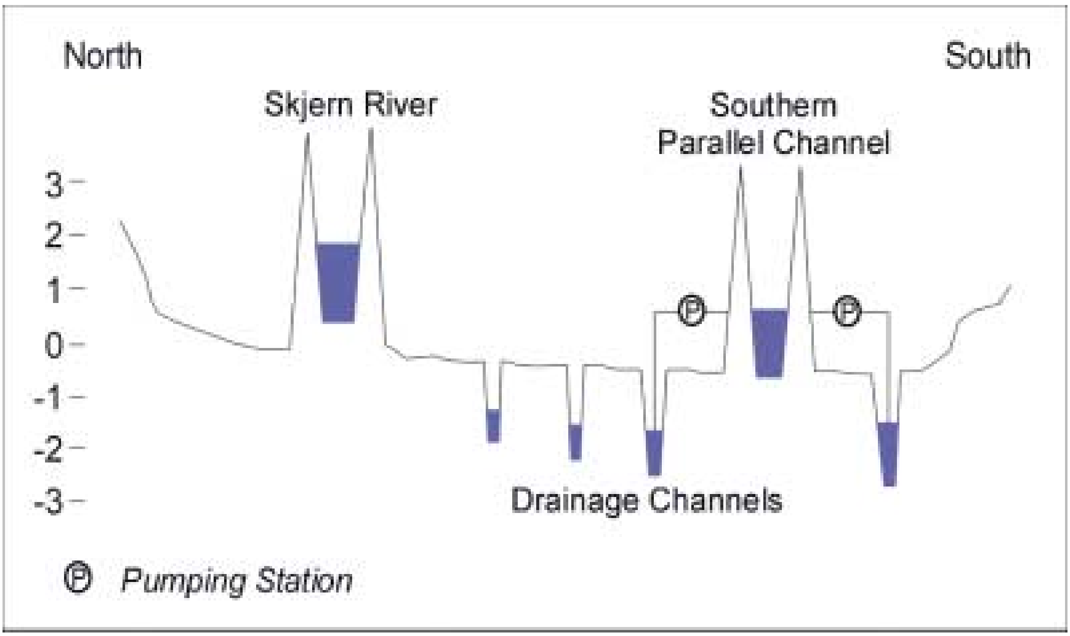

Figure 3. Schematic cross section of the drainage scheme.

An intensive leakage of ochre occurred, mainly from the central part of the floodplain, nutrient leakage increased, while the previous retention of nutrients brought in by the river increased.
The dramatic decrease of natural habitats and the regulation of the river affected many species of flora and fauna, including a rare wild stock of Atlantic Salmon.
The dynamic floodplain system that was lost by the drainage was unique in Denmark.
Further, it became apparent after some years that a major part of the drainage scheme was suffering from land shrinkage, caused by oxidation of the organic soils. The most affected areas were found to subside up to one meter in 20 years. This meant that considerable future expenses for upgrading of the drainage system and increased pumping height had to be foreseen.
In 1987 the various concerns lead the Danish Parliament to the decision to initiate conceptual studies with a view to restoring the natural course and the self-purification capacity of the river.
After consideration of a number of alternatives, an overall scheme for restoration and delimitation of the project area was agreed upon, and land acquisition for the was initiated in 1988.
Surveying and detailed design started in 1995, when sufficient land had been acquired to ensure the basis for the restoration.
After presentation of the design, stakeholder hearings and Environmental Impact Assessment, the restoration project was finally approved by a public works act of the Parliament, and the implementation works started in June 1999. The works are scheduled to be completed at the end of 2002.

The final design was based on the following objectives:

- Restore meandering and natural dynamics;
- Improve conditions for flora and fauna;
- Ensure high water quality in the river system and the Fjord;
- Improve the basis for outdoor leisure.

The design aims at restoring the natural floodplain dynamics as far as practical within the project area. The re-meandering follows old meanders when possible.
The final delimitation of the project area is based, as far as possible, on natural elevations and existing dikes, so only a few new dikes had to be constructed. Obsolete dikes and pumping stations are demolished and the remaining pumping stations are adapted to the changed hydraulic regime.
The widespread land shrinkage will of course give the floodplain a different appearance compared with the times before the regulation. Some of these areas are presently below sea level. During previous design phases it was planned to lead the river into these areas and let them be filled up gradually by sedimentation. This design, however, was found to provide an unacceptable predatory pressure on the Salmon smolts, as the shallow lakes will get large populations of Pike.
The final design overcomes this problem by letting the river pass the low areas behind low levees, which are designed to simulate the natural levee formation of the river, and which are flooded during high flows.
The meandering course of the river follows the old meanders (as mapped in the 19th century) as far as practical (Figure 4). In this way an authentic restoration is approached, the geomorphologic dynamics is re-started, and the earth works are minimised, as many old trenches are still present.
As the floodplain is crossed by several roads and a railway, the design has in general been adapted to fit existing bridges, except for two sites, where new bridges are built because the old meanders were found to be so characteristic for the landscape, that authentic restoration was the first priority.
Certain stretches of the parallel channel are kept as connection to tributaries in order to maintain a population of the red-listed water plant Luronium natans, and allow it to spread into the restored river.
The project area is planned to be maintained by cattle grazing and reed harvesting. This practice will

maintain the open landscape, which has been characteristic for West Jutland since pre-historic times. A mosaic of wetland and meadow types as well as patches of heath are expected to develop, depending on elevation.

A network of facilities for the public is planned, including foot and bike paths, parking facilities with information boards, and observation points for bird-watchers.

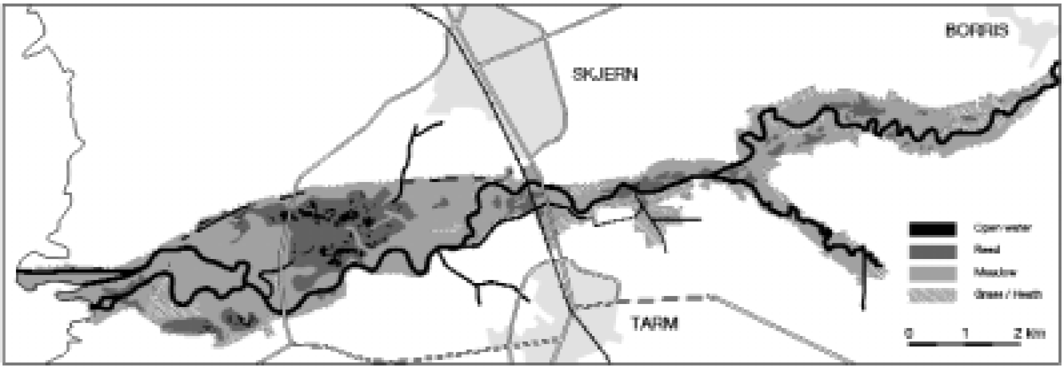

Figure 4. Outline of the restored course of the river.

RESTORATION PROGRAMME OF THE LOIRE BED IN THE 'PLAN LOIRE'

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Abstract
Plan Loire Grandeur Nature is a French national programme on the Loire basin environment, which began in 1994. It is managed by French state offices in co-operation with the other public authorities of the Loire basin :
- *The 'EPALA' (public establishment for the management of the Loire and affluents);*
- *The 6 regional authorities of the Loire basin;*
- *The 'Agence de l'Eau Loire-Bretagne' (Water agency of Loire-Britain basin).*

Our poster presents some examples of studies and works, realised by the state offices on the Loire river during this programme of restoration of its large bed.
The poster will describe :
- *Hydraulic, morphological (river dynamic and water resources) and ecological objectives of this programme;*
- *Physical and biological preliminary studies on the environments;*
- *Operation realised for the restoration, with works and monitoring of the impacts on the environment.*

1. Introduction, Context and Objectives

Plan Loire Grandeur Nature is a French national programme on the Loire basin (20 % of the France area, Figure 1), which began in 1994. It is managed now and developed from 2000 to 2006 by French state offices in co-operation with several public authorities of the Loire basin:
- The *'EPALA'* (public establishment for the management of the Loire and affluents);
- The 6 regional authorities of the Loire basin;
- The *'Agence de l'Eau Loire-Bretagne'* (Water agency of Loire-Britain basin).

In order to correct serious problems consecutive to massive sand extraction in the Loire River, like the water level drop, the 'restoration and maintenance programme of the Loire bed' was developed from 1994. This is now realised for a large part, on the Loire river and its main affluent 'Allier'. This programme has 3 major objectives:
- A hydraulic one, to limit rise in water level during floods (300 000 persons concerned in the middle Loire valley, Figure 2);
- A morphological one, to increase river dynamic and sediments and try to stop the water level drop;
- An ecological one, to restore biodiversity in the several units of the fluvial ecosystem (Figure 3).

In order to answer to these objectives, an action plan has been studied over the global course of the Loire and Allier Rivers, with an actual cost around 100 million Francs (or 15 millions Euros), for around 100 operations.

Figure 1. The Loire catchment area in France.

Figure 2. Saumur town in the middle Loire valley.

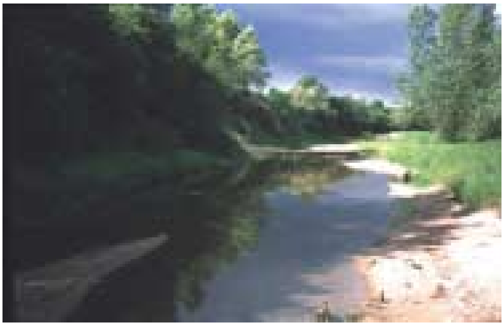

Figure 3. An old arm in the middle Loire valley.

2. Methods and Previous Studies

For each setting, an environmental evaluation is realised, defined with terms of reference for the different areas of the environments:

- A physical one, with hydraulic and morphological studies, based on topographical and hydrological layouts;
- A biological one, with vegetation, aquatic invertebrates and fishes layouts, completed by data on birds and some mammals populations if the area is large enough.

As a result of the richness of Loire River, more attention is paid to the species which are part of some regional, national or European control regulation, like beaver *(Castor fiber)*, common tern *(Sterna hirundo)* or otter *(Lutra lutra)*. These species, particularly beavers and terns, are present on the Loire bed in relatively numerous populations at several places, because the ecological conditions are very good for them.

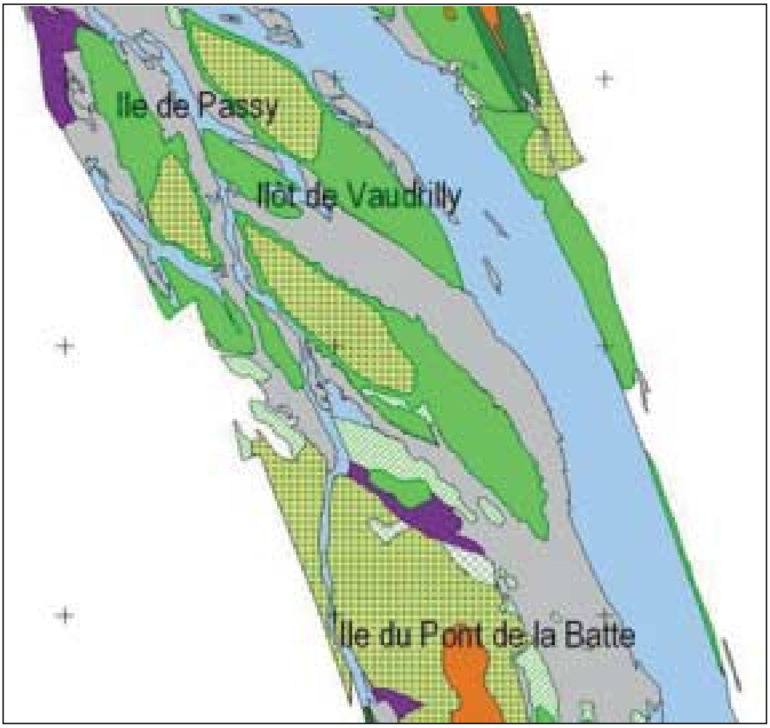

Figure 4. Vegetation map in Loire valley downtream of La Charité sur Loire.

Moreover, thanks to these studies, it is now possible to produce vegetation maps of the Loire bed, based on a typology of the vegetal and ecological groups (Figure 4). These maps are drawn with a GIS *(on Arcview)* combining aerial photographs, topographic plans, water levels and ground layouts. This information system is called *SIEL (Système d'Information sur l'évolution du lit de la Loire)*. When the *SIEL* will cover the Loire bed along its entire course, it will enable the state offices to manage this large river, and operate only on places where it is strictly necessary for the main objectives of the restoration programme. So the impacts will be less on the environments of the Loire bed.

3. Restoration and Maintenance Works

Training courses for the officers

Restoration actions are proposed for the state offices in order to implement the objectives of the restoration programme. Environmental impacts of these actions are assessed. These works take into account the vulnerability of the different biological communities, as demonstrated by the previous studies. It was necessary to create awareness among the different officers of these ecological features. Terms of references and a practical guidelines were written and put at state offices disposal in order to help them for better practices on the river bed. Then training courses were organised, on this subject for most of the officers.

Works on the ground

Different kinds of restoration works are implemented on the Loire bed like:

- Selective removal of soft-wood forests and shrubs (Figure 5);

- Scarification of sandy isles and banks, to remove sediments (Figure 6);
- Restoration of active and old river arms, particularly for the fishes reproduction and to revive river dynamic, reduced by the water level drop.

Monitoring of the results

Some areas are now monitored, with the same protocols on physical and biological environment. Evaluation of results in relation to the set objectives is very difficult, particularly to distinguish between the natural dynamics and the effects of the implemented works effects. The studies continue and scientific researches are now being develop for difficult subjects, like morphology and biological indicators.

Figure 5. Removal of soft-wood forest and shrubs in a large Loire arm.

Figure 6. An example of machine for scarification of sandy isles and banks.

4. Conclusion

Because of the massive sand extraction in the Loire River and all the difficult problems which follow, a 'restoration and maintenance programme of the Loire bed' was necessary to developed in the 'Plan Loire Grandeur Nature'. After more than five years of different studies and works, several methodological aids are at the disposal of the offices, directly applied on the ground.
The Loire river bed functioning is now better known, and programmes of monitoring has been beginning in the two last years.
These studies will enable us to better understand the different processes in the Loire River fluvial ecosystem, and finally better preserve its biological diversity.

CONSERVATION OR RESTORATION OF SOME FUNCTIONS OF THE LOWER SEINE RIVER ECOSYSTEM: A HIERARCHICAL APPROACH

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Abstract
Like many European rivers, the Seine River was nearly entirely channelled at the beginning of the century to enhance agricultural use of the rich alluvial soils, secure river navigation and prevent flooding. Today, the flood disturbance regime of the Seine floodplain is no longer maintained, and the Lower Seine River habitats undergo a strong pressure of human activities, namely agricultural. Habitat degradation along the Seine River caused by changes in land use (intensification or abandonment); modifications of the hydraulic system and deterioration of the water quality in turn affect the ecosystem functioning.
Experience on ecosystem restoration along the Seine river is scarce, but much methodological research is undergone to find out (I) what is the right scale for restoration, (II) what are the right tools to measure ecosystem function and the impact of management, and (III) how do we choose the best management targets (rehabilitation, conservation, restoration). Hierarchy theory and organisation theories constitute an interesting conceptual framework to answer such questions related to monitoring of spatial processes. Among the important functions ensured by riverine systems (notably the floodplains) our study cases on the lower Seine floodplains have focused on the biodiversity function (diversity of plant communities, avifauna, amphibians). Results of a hierarchical approach to the Seine study case have shown that these functions are closely related to each other and to the habitat quality (at local and landscape scale) of the riverine system. They confirm that restoration strategies of these species rich habitats and their functions implies an integrated study of the ecosystem at different scales.

1. Introduction

Most of the large river-floodplain ecosystems in the world have been altered by human activities (Bravard and Petts 1993). Large river-floodplains are unique and rich ecosystems whose integrity is maintained by hydrological dynamics and river floodplain connections (Junk *et al.* 1989). Their biodiversity is important for a variety of reasons having to do with their age, size, habitat complexity and variability (Ward 1998). Large rivers also link distant ecosystems, not only by being a migration corridor, but also by the transport (or retention) of water, sediments, nutrients, and contaminants.

The Seine River ecosystem has reached today such a degree of artificiality, whether one considers hydrology, main bio-geo-chemical cycles, fauna or flora or contaminant levels, that it is difficult to imagine what could have been the 'natural state' of this river i.e. the ideal reference. In the lower Seine valley, the impact of man has been felt since the Bronze Age with the first cultivation of the alluvial plain modifying the wetland functioning, followed by the construction of mills, navigation dams, sewage discharges. At the beginning of the century, the Seine was almost entirely channelled to enhance agricultural use of the rich alluvial soils, secure river navigation and prevent flooding (Lefebvre *et al.* 1974).

The conclusions of a recent research programme on the lower Seine basin (Meybeck *et al.* 1998) describe the Seine waters as among the most polluted of the world. The urban excretions bring high contents of metallic micro pollutants (Cadmium, Mercury, Zinc, Lead) and organic pollutants. The high nitrate and phosphorus contents also suggest a large part would also be attributed to agricultural activities in the basin. If much has been studied concerning water quality of, what can now be ironically described as a 'tube', little attention has been focused on the floodplain.

This paper presents some results and methodological approaches concerning the issue of restoration in the Seine Valley. Many of these results were developed under a national programme whose aim was to understand the functioning of French wetlands (Poudevigne and Alard 1997; Alard and Poudevigne 1999; Alard and Poudevigne 2000; Poudevigne *et al.* 2000; Leuven *et al.* 2000). The issue of this programme (*Programme National de Recherche sur les Zones Humides*, financed by the Ministry of Environment) is to propose methodological frameworks to counteract the degradation of wetlands in France.

2. Results

Landscape dynamics of the Lower Seine floodplain

The lower Seine floodplain is subject both to tidal and winter flooding. But in both cases, because the river is entirely channelled, flooding is mainly due to the rise of the water table level. Traditional agriculture has modelled the landscape of the floodplain to create what was called a *'bocage'*: a mosaic of wet grasslands for bovine breeding, hedges for cattle retention, ditches and ponds to control water movement, and a little crop on the driest lands. This landscape corresponded to what can be described as a highly organised system (in our case a high correlation between agricultural activities and natural conditions of the landscape).

During the last forty years, the floodplain has undergone a strong pressure of human activities. Changes in agricultural systems have led to both intensification processes (more crops, larger plots) and abandonment (of very wet grasslands, hedges, ditches). As the landscape changes, new habitats appear, but on the whole this landscape looses its specific character: it is what we would intuitively describe as degraded. Another way of presenting this is to say that the organisation of this landscape has changed. The landscape which was highly organised along a traditional agricultural pattern is today disorganised in the sense that it is not organised along the same pattern. Because organised systems are more stable (Kolassa and Pickett 1989), maintenance of species diversity and thus species co-existence in such landscapes is based on equilibrium mechanisms. This loss of organisation thus suggests deterioration of the 'health' of the River floodplain. Measures based on the information theory can be used to evaluate the organisation level of landscapes (De Pablo *et al.* 1988; Phipps 1999)

Assessing biodiversity: the need for a hierarchical approach

Conservation and restoration of nature implies measuring and monitoring nature. Biodiversity is a common attribute of an ecosystem, selected for such purposes. The difficulty of such studies lies in the selection of the biological component considered to be representative for our 'nature', the relevant scale at which this assessment can be made, and what is the right way of measuring this biodiversity. In our studies we have addressed three different biological components which are considered to be representative for wetlands: grassland vegetation, avifauna, amphibians. This paper presents only the results concerning avifauna.

A first field survey of avifauna in a wetland of the valley near the estuary showed the surprising result that though many habitats were degraded or had disappeared during the last forty years, the number of species had risen. A closer look at the results revealed that the species gained were only species found commonly in the Seine Valley. Concomitantly, many species found only in specific habitats of this wetland had disappeared. This confirms that number of species is not the only measure of biodiversity which needs to be considered. Our studies have underlined the need for a broader approach to biodiversity which includes other dimensions (structure, composition, function).

Scale is also an important consideration in conservation and restoration issues. The life cycle of a bird involves different scales of time and space. The daily search for food is a process which takes place at the habitat scale (a reed bed). Looking for a suitable nesting place every year is a process which takes place at the biotope scale (a wetland). Population emigration to suitable habitats is a process which takes place on the long term and concerns broad spatial scales (the Valley). The hierarchy theory (Allen and Starr 1982) suggests many new lines of thought for conservation or restoration issues. Each of these independent, but integrated processes, are linked to their own spatial and temporal scales. This suggests that conservation or restoration processes must be addressed at each organisation level. Higher levels have constraining effects (a wetland species cannot be in a wetland if the climatic context of the valley concerned is not appropriate), while lower levels have limiting effects (a wetland species will not be in a wetland which cannot provide the food it needs). Restoration measures thus need to restore all the levels addressed by the species. These levels are different for each species which implies choosing representative species of study. Spatial and temporal scales are linked: this implies that restoration of biodiversity along an entire river landscape can only be achieved on a the very long term. Even if the habitats seem to be properly restored, biodiversity cannot, on such scale, be expected to be restored on a short term.

3. Conclusion

What reference for restoration of the Seine valley?

Organisation and hierarchical theories provide a interesting framework for restoration and conservation issues. They underline the need for a multiscale approach. Hierarchy theory also gives the references as to what are the results which can be expected from the restoration measures chosen. Restoration strategies on a large spatial scale implies long term restoration. This brings forth a major issue in restoration strategy: which reference should the restoration aim at. In the case of the Seine Valley only two options can be proposed: either we aim at restoring the traditional agricultural organisation of the *'bocage'* landscape (forty years ago) or we aim at restoring the pristine organisation of the alluvial floodplain (4000 years ago). This is a question of time (the first option will take years, the second would take centuries), but also of economic sustainability.

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RIVER RESTORATION IN BAVARIA

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Abstract

The terms river rehabilitation, nature orientated river construction or ecological water construction reflect the efforts to restore sections of rivers and streams once constructed to improve for example land drainage with the result ,that typical habitats for wildlife, plants and also the recreational value of such rivers are today impoverished. The target of river restoration is to re-establish the natural abiotic conditions like morphodynamic and discharge as much an possible to ensure the ecological functions of the river system with a minimum of interventions by maintenance work. The model for restoration is orientated towards the potential natural condition (reference conditions) of the river and the flood plain

If there is limited space like in urban areas, the restoration may be restricted to a nature orientated modelling of the riverbed. In the open landscape, where land is available for restoration projects, the natural migration of the river channel including its solids transport can be supported and the habitats typical for this river and its flood plain can be enlarged.

For this new way of restoration it is essential to have a vision for the future of the river landscape. This vision and the targets for river restoration are depending from the existing demands like shipping, hydroelectricity, flood protection and land drainage for agriculture. They have to be presented in plans for river improvement and have to be discussed with different interest groups. Nature orientated river restoration requests the understanding of neighbours, farmers, fishermen and others.

The restoration of rivers and streams by supporting the natural migration cannot be fixed to time schedules. It depends for example from the bed building discharge. Therefore it is necessary to deviate from the usual administration praxis. The staff responsible for river restoration has to watch and support the sustainable development of the river with a 'knowing calmness' and new techniques controlling the migration of the riverbed

1. Results of River Construction Work

In the first part of this century many rivers and streams were constructed for the use of shipping, water power, flood protection of settlements, highways and agriculture. The results are geometric river beds with stone-paved banks, and drained wetlands. Aquatic and wetland habitats were especially negatively effected.

Today only 10% of the rivers in Bavaria can be classified as natural. In the two centuries, about 90% of the rivers were more or less technically constructed. The intensive pressure of land use becomes evident, not only for running waters, but also in the flood plains. Traffic lines, settlements and dikes reduce the retention volume for floods, drainage in the alluvial plain enables crop farming. The recreational value of such rivers is reduced (Binder and Wagner 1994).

One of the consequence is the loss of river and flood plain as an ecological unit. This result is a drastic decrease of habitats .This situation of our riverine landscapes becomes evident if we look at historical maps and survey the plant and animal species.

2. Reference Conditions, a Model for River Restoration

Rivers and streams with their inundation areas are formed by the natural characteristics of the drainage basin. Depending on rainfall and storage capacity the discharge is fluctuating. The power of running water and the amount of transported solids influence the morphological process like bank erosion and sedimentation, the rebuilding of riffles and pools and the migration of the riverbed within the alluvial plain.

The model for restoration describes the ecological function of a river system, its potential natural condition, that means the condition which could appear if the present human impact is given up. Rivers are called natural, if they are not polluted and can migrate freely in the floodplain with the undisturbed discharge and transport of solids. The vegetation along the river and in the floodplain is in natural succession from pioneer vegetation to alluvial woodland.

The continuous migration of the river bed and the changes of the structures in space and time lead to a continuos replacement of typical structures and habitats in and along rivers. This includes the movement of sand and gravel, of trees and shrubs, the erosion of steep banks and the sedimentation in flat zones. The natural laws of river development is this continuos process, which causes a variety of habitats and structures in detail, as well as the unity of the river landscape in the overall view (*DVWK* 1996).

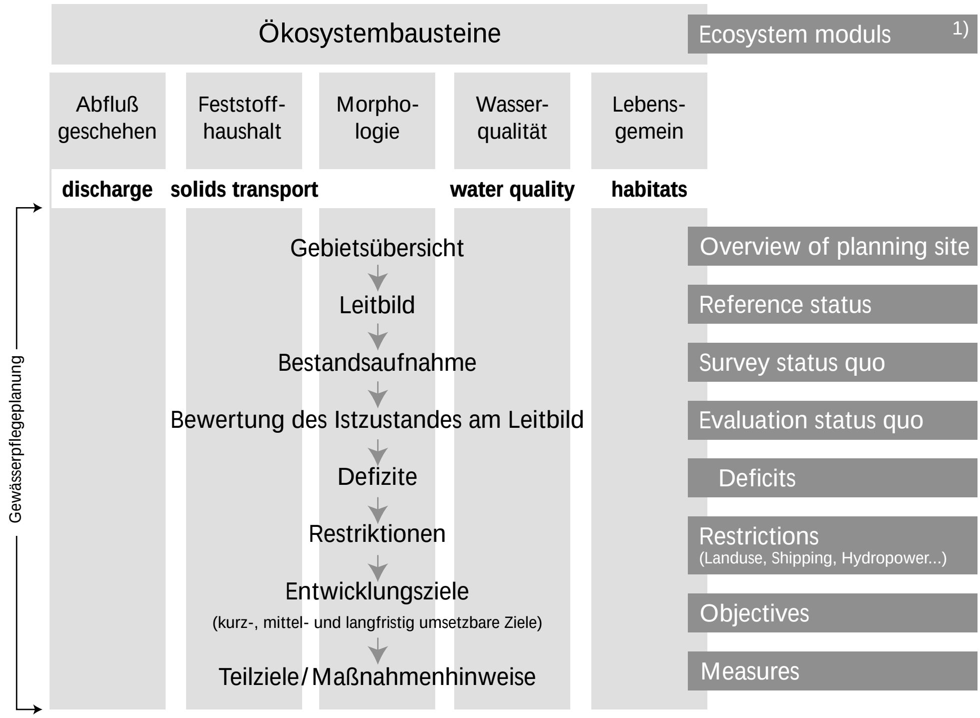
Along constructed and regularly maintained river sections the migration of the river bed is restricted. Bank protection stops the migration; pioneer habitats like gravel banks are lost. The once dynamic river system is changed to a more static system. Today the objective for river restoration is to restore the ecological functions with a minimum of intervention by river work. That means: bring back the dynamic processes. The most important condition to achieve this, is that enough land should be available.

3. Concepts for River Development

In Bavaria for more than twenty years river development plans were introduced. The objectives of these plans are to restore or to conserve river systems as far as possible and to preserve flood plains with their retention volume. By the comparison of the reference conditions, the given situation and the existing restrictions like dikes for flood control, weirs, etc., the development objectives can be set. Based on the survey of the present situation, the plan contains proposals for the restoration of the ecological functions. The guidelines for the planning processes for river restoration are shown in Figure 1. Based on the ecosystem models *'Abflussgeschehen'* (discharge), *'Feststoffhaushalt'* (solids transport), *'Morphologie'* (morphology), *'Wasserqualität'* (Water quality) and *'Lebensgemeinschaften'* (habitats) the steps of the planning process are shown.

The objectives for developing nature, like river-landscapes, include:

- The restoration of the unity of river and flood plain;
- The dynamic of discharge and river bed migration;
- The through-passing for aquatic organisms, for gravel and sand;
- The diversity of substrates and structures, which are typical for the river system;
- The variety of habitats connected to the river system and its wetland;
- The individuality of the river and its flood plain based on the natural characteristics of the drainage basin.



[1] Scenery is not an ecosystem modul but it is important to be observed.

Figure 1. Guideline for river restoration-planning process.

The planning scale depends on the size of the river, the objectives and the recommended measurements. Useful scales range between 1 : 5000 up to 1 : 25 000. The planning process should be interdisciplinary and should integrate other plans and programmes, like side plans, landscape plans, etc. The state offices of water management advises community and maintenance boards for the allocation of river development plans. Interests of fishery, nature conservation and of land owners, especially farmer, have to be respected.

The federal water law *(Wasserhaushaltsgesetz)* says in § 1: Rivers and streams as a part of the ecosystem are to be managed in such a way that they can serve for the benefit of the general public in harmony with the use by individuals and that every avoidable disturbance is excluded. For the citizens the river development plans offer the possibility to support a more natural development and maintenance of the river, to improve the recreational value and to protect and improve the aquatic and the wetland habitats. Agenda groups on regional level are formed to exchange the practical experiences about restoration projects with river engineers, nature conservationists, fishermen and raise the understanding for restoration projects *(LAWA* 1997*)*.

4. River Restoration within Urban Areas

The possibilities for the restoration of rivers in settlement areas are normally limited by the space and the need for the protection, for example of buildings close to the river, requires often hard measures of water construction with concrete or stone. Those river sections become impoverished regarding the habitats. Without additional space measurements for ecological improvements and enhancement, the landscape is reduced. Here, the use of biological engineering methods, like the combination of plants and stones or the replacement of weirs by ramps, are already the right step to improve the river system. An interdisciplinary team work supports ecological and structural solutions. These may include:

- To re-establish the through-passing at weirs;
- To widen the river bed;
- To plan river corridors;
- To use biological engineering methods;
- To support the native vegetation;
- To plant trees and shrubs;
- To build and improve habitats;
- To improve recreation along the river.

Sufficient space has to be available to plant trees and shrubs and to develop a woodland zone along the river.

5. Rivers in the Open Landscape

Constructed rivers, regularly maintained, are kept in a static situation. Natural rivers are formed by dynamic processes, which are caused by the continuos migration of the river. Wherever possible, it is recommended to restore the dynamic processes of channel migration. Due to a change of the agricultural land use, it is possible to take new ways in the treatment of natural rivers and streams. That means that were land is available the opportunity should be seized to re-establish the dynamic processes in such rivers. The needed land depends on the size of the rivers and its migration potential, which can range between some few centimetres and more than an meter per year. Information about the migration potential can be found by the evaluation of historical maps and aerial photos taken in the lasts decades and also by field survey. Usually a two- to fivefold sized width of the riverbed makes a sufficient corridor for bed-migration. The steps from a static back to a dynamic system are shown in Figure 2.

At the Isar River, south of Munich about 7000 m of bank protection were taken off in a pilot project (1998/99). The land for this restoration project is in the property of the State of Bavaria, which was helpful to start the project. The stones were broken down to gravel and given back to the river to feed the bed-load. Now the dynamic process of bed migration started again, the Isar widened its bed. Habitats for fish spawning, for birds breeding on the gravel-banks are back and the recreational value of the river section is increasing. Within two years, from 1997 to 1999 the width of the riverbed was increased with a factor 2.

6. Costs and Qualified Employees

Nature orientated development of rivers and streams can be a far better economic solution than using intensive engineering methods to constrain a stream’s course. Planning and construction are on a new way. The constructional measures are reduced to the removal of existing constructions and to selected interventions to control bed migration as far as necessary. A fixed time schedule for the development cannot be planned because it depends on the bed forming discharges (floods). This type of restoration of constructed rivers gives a new start to bring back the morphodynamic processes. The nature

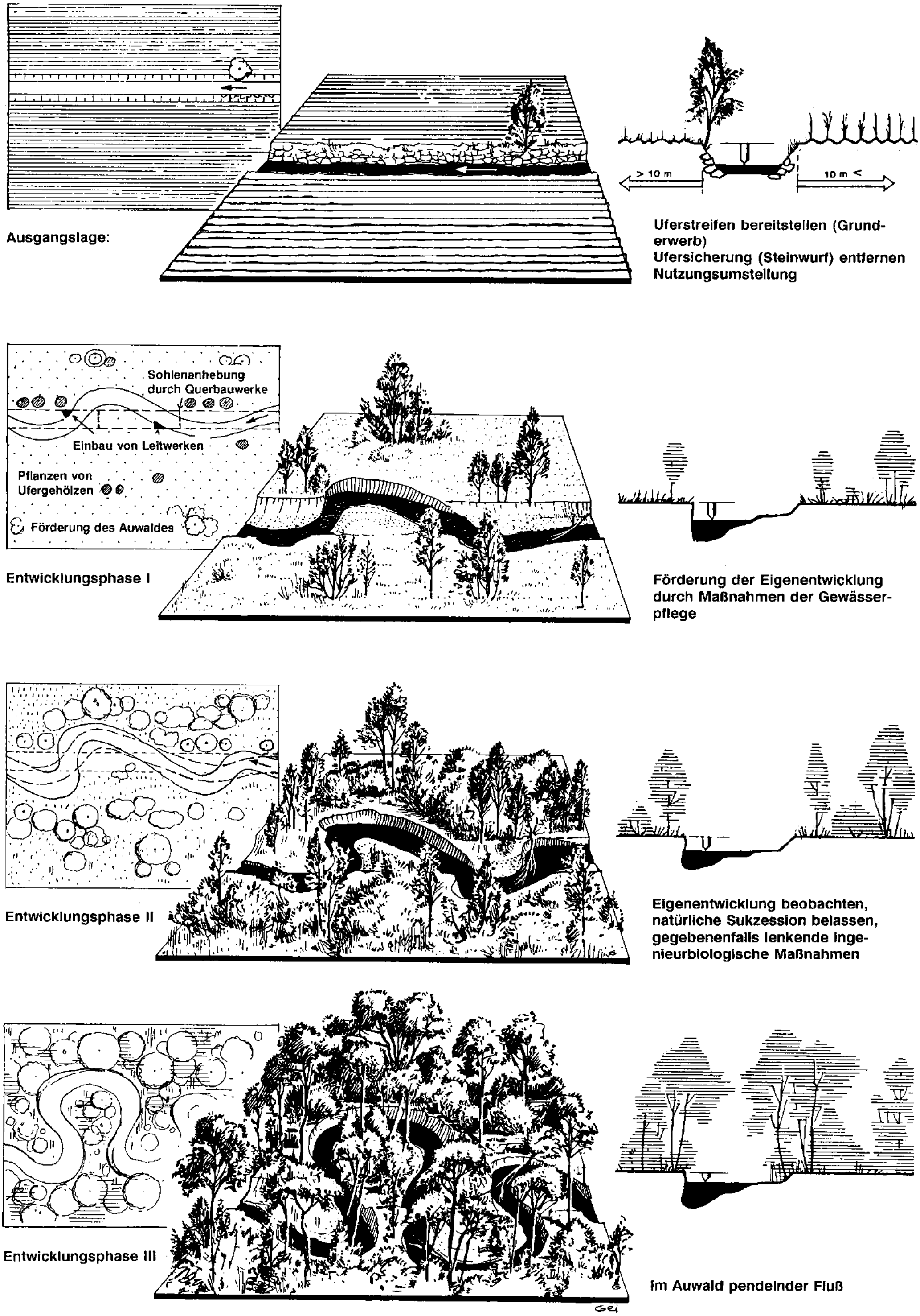


Figure 2. From static to dynamic. Steps of river restoration from a channelised, back to a natural river.

orientated, morphodynamic restoration of rivers and streams has to be controlled by skilled staff. This work needs experience and prudence of the involved personnel. They have to observe the restoration process with knowing calmness and intervene with ‘more brain and less stones’.

If necessary for the security of lives and goods, special protection measures has to be taken, like biological engineering. It may be reasonable to apply new ways of construction or to use old methods proven to be applicable. Figure 3 shows wooden trunks used to reduce bank erosion and to protect the land behind. The new way of river restoration means: Bring back the morphodynamic processes to the river and the flood plain and support carefully the process of self restoration *(STMLU* 1997*)*.

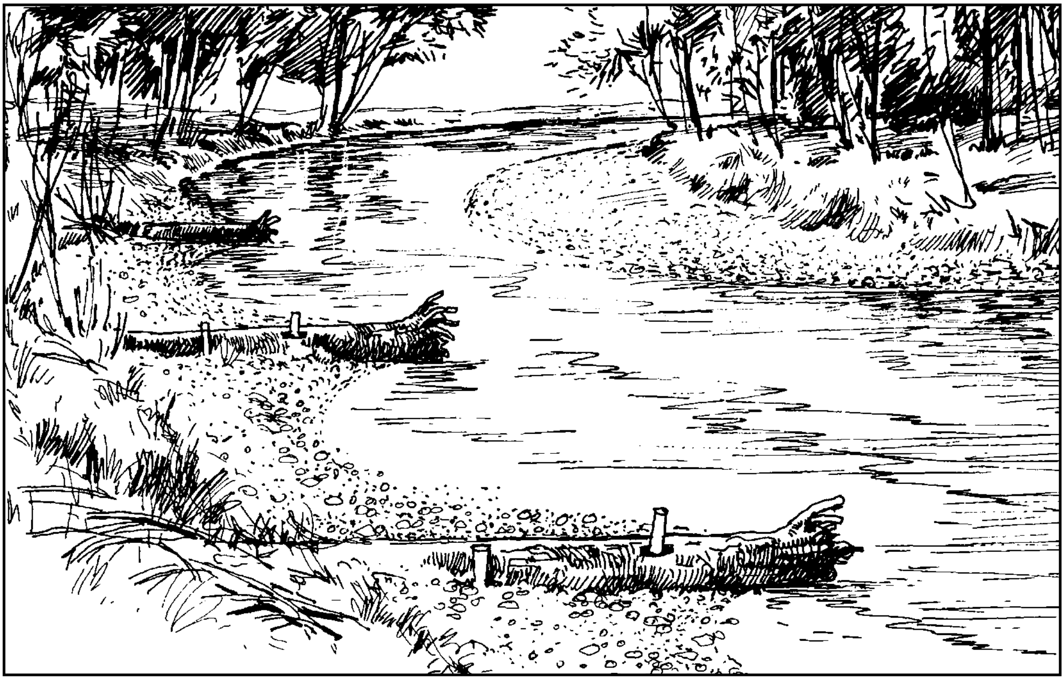


Figure 3. Tree trunks used to support river restoration and to control bank erosion.

7. Outlook

Aldo Leopold, an American nature philosopher and father of the U.S. wilderness areas, visited Germany in 1935. Seeing the constructed rivers in geometrical forms with stone paved banks, lying like dead snakes in their beds he asked: ‘Is it possible to restore such rivers?’ Today we can say: Yes, it is possible. For the restoration of rivers we need engineers with an ecological and morphological understanding and the ability for teamwork with biologists, landscape architects, outdoor recreation experts and engaged citizens, fighting for their rivers.

In a landscape like Middle Europe, river restoration cannot mean to re-establish the original landscape, which existed before people settled on the land. The target rather should be, to restore such river landscapes, constructed for the needs of yesterday, for the demands of tomorrow.

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TROUT 2010 - RESTRUCTURING URBAN BROOKS WITH ENGAGED CITIZENS

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Abstract:
Running waters in Hamburg have been corrected, most of them look like straightened and deepened canals filled with mobile sand. For the limnologist, however, they are headwaters normally characterised by a stable bottom with gravel and boulders, being thus salmonid biotopes with summer cold water. Unfortunately, the knowledge about their potential richness has been lost. The poor status of brook habitats and the willingness of citizens to lend a helping hand, led to the idea of brook sponsorship in the eighties. These groups, 'Bachpatenschaften', offer exciting activities and the chance of special identification with citizens' living sphere. After brook improvement work the observed species change from ubiquitous invertebrates to organisms of lively running waters is a real reward. The new perception of the watercourses is a phenomenon: You can hear riffles and where there was a silent slow flowing canal suddenly a murmuring brook appears.
A vision to restore the salmonid region in one pilot brook was transferred to action after checks of chemical and physical data of the Wandse and successful experiments to breed brown trout eggs. One main task will be to re-establish the river continuum by-passing park ponds which disturb the brooks` temperature regime and release nitrite from sedimented mud. – 'Trout 2010' will solve necessary changes via co-operation of NGOs, the 'Bachpatenschaften', sponsors and the Wandsbek administration. Universities will be engaged in special tasks. All of this can be considered as an aspect in Agenda 21 activities and a support for the improvement of the urban society.

1. Introduction

Having reported on sea trout catches in lowland brooks in North Germany (Tent 1984) and, ten years after, about exciting changes (Tent 1994) it was an interesting experience to watch the variety of SALMON 2000, recently named Salmon 2020, programmes running. So in an oral presentation on the detrimental effects of river maintenance in the watercourses` reality at a meeting of the German Society for Limnology (Tent 1998a) in the last overhead sheet something like a joke has been shown: There will be no sustainable Salmon 2000/2020 without a successful approach towards TROUT 2010 (Figure 1).

The original slide shows the place name sign of the Danish city of Skive, which has been altered by computer work.
What in fact hides behind this vision is the nowadays situation with migratory gravid salmon and other gravel spawners reaching devastated spawning reaches and *'Kinderstuben'* (nursery areas). Nowadays breeding and stocking programmes will have the same negative fate as they had with millions of fry and fingerlings in the beginning of the 20th century along the river Weser after the huge spawning areas had been lost by the construction of the Eder reservoir. Only the restoration of the headwaters, the salmonid regions of our watercourses, named by indicator organisms like brown trout and

Figure 1. Agenda 21, without visions there will be no development: Wandse in Wandsbek, Trout 2010.

grayling, will guarantee success. The emphatic reactions of the limnologic auditorium ('You want to catch brown trout at your place of work before your retirement in the 2010s.' – 'No, it is not trout, but the salmonid region's community we talk about, brown trout being but one key species which is known by the public.') gave the start for first checks whether the overhead joke might be a reasonable project to become reality.

2. First Checks and In-stream-tests

Are there or have there been salmonid streams in the lowland of North Germany? Regularly, especially in engineers talks, it is reported about slow, nearly not flowing watercourses. This, however, is highly contrasting to the geographic situation with most of the area being at least hilly shaped and it neglects the detrimental effects of construction works (Madsen and Tent 2000). The total length of running waters in the Hamburg Borough of Wandsbek (14 755 hectares, 400 000 inhabitants), the name of which arose from the beck 'Wandse', is about 360 km. Up until the last few decades they have been corrected for housing and other construction purposes so that most of them look like straightened and deepened canals filled with mobile sand and mud. Bank vegetation has often been dominated by grassland of parks. Hydraulic engineers in the past talked about having no running waters but open rain water pipes in the urban surroundings. For the limnologist these stretches are headwaters in a landscape formed by the glacial ages characterised by a stable bottom with gravel and boulders, being thus potential salmonid biotopes with cold summer water. The bank vegetation normally consists of alder wood plants. Unfortunately, the knowledge about the potential of species richness and natural fish production has been lost. The Wandsbek brooks, like most urban running waters nowadays, are inhabited mainly by roach and perch with a few other mainly cyprinid fish species. This discrepancy reveals a huge amount of work needed to change today's status to a more sustainable environment. So a thorough investigation probably will lead to results.

Available data on temperature and water chemistry have been checked by students at the Wandsbek administration, specific situations like hot summer periods have been measured in detail. The results stand in close connection to the reality of the Wandse beck (Figure 2). The summer cool water enters a chain of park ponds/lakes being called rain water retention basins. By this not only the river continuum is interrupted but the temperature regime is altered, as well. Undercooling in winter and overheating during summer time, in connection with the river construction works of the 1960`s, has lead to a potamalised situation of the former salmonid region. What might be even worse is the release of nitrite out of the sedimented mud in the park ponds (Figure 3). By this chronic toxicity for developing salmonid fry might occur. As a result of the tests, however, there was no sign of unsolvable problems.

In the winter 1998/99 an in situ test was run by the Junior Group of the Hamburg Angling Association trying to breed brown trout eggs in WV-boxes in the Wandse and in a tributary. Ten boxes in 5 places have been used (500 eggs each) and all but two were successful in breeding fry. Two places were destroyed by vandalism.
These results lead us to continue the in situ breeding and to start efforts for a long term project.

3. How to Realise the Project

After the positive results of the first checks the project had to be described, the project manager and sponsors had to be found. The Wandsbek administration – water authority, nature conservation and

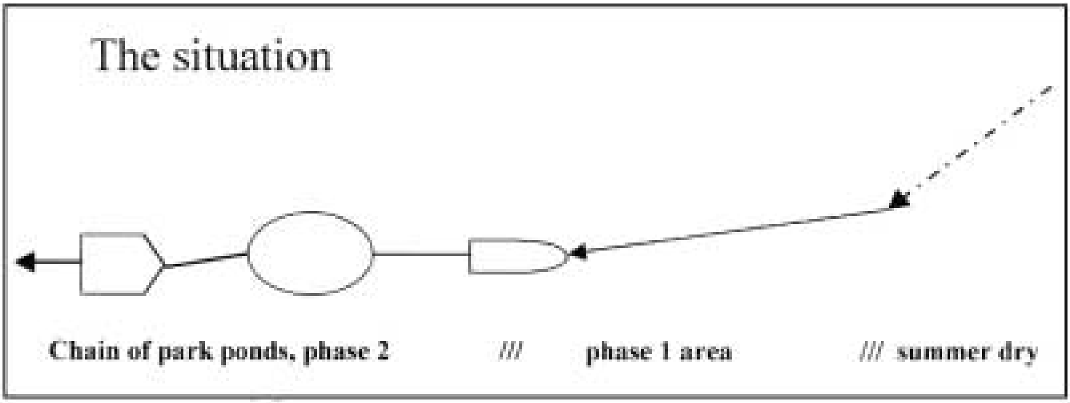

Figure 2. Scheme of the Wandse beck situation.

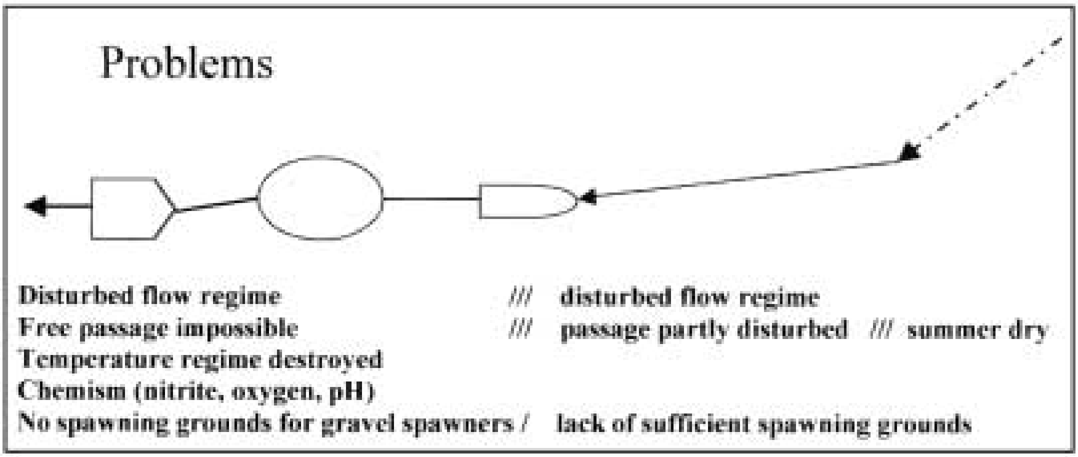

Figure 3. Wandse beck problems to be solved.

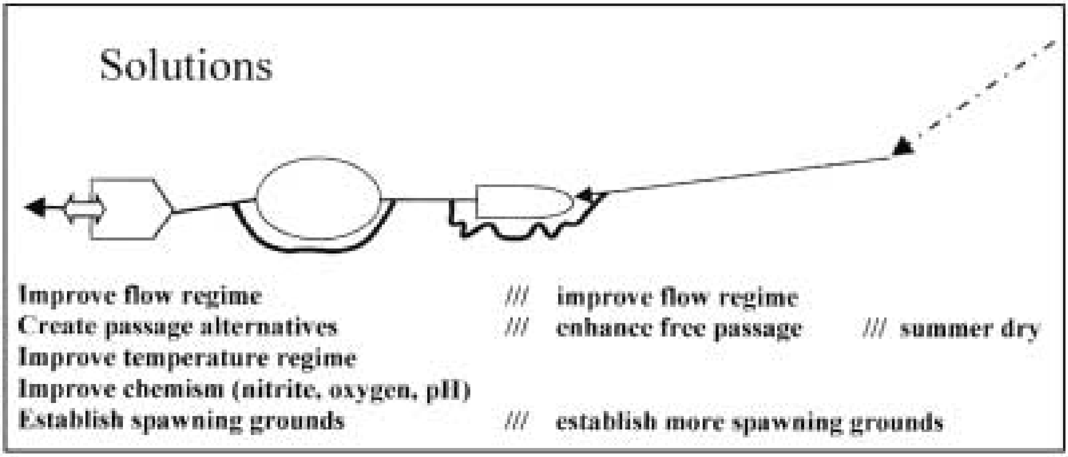

Figure 4. Solutions for the Wandse beck.

environmental protection – discussed necessary steps to improve the Wandse catchment. There should be in situ activities like inducing turbulence and establishing spawning grounds, the necessary amount of this leaving it not as a 'minor' task of the project. For this *'Bachpatenschafte'*, groups of engaged citizens (Tent 1998b), were already active in other river catchments and showed good results. Heavier construction work, however, is needed for the restoration of the river continuum with bypasses alongside the park ponds or at least fish ladders. Furthermore, proposals have to be elaborated how to lower storm water flows and how to improve periods of low flow. For a first regional phase of 'Trout 2010' a several 100 000 *Deutsche Mark/DM* frame work was projected (Figure 2, Figure 4). This covers a period of 4 years and wants to realise steps in the upper part which is not summer dry.

Meanwhile the project had its official start with Friends of the Earth as project manager, the *'Umweltstiftung der Hamburgischen Electricitäts-Werke'* as the main sponsor and the Wandsbek administration as co-operator.

4. The Hands-on Approach

The aspects of water in the urban situation are not only tasks to be dealt with by administrators, planners and engineers but interesting themes for the public as well. Co-operation in water related themes in schools, in adult education courses and active participation e.g. in *'Bachpatenschaften'* (brook sponsorship schemes/'adopt a brook') can lead citizens of different ages to feel more familiar with their place of residence.

The poor status of brook habitats and the willingness of engaged persons to lend a helping hand, led to the idea of brook sponsorship in the eighties. These *'Bachpatenschaften'* offer exciting activities for urban citizens thus being places of identification with their living sphere. Tasks of brook sponsors vary with personal interest and prior knowledge and the condition of the stretch of water. Following suggestions for remedial action, removing artificial bank protection systems, planting trees, introducing gravel beds and current deflectors, etc. (Figure 5) are examples of the wide variety of actions. These activities base on sound practical approaches (cf. Madsen 1995; Newbury 1995; Hansen and Madsen 1997) induce or enhance river dynamics and return characteristic river bottom features. Exhibitions

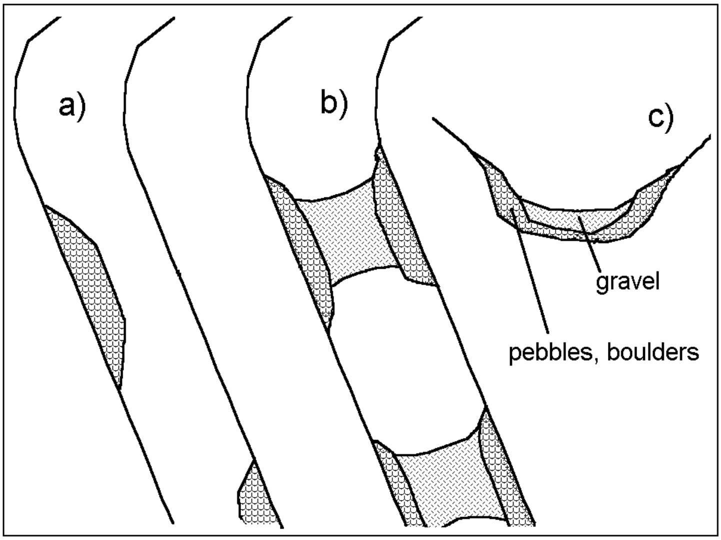

Figure 5. Induction of turbulence (a) and establishment of spawning grounds (b) from above, c) cross section).

with presentations of invertebrate life to other citizens are exciting efforts carried out by brook sponsors as well. In the Borough of Wandsbek more than 70 brook sponsorship schemes exist. More than 800 individuals from pupils to the elderly feel responsible for their ‘brook on the doorstep’ and are active in improving urban waters and their surroundings. Information contacts have been established by several groups on a regional and an international scale using offers like GREEN. (Global Rivers Environmental Education Network) and GLOBE (Global Learning and Observation to Benefit the Environment).

After brook improvement work the documented species change from ubiquitous invertebrates to indicator organisms of lively running waters like mayflies and caddisflies (stone flies are still scarce) is a real reward for the participating citizens. And it is not only an ecological but a socio-psychological approach as well (Tent 2000). The new perception of waters is a real phenomenon: you can hear riffles *(in German: Rauschen rauschen)* and where there was a silent slow flowing canal suddenly a murmuring brook appears.

Since the end of the 1980s engaged citizen groups are active to restore river dynamics in the Borough of Wandsbek (Tent 1998b).This has been mentioned as a best practice approach within the metropolitan region of Hamburg *(Lenkungsausschuß der Gemeinsamen Landesplanung 1999)*.

5. Future Aspects

It is expected to realise a species change, e.g. with the decrease of roach and perch numbers and dace, minnow, stone loach, grayling and brown trout increasing after re-introduction.

Scientific institutions like universities will engage in special tasks like elaboration of catchment improvements and low water level elevation. Environmental advice will be given to the citizens of how to enhance sustainability for the urban water cycle. After phase 1 it is planned to elaborate solutions for a river continuum from the Wandse via the Alster to the Elbe river. By this in the long term the return of migratory species like sea trout, river and sea lamprey is to be awaited in the Borough of Wandsbek.

All of this can be considered as an important aspect in Agenda 21 activities and a support for the improvement of the urban society. As such it is part of best practices for the 'Metropolitan Region of Hamburg', covering large parts of the federal states of Schleswig-Holstein, the Free and Hanseatic City of Hamburg and Lower Saxony.

Acknowledgements
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SALMONID RIVERINE HABITAT RESTORATION IN THE REPUBLIC OF IRELAND

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Abstract
Over the period 1995 to 1999 the Irish Government, in collaboration with the EU, have invested £12.2 m (Punts) in the restoration of salmonid riverine habitat in our country. Most projects have been implemented on a catchment wide basis. Programmes were concerned with the restoration of natural river form and the re-establishment of riparian corridors. Detail with regard to planning, implementing and monitoring individual projects are provided. A total of 400 km of channel have been rehabilitated over this period. Monitoring data indicate that the programmes are already proving successful.

1. Introduction

Over the period 1995 to 1998 the Irish Government, with the assistance of EU Structural Funds, have embarked on a major angling development programme. The objective of the programme is to enhance the resource thereby increasing tourist angler revenue. A total of £17 million (Punts) is being expended across the game and coarse fish angling areas and monies are also being invested to upgrade the sea angling facilities. A total of £12.2 million (Punts) has been invested in the salmonid area. In Ireland, the most prolific native salmonids are Atlantic salmon (*Salmo salar* L.) and brown trout (*Salmo trutta* L.). Both species are highly valued by local and tourist anglers alike. This paper outlines how these monies have been spent. The nature of works carried out are outlined. Initial general findings in relation to the success of these programmes is also provided.

2. Background Information

As a result of completing many catchment surveys in recent years a clear picture has emerged of the land management practices which have impacted on salmonid production in Irish rivers (O'Grady and Gargan 1993). The more important include, overgrazing, bank trampling, arterial drainage, tunnelling (by deciduous trees) and to a lesser extent gravel extraction, channel re-alignment to accommodate roads and coniferous afforestation. The physical impact of all of these problems is remarkably similar, channels become artificially broad and shallow, a thalweg is usually ill-defined or absent and pool areas are either lost or reduced in terms of both their number and quality. Spawning gravels become unnaturally compacted and their value as salmonid spawning sites is reduced. The number of stable undercut banks which provide cover for fish are also greatly reduced.

3. Survey Procedures

Salmonid rehabilitation programs in Ireland have been carried out, for the most part, on a catchment wide basis. Initially detailed physical and biological surveys were carried out over an entire catchment.

Methodologies involved have already been described in O'Grady (1995). Essentially procedure involved dividing river catchments into discrete zones. Zonation was based on variation in four primary factors:

- River slope or gradient;
- Streambed type;
- Summer discharge values (Q);
- The nature of the riparian zone.

Once a catchment was zoned individual representative reaches in each zone were examined in detail both in physical and biological terms. In this way an overview of the imbalances in a catchment could be built up and used to formulate and cost an enhancement programme.

4. First Principals

It is very important that one does not loose sight of the primary objective of a habitat enhancement scheme, which is to restore the natural physical and ecological balance of a catchment. If we can achieve that objective and guard against water pollution then the fish will look after themselves. Schemes should only be designed knowing what an undisturbed channel with a particular fluvial geomorphology should look like in its natural state. Rosgen (1996) is a very useful guide in this regard. He (Rosgen) also provides practical guidelines in relation to the type of structure most suited and likely to remain functional in a particular type of channel. Most of Ireland's salmonid rivers are within the broad 'B' and 'C' categories as defined by Rosgen (1996).

5. Work Programmes in Irish Rivers

The channels currently being enhanced in Ireland cover a relatively broad range of geomorphological types. Consequently a broad range of enhancement techniques are being employed (Table 1).

Table 1. An inventory of salmonid riverine enhancement techniques being used in Ireland.

Timber Structures	**Rock Applications**
Notched straight log weirs	Horseshoe shaped stone weirs
V-notched log weirs	Vortex stone weirs
Paired timber deflectors	Rubble mats
Timber channel constrictors	Gravel beds
Crosslog revetments	Alternating deflectors
Plank/log deflectors	Rip rap
Log/Xmas tree bank revetments	Individual random boulders
Log/rock bank revetments	Cover shelves on lateral scour pools
Plank/rock cover shelves on lateral scour pools	Rock breaking to reintroduce sinuosity, create pools and step impassable falls
Conifer tree bank revetments	
Half logs	
Bed logs	
Rootwads	
Shrub pruning and tree planting	

The techniques being used are not novel as most have been widely used in North America, some since the 1930's. Many of these techniques have been adapted in Ireland to suit local conditions and their use in specific areas often reflect the cost and availability of local supplies. For example, many log/tree bank revetments in North America use juniper bushes. In Ireland, conifer treetops or whole willow bushes have been substituted simply because of their local availability. Stone cover shelves have been used in some streams again because flagstones are available locally at reasonable cost. One must always take cognisance of the availability of local materials to minimise costs. Nearly always there is a choice of materials which can be used to restore the natural stream form. A log/tree top structure is favoured over Rip rap for repairing bank erosion. The former option provides a degree of bank stability long enough to allow a naturally stable vegetated bank to regenerate. The Rip rap option provides a very rigid bank which, in the long-term, will not allow the normal level of erosion associated with some types of channel to occur. In extreme circumstances, where a channel has become braided, one has little option but to use stone to reconstruct the bank.

In-stream timber structures are likely to last a long time in Irish rivers. They are not subject to the same extreme weather, long arid periods or extreme cold conditions, as in parts of North America where the pins securing logs can be pulled from the streambed and where ice floes can seriously scar timber structures. A recent inspection of timber weirs built in an Irish stream 30 years ago showed that the logs were still in good condition. Log revetments are merely a holding operation, regeneration of the natural bankside vegetation will have restored bank stability long before the logs have rotted. Even in the more extreme climatic conditions of North America many timber structures built in the 1930's are still intact.

In Ireland, the fencing off of riparian zones is considered an essential part of these programmes. Planting willow slips and other native deciduous trees are also undertaken routinely. The positive fishery impacts of excluding farm stock from rivers and streams have been well documented in many countries. In Ireland, the dramatic recovery of both the riparian zone and the in-stream aquatic flora only one year after the completion of a fencing programme has been equally impressive.

A relatively novel technique has been used to provide fish passage over a number of impassable waterfalls. Large (20 to 40 tonnes) tracked hydraulic machines fitted with 'rock breakers' have been used to excavate a series of stepped pools through the rock to provide fish passage. This has proved to be a very cost-effective option compared with building concrete fish passes. For example, two such fish passes were excavated for £3,500 and £20,000 respectively. The estimated costs of constructing concrete fishways at these locations were £68,000 and £250,000 respectively. Salmon and trout have been observed ascending these 'fish ladders' as soon as they had been completed.

Bed excavation for arterial drainage purposes, has left a smooth bedrock base in some drained Irish rivers. This substrate is exceptionally barren in terms of its macro-invertebrate carrying capacity. In addition, the smooth bed provides few resting-places for fish. Rock breakers have been used in Ireland to excavate a thalweg through the rock. Rubble or gravel mats have been built at intervals to create riffles and pools have been excavated. Boulders have been placed in these channels to increase the hydraulic diversity and to restore the natural physical form of the stream. This technique has also been used to recreate salmon angling pools in sheet bedrock zones of some large rivers which had previously been canalised.

A number of baseline fishery surveys of Irish catchments have illustrated that channel sections in excess of 100 m in length which had been 'tunnelled' by deciduous vegetation supported significantly smaller numbers of fish than adjacent open stretches. Pruning this vegetation, particularly along riffle sections, very quickly increased their capacity to support larger standing crops of juvenile salmonids (O'Grady 1993). Shrub pruning has since become an integral part of Irish salmonid catchment enhancement programmes.

Internationally there is a growing awareness that salmonid stocking programmes, as a fishery enhancement tool, are no longer the panacea once assumed. Stocking has played no part in any of our major programmes except in some catchments where sea trout stocks had completely collapsed. The pre-development baseline surveys which have preceded all of these enhancement programmes have illustrated that it was a lack of quality habitat and not a lack of spawning escapement which was limiting fish production. There is no point in releasing additional juvenile fish to boost stocks where habitat problems are readily recognisable as the primary factor limiting fish numbers.

6. Results To-Date

These enhancement programmes commenced in 1995. Post-works, to date, fish numbers have been monitored at many sites and compared with similar data from adjacent undeveloped sites on the same stream. Results to date can be summarised as follows:

- Substantial increases in juvenile salmonid stocks have occurred as little as one year post-works;
- When Atlantic salmon and brown trout are present in a stream the stocks of both species have been enhanced;
- The restoration of adult brown trout stocks has been achieved in larger rivers. Increases in yearling salmon and trout numbers have been observed in channels *despite* the increased presence of the larger older trout;
- In some channels increases in non-salmonid species have also been noted;
- Pools excavated to provide additional salmon angling opportunities in drained and badly eroded rivers have proved to be successful;
- The regeneration of natural riparian zones has also provided a niche for many species of insects, birds and small mammals, i.e. a significant recovery in the general biodiversity of river corridors is already evident.

Some results from this and previous Irish programmes have been published, all of which illustrate positive results (O'Grady 1991; O'Grady 1993; O'Grady 1994; O'Grady 1995; O'Grady *et al*. 1991; O'Grady *et al. In Press* and O'Grady and Duff *In Press*).

7. Costs and Gains

Clearly one needs to be highly selective in targeting damaged salmonid habitat for restoration because a failure to do so may result in little or no return on your investment. An essential prerequisite is a baseline survey of the catchment to identify the key factors which are limiting salmonid production. The likely return on an investment cannot be estimated until the imbalances are identified and their remedial costs estimated. Many baseline surveys have identified the paucity of 1+ year-old salmon parr nursery areas as the key factor limiting smolt production; most Irish salmon smolts are 2 year old fish. If the capital cost of repairing these nursery areas is written off over a 25 to 30 year period stock monitoring results to date suggest that many additional smolts can be produced for as little as £0.5 (Punts) per fish in Irish channels. Studies some years ago, in Ireland, indicated a 3 to 4 fold difference in the relative numbers of wild and ranched salmon smolts returning home to Irish rivers as adults; the former group as one would expect were the more successful (Mills and Piggins 1983). If one assumes that each ranched smolt costs £0.8 Punts to produce the real value of these habitat enhancement programmes is put into perspective.

The generation of increased salmonid stocks are only a part of the net gain from riverine habitat enhancement schemes. Many of Ireland's lake brown trout fisheries have also benefited from the restoration of their riverine sub-catchments. River corridors, in a healthy state, are one of our most complex ecosystems accommodating a host of plant, macroinvertebrate, avian and mammalian species. To describe the success of these schemes simply in terms of increased fish numbers constitutes serious understatement.

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GEOMORPHOLOGICAL EVALUATION OF RIVER RESTORATION SCHEMES: PRINCIPLES, METHOD, MONITORING, ASSESSMENT, EVALUATION. PROGRESS?

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Abstract

At present, river restoration projects are mostly experiments. Irrespective of the care taken in planning the projects, in producing suitable baseline assessments and in designing appropriate installations, the environmental benefit of individual restoration schemes cannot be predicted fully. This is often because the geomorphological impact of the scheme is dependent on a sequence of weather events after installation. Therefore, it is imperative that the environmental outcomes of restoration schemes are communicated widely and according to a rational framework that facilitates inter-scheme comparisons. The basis for this evaluation is Post-Project Appraisal (PPA), the final, but often overlooked, component of Environmental Assessment.

PPA is argued to consist of three assessments: a compliance audit of installation accordance with design intentions, a performance audit of the short-term tendency of key geomorphological variables that indicate the probable 'sustainability' of the scheme, and a longer-term geomorphological evaluation of the physical environmental benefits of the scheme. The paper outlines three investigations into 'good practice' PPA and provides some preliminary indication of whether river restoration in the UK is providing sustainable environmental benefits.

1. Introduction

At present, river restoration projects are mostly experiments. Their success is affected by the care taken in: planning the project, producing baseline assessments, designing an appropriate scheme, installing the scheme to the design specifications and receiving the expected sequence of weather events prior to and following installation. Therefore, the environmental benefit of individual restoration schemes cannot be predicted fully. Despite the best intentions on the part of the designers, there can be no guarantee that the restoration scheme will achieve a level of environmental improvement that is commensurate with the level of investment.

Therefore, as a service to project managers, to funding authorities and to environmental scientists, it is imperative that the environmental outcomes of restoration schemes are communicated widely and according to a rational framework that facilitates inter-scheme comparisons. The basis for this evaluation is Post-Project Appraisal (PPA), the final, but often overlooked, component of Environmental Assessment. In the context of river restoration, Post-Project Appraisal is defined as the 'effectiveness of restoration projects based on systematic data collection and assessment tested against measurable success criteria' (Downs and Kondolf *in prep*.). In practice, this definition may already imply an ideal practice that is not commonly met.

In many river restoration projects, the desired outcomes relate to biodiversity improvements and the re-introduction of flora and/or fauna that are deemed to be natural to the particular river corridor. The outcomes are usually achieved by altering the physical habitat template of the river towards a condition suitable for the species. However, there is often a large year-to-year variability in the abundance individual species due to factors that are extraneous to the usual scale of river restoration projects. Also, it is unlikely that assessment of individual species can inform the assessors about the likely sustainability of the scheme, and this is a vital aspect for restoration designers. The alternative is to exploit the proven link between species and their preferred physical habitats and to assess the scheme against its provision of a habitat template that is sustainable in relation to the hydrology and geomorphology of the river system. While habitat assessment is, in itself, complex to achieve (see below), it is at least one step removed from the level of individual species and, should form the core of a more robust procedure, if applied with care.

2. Method

The primary distinction between post-project appraisals of 'traditional' river channel management schemes and those of river restoration projects is that the assessment must move from being 'construction-centred and short-term' to 'effect-centred and long-term'. It is no longer sufficient to equate the degree of compliance with the scheme design as the basis for judging success or failure. Many restoration schemes may require many years to reach their full habitat potential. Consequently, the quality of the PPA is in itself a variable, and will depend primarily upon whether the PPA was planned in advance of project installation, to ensure that suitable pre-project data are collected, and on

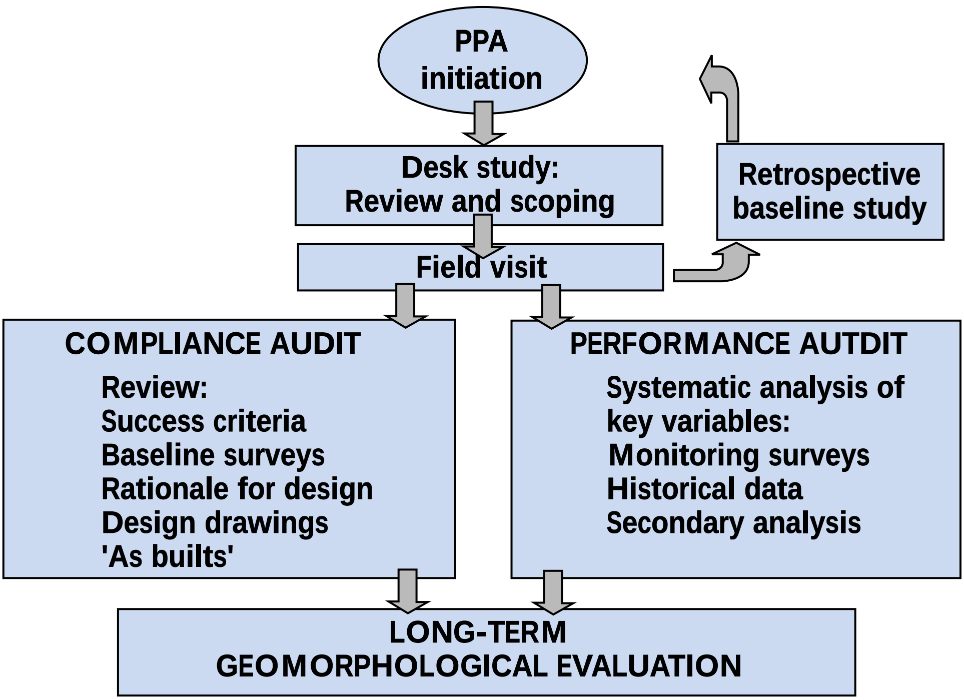

Figure 1. A framework for PPA (adapted from Downs *et al*. 1997; Skinner 1999).

the time of commitment to post-project monitoring and evaluation.

Figure 1 outlines a framework for PPA that encapsulates that need for an 'effect-centred and long-term' commitment. Under this framework, the PPA is argued to consist of three linked components. First, there is a requirement for a 'compliance audit'. This audit involves the study of background documentation and drawings related to the scheme in order to assess the 'scheme as installed' relative to the 'scheme as planned'. Clearly, it makes no sense to criticise a scheme's performance relative to criteria based on the design if, during installation, alterations occurred to the project specifications. If alterations have occurred, new success criteria may be necessary. Suggestions for suitable compliance audits have been made previously (Downs *et al.* 1997; Brookes *et al*. 1998; Skinner *et al.* 1998) and are not considered further here.

The second component is a 'performance audit' of the scheme. This attribute is largely based on periodic monitoring of the scheme since installation and may involve the use of secondary data sources to complete the data set if the project monitoring did not begin at the time of project installation. However, monitoring data require some form of secondary interpretation to assess the scheme's performance. This interpretation may be qualitative and judgmental and relate only to the individual scheme or may be designed to facilitate cross-comparison of scheme performance according to key variables reflecting the likely sustainability of the project. Downs and Kondolf *(in prep.)* contend that five 'levels of investment' in PPA exist but, even with good data sets, interpreting the data requires considerable care and a systematic understanding of river environments.

One problem with PPAs based on repeat monitoring is that the data are inevitably of limited extent when set against the ultimate test for restoration projects: sustainability and impact on geomorphological time scales. Rarely does monitoring data extend more than ten years, yet this may not encompass a sufficient range of formative flow events against which to make a 'geomorphological evaluation'. This theme is explored further below.

Below, three experiments are briefly outlined and offered as examples of 'good practice' in restoration PPAs. The first example, a monitoring scheme of rehabilitation structures on the River Idle, Nottinghamshire, UK, is used to introduce the complexity in drawing conclusions about scheme 'performance' from short-term monitoring (Skinner 1999). The second experiment investigates a means of achieving an objective context and inter-scheme comparison assessment potential via a *Channel Geomorphology Profiler* (Skinner *et al. in prep.*) using selected English rivers for a pilot data set. The third example introduces an experiment in achieving a measure of true 'geomorphological evaluation' over longer time scales using a modified magnitude-frequency analysis (Downs *et al.* 1999; Downs and Soar *in prep.*). It also focuses on the River Idle and uses the monitoring data for initial validation.

3. Monitoring 'Short-Term' Performance

Early in 1996, river rehabilitation initiatives were installed to enhance the in-stream habitat of the channelised, sand-bedded, River Idle. The initiatives centred on improving the diversity of the channel bed and included a series of flow deflectors intended to prompt selective scour and deposition (details in Downs and Thorne 1998; 2000). Four morphological surveys were undertaken up to May 1998 at six monumented cross-sections around six of the deflectors, in addition to a survey in January 1996 prior to deflector installation (Skinner 1999). From the cross-sections, estimates of net channel bed scour or deposition were calculated for each period.

The results indicate a progressive modification of the channel bed during the 2.5 year period. Between January 1996 and the first post-installation survey in May 1996, there is deposition generally through the rehabilitated reach. This can probably be ascribed to an initial deposition of sediments in the lee of each deflector, aided by disturbance to the channel bed during installation. There is a continuation of the general trend for deposition from May to October 1996 but rates are low, reflecting low flows during this period. Most of the deposition occurs in the upstream cross-sections and this may reflect incoming sediment trapped following channel works further upstream. During the next period, to July 1997, the trend reverses to net erosion in all but 7 cross-sections. The majority of the work was probably achieved by several high in-bank discharges around New Year 1997. Conversely, the period July 1997 – May 1998 is considerably wetter in general and erosion rates are the highest experienced.

The monitoring was undertaken carefully and consistently, at an appropriate frequency (Kondolf and Micheli 1995) and over a period that commonly marks the upper limit of restoration monitoring (Downs and Kondolf *in prep.*). It includes a survey taken prior to the project installation. However, the monitoring period shows that the channel morphology has not yet reached equilibrium with the installed deflectors. There has been a clear shift in the dominant net trend in most reaches from deposition to erosion, and the rates of change were highest in the final period. Therefore, the performance assessment possible from this monitoring is restricted to comments interpreted from surveys in conjunction with supportive observations from the field site. Together, it appears that the deflectors are indeed increasing channel bed morphology; scour holes are developing and the depositional bars are supporting a variety of aquatic marginal plant species and are acting as refugia for fish fry. However, the transferability of the learning experience gained in this restoration 'experiment' is restricted by the lack of a unifying context for the data, and by the on-going changes.

4. Assessing 'Short-Term' Performance

To provide a better context for translating 'interpreted morphological surveys' into 'objective performance assessments', Skinner (1999) has developed a *Channel Geomorphology Profiler* (CGP). The CGP aims to be diagnostic of physical habitat conditions over a 'extended reach' of a restoration scheme (equivalent to two meander reaches) by measuring key morphological variables that, together, act as indicators for the likely sustainability of the scheme. The scheme has two additional advantages that enhance its usefulness. The first is that is requires only one survey and is thus practicable for poorly-budgeted PPAs. The second is that, in defining the key variables, the assessment is essentially defining its own 'success criteria'. This is a benefit because, to date, very few restoration schemes are seen to define specific, measurable, success criteria.

The variables for the CGP pilot study were chosen to represent reach-averaged key elements of the in-stream habitat (depth, asymmetry, velocity, Fredle index – measure of bed material) combined with variables indicating naturalness in the channel planform (sinuosity and the ratio of bend radius of curvature to width [r_c/w]). The boundary conditions are defined by the empirical limits of the data collection. Therefore, the device was tested on 13 reaches from 11 rivers in England including four 'semi-natural' reaches, four channelised reaches and five rehabilitation sites. It was presumed that the semi-natural and channelised reaches would define the boundaries for 'best' and 'worst' conditions, respectively, and that the rehabilitation reaches would plot between these extremes. Principle components analysis (PCA) on the six variables illustrated that variation within the group was explained mostly by asymmetry (52.9%), depth (20.7%) and the Fredle Index (12.5%) (Skinner 1999). Less important variables included r_c/w (9.3%), sinuosity (3.1%). The velocity variable explained very little variance (1.5%) because the variable describes only an the instantaneous hydraulic condition of the channel whereas the variables of depth and asymmetry reflect the result of multiple hydraulic conditions at formative flow discharges. CGP output is profiled via a series of graphical plots (Skinner *et al.* 2000). Depth and asymmetry are combined to be diagnostic of in-stream flow conditions. Sinuosity and r_c/w are combined to indicate likely planform sustainability (i.e. comparability to a natural channel planform). The final plot combines the Fredle Index measure of sediment with slope to indicate the environmental suitability of the restoration design. Reviewing the data in each plot indicates the prospect that river restoration schemes are creating new river environments that require ecohydraulic characterisation and assessment (Skinner *et al. in prep.*)

Using cluster analysis, the tested sites fall into three groups distinguished by the three diagnostic criteria noted above. Group 3 (high in-stream diversity, curved planform, variable bed sediment size) includes three of the four semi-natural sites, but also the rehabilitation reach of the central River Blackwater, indicating a ‘successful’ rehabilitation towards a semi-natural condition. The majority of the channelised reaches are in Group 1 (low in-stream diversity, curved planform, variable bed sediment size) but this group also includes the most lowland semi-natural river (Cripsey Brook) and the restored River Cole. This result probably reflects previous channel management works on the Cripsey Brook and the naturally lower diversity expected in lowland clay channels like the Cole. Group 2 (variable in-stream diversity, near straight and fine bed sediments) involves two rehabilitation reaches using low weirs (Fal and Smyte) suggesting that, while some in-stream diversity is achieved by this method, the overall naturalness of the channel is not greatly improved and reflects the creation of new artificial habitats.

5. ‘Long-Term’ Geomorphological Evaluation

While the CGP provides a ‘snap-shot’ of restoration performance assessment, it does not provide a genuine geomorphological evaluation, that is, information on the long-term impact and sustainability of the scheme. An experiment into providing a suitable measure has been performed on deflector 6a on the River Idle. The test assesses the geomorphology-hydrology inter-relationship of the reach (rather than its geomorphology-hydraulic nature) using principles of sediment transport continuity set against the long-term flow record. For each discharge, the flow elevation is calculated at the deflector cross-section and a control section upstream by sub-dividing each cross-section into segments defined by shape and roughness characterisation. Assuming mean flow velocities in the two sections converge at very high discharges and the water surface slope is consistent, the velocity in the restored reach is then re-calculated both around and (where applicable) over the deflector. Both assumptions are reasonable in the case of the Idle. Sediment transport through the restored section is then calculated using a compound version of Brownlie’s (1981) equation and compared to the upstream control site. Initially, a large imbalance exists between sediment supply from upstream and the sediment transport capacity of the restored reach. However, this situation cannot persist and the restored reach begins to adjust morphologically by the formation of a scour hole that, in theory, reaches an equilibrium once the depth of scour allows sediment continuity between the reaches to be restored (i.e. a capacity:supply ratio of 1).

Using the long-term flow record (13 years), the depth of morphological scour around the installed deflector is predicted to be 0.55 m. This measure is termed the ‘Total Restoration Potential’ (TRP).

However, when the post-installation flow distribution varies from the long-term record then the TRP may not be achieved for weather-related reasons, and not simply poor design. To make this assessment, the scour potential can be re-calculated using just the post-installation flows ('Performance Since Installation', PSI). Using this 4-year flow record suggests that, because of lower flows particularly in 1996 and 1997, the expected scour is only 0.32 m at present. Monitoring of the site reveals mean scour of the channel bed around the deflector to be 0.25 m, indicating a fairly good approximation of the PSI (Downs and Soar *in prep*., some early concepts in Downs *et al.* 1999). Therefore, the test provides both a measure of the long-term potential of a restoration initiative (TRP) and a temporally specific understanding of the achieved performance (PSI). By using the device in the project design stages, we begin truly to 'design-with-nature' and to be able to set specific, measurable success criteria in terms of prompted river channel adjustment.

6. Conclusion

Three experiments have been outlined, briefly, to summarise some developing PPA best practices in performance monitoring, performance assessment and long-term geomorphological evaluation. Each reflects, to differing degrees, the challenges inherent in the need for restoration PPA to be 'effect-centred and long-term' rather than 'construction-centred and short-term'. The following tentative conclusions are advanced (further details in Downs and Kondolf *in prep.*).

It appears from experience in the UK and USA that there are few systematic, well-funded PPAs with a commitment to long-term monitoring. Further, pre-project data, especially measurable success criteria, are critical to the *compliance audit.* In the (short-term) *performance audit*, monitoring is necessary but not sufficient. The case study showed that when taken without context, performance assessments are interpretative and judgmental and difficult to compare between sites. Inter-site comparability requires additional analysis that provide of the geomorphology-hydraulic relations in the restored reach relative to other schemes, and to semi-natural and channelised reaches. In this regard, the Channel Geomorphology Profiler may provide contextual assessment. Finally, river restoration ideally requires a long-term *geomorphological evaluation* of scheme performance. This assessment must be explicitly temporal, and involve the catchment hydrology rather than simply the reach hydraulics. An method is outlined using a modified magnitude-frequency approach to calculate the long-term (TRP) and post-installation (PSI) morphological impact of attaining sediment continuity in the restored reach. PPA is often characterised as the ability for us to learn from our mistakes (e.g. Kondolf 1994) and it is apparent that consequent benefits to design achieved by PPA are largely a function of the level of investment and our ability to place our assessments in context. Once this is achieved, then we may begin to complete the cycle of Environmental Impact Assessment.

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GEOMORPHOLOGICAL PROCEDURES AND RIVER RESTORATION: SCIENCE, SURVEY AND SUSTAINABILITY

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Abstract
The potential contribution of Fluvial Geomorphology to many aspects of strategic and operational river management has only recently become realised in the United Kingdom. The paper presents practical experiences in the role of geomorphological principles in guiding restoration/rehabilitation, in particular:

- *Development of the 'vision' of naturalness or functionality required of the scheme;*
- *Assessment of the broader sustainability of project 'lengths' within the basin- or reach-scale sediment system;*
- *Empirical guidance on the dynamic requirements of desirable features and the degree to which 'mimicking' is possible for broader functional outcomes;*
- *Utilisation of 'physical biotopes' for the design and assessment of habitat gain;*
- *Guidance on the maintenance and monitoring of restored/rehabilitated lengths.*

1. Introduction

The application of the principles and techniques of Fluvial Geomorphology is new to UK river management (Newson 1986; Sear *et al.* 1995; Newson and Sear 1998; Thorne *et al.* 1997). The mainly academic background of Geomorphology and confusion about its contribution (relative to that of Engineering Science) have hitherto mitigated against widespread incorporation to both strategies and operations.

Thanks, however, to a programme of R&D initiated by the river management authorities in England and Wales and to the incorporation of Fluvial Geomorphology in a number of practical river management projects, including those involving rehabilitation and restoration, the potential of the subject is being exploited (Newson *et al. in press*).

Fluvial Geomorphology studies the sediment system of rivers from source to mouth and classifies the large range of forms produced by erosion and deposition. The survey element of the science has recently found fruit in such collaborative ventures as the River Habitat Surveys (Raven *et al.* 1996); again a geomorphological training element was involved (Environment Agency 1997a; 1997b). The survey element is also essential to Post Project Appraisal, a crucial part of the application of a new science to important 'real world' issues; we are still learning!

Geomorphologists have also derived an array of predictive techniques (largely empirical) which, allow predictions of channel form and the location and rate of channel adjustment. Geomorphology is, therefore, well-placed to comment on issues of channel 'stability' (Simon 1995; Sear 1996).

Geomorphology also works at the catchment scale and this larger, longer view is always the context for geomorphological predictions, adding a much-needed element of sustainability to river management and to the decision process behind the choice of options (which include 'do nothing').

2. Contributions to River Restoration

Geomorphology can assist in the strategic choice of where to restore (in system terms); it also can advise on what to restore in terms of fluvial features. Once such a decision is made (sometimes with, but often without, considering the catchment or sediment-system context) the empirical equations from Fluvial Geomorphology can be employed to design features and predict adjustments. Working at the catchment scale, geomorphologists can often advise about the protection of a rehabilitation or restoration investment by alerting managers to e.g. new sources of siltation (Sear 1994; Kronvang *et al.* 1998).

Currently, the contribution to restoration schemes has been relatively low-level; no scheme has yet been designed entirely by geomorphological principles and in a multi-disciplinary context this is inevitable. High levels of community 'vision' are appropriate to the design of restored channels but a new context, provided by fatal flooding in the UK (Bye and Horner 1998), means that increasing levels of hydraulic and geomorphological investigation may be required before restoration (or even rehabilitation) schemes are approved (Downs and Thorne 1998).

Because of the important social, economic and quasi-legal context of the work of geomorphologists an output from the R&D performed for EA was a set of procedures (Table 1) through which an escalating degree of geomorphological input can be judged, facilitated and appraised by managers. Post-Project-Appraisal is especially important to aid judgement by society about the 'stability' of restored rivers (Sear *et al.* 1998).

A major remaining task for the Fluvial Geomorphology community is to carry out research programmes related to the requirements of river management, especially to the restoration of higher energy systems than have currently been tackled, and to work more closely with ecologists to model in-stream habitats. An example of the latter approach is via the calibration of in-stream habitat conditions through mapping hydraulic biotopes, relating them to morphology and hence river classification (Newson *et al.*1998a; 1998b; Newson and Newson *in press*).

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Table 1. Geomorphological procedures recommended by Environment Agency, 1998

Stage	Planning	Project		
Procedure	**Catchment Baseline Study**	**Fluvial Audit**	**Geomorphological Dynamic Assessment**	**Geomorphological channel design**
Aims	Overview of the basin sediment system and morphology.	To suggest sustainable, geomorphologically-based options for problem sites.	To relate reach processes and rates to morphology, allowing management of either.	To design channels within the context of the basin system and local processes.
Scale	Often a gauged catchment (modal size 100-300 km^2).	Those reaches identified in CBS or by managers.	Problem or project reach.	Project length.
Methods	Data collation, inc. RHS; consultation; reconnaissance fieldwork at key points throughout catchment.	Detailed field studies of sediment sources, sinks, transport processes, floods and land use impacts.	Field survey of channel form and flows; hydrological and hydraulic data.	Quantitative description of dimensions and location of features, substrates, revetments.
Core information	*Characterisation* of river lengths and sediment management problems.	Identifies *range of options* and 'potentially destabilising phenomena'.	Sediment transport *rates* and morphological *stability/ trends*. 'Regime' approach where appropriate.	The 'appropriate' *features* and their *dimensions* within a functionally-designed channel.
Outputs	5-10 page report; maps or GIS; field forms and photos.	Maps at 1:10 000; time chart; report; recommendations.	Quantitative guidance to intervention (or not) and predicted impacts on reach and beyond.	Plans, drawings, tables and report suitable as input to QS and engineering costs.
Destination	LEAPs; Feasibility studies for rehab/restoration.	Investment/management staff or policy forums.	Engineering managers and project steering groups.	Funded projects of flood defence, erosion protection, rehabilitation or restoration.
Follow-up		GEOMORPHOLOGICAL POST-PROJECT APPRAISAL		

FLOODPLAIN BIODIVERSITY AND RESTORATION (FLOBAR): HYDROLOGICAL AND GEOMORPHOLOGICAL MECHANISMS INFLUENCING FLOODPLAIN DIVERSITY AND THEIR APPLICATION TO THE RESTORATION OF EUROPEAN FLOODPLAINS

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Abstract

Research for this project took place between 1996 and 1999. The main aims of this project were to:

(1) Contribute to the development of a scientific methodology for determining the flow needs of riparian plant communities on selected European floodplains.

(2) Create effective links between the scientific understanding of the functioning of riparian ecosystems and the institutional mechanisms by which river management for conservation and restoration occur.

These aims were achieved by a series of linked scientific and socio-economic studies:

- *To identify and quantify hydrological and sedimentological conditions favoured by riparian species for their establishment and growth (Objective 1).*
- *Link contemporary floodplain patterns to our understanding of past climatic and land use changes at a catchment scale and over a range of time scales (Objective 2).*
- *To investigate the institutional framework within which river restoration projects take place and the degree to which knowledge of the functioning of floodplain ecosystems influences their implementation in a range of EU countries (Objective 3).*

By combining the results of the studies carried out under the three objectives it has been possible to develop:

- *Simple river flow recommendations for the management and restoration of floodplain ecosystems.*
- *A conceptual model of the linkages between river type and river processes (at both a catchment-scale and reach-scale) which contribute to vegetation patterns on floodplain.*
- *An analysis of types of river restoration and of the role played in their implementation by both formal and informal institutions.*

1. Introduction

Research for this project took place between 1996 and 1999 with funding from the European Commission's Environment and Climate Programme (EC Contract No. ENV4-CT96-0317). The partners involved in the research included:

1. University of Cambridge, UK (co-ordinator)
   Keith Richards, Francine Hughes, Bill Adams, Martin Perrow, Adrian Hayes, Nadia Barsoum, Mark Winfield and Angus Carpenter
2. Université Joseph Fourier, Grenoble, France Jean-Luc Peiry, Guy Pautou, Jacky Girel, Phillippe Belleudy, Rémi Foussadier, and Franck Vautier

3. CNRS/Université de Toulouse, France Etienne Muller, Henri Décamps, Luc Lambs and Hélène Guilloy
4. University of Umeå,Sweden Christer Nilsson and Mats Johansson

This paper presents a resumé of the objectives and achievements of the first FLOBAR project and of the work proposed in a follow-on project entitled: 'Floodplain Biodiversity and Restoration (FLOBAR 2): Integrated natural science and socio-economic approaches to catchment flow management'. (Appendix 1). FLOBAR 2 is also funded by the EC under the 'Environment and Sustainable Development Programme' of Framework Programme 5.

Aims and objectives of the FLOBAR project

The aims of FLOBAR were:

1. To contribute to the development of a scientific methodology for determining the flow needs of woody riparian plant communities on selected European floodplains; and
2. To gain an understanding of the links between the scientific understanding of the functioning of riparian ecosystems and the institutional mechanisms by which river management for conservation and restoration occur.

These aims were achieved by three linked natural science and social science objectives. The first objective was to identify and quantify hydrological and sedimentological conditions favoured by woody riparian species for their establishment and growth. This was achieved by a combination of field monitoring (vegetation and hydrology), field experiments, controlled greenhouse experiments and numerical modelling. Field sites were installed in four river systems situated along a north-south European climatic gradient representing sub-Arctic (R. Øre, Sweden), Atlantic Maritime (R. Ouse, UK), Humid Alpine (Isère River, France), and Atlantic Pyrenean (Garonne River, France) environments.

Secondly, the project sought to link contemporary floodplain patterns to our understanding of past climatic and land use changes at a catchment scale and over a range of time scales. This required the collation of existing data on historical flows, post-glacial changes in flows, sediments, morphological evolution and management histories for each river; and the development of a simple conceptual model of river evolution, type, and management.

Finally, the institutional frameworks were reviewed within which river restoration projects take place, as was the degree to which knowledge of the functioning of floodplain ecosystems influences the implementation of such projects in a range of EU countries. This pilot study included an attempt to classify river restoration projects, and a study of the varying institutional frameworks within which river and floodplain conservation and restoration projects have taken place.

2. Methods

A combination of scales of investigation characterised the approach of all research groups during the three years of the project.

Field experiments were established to investigate, for a range of woody riparian species, seedling and cutting growth rates in relation to hydrological and sedimentological controls with a particular emphasis on energy allocation to roots and shoots, on the differences between male and female performance under different abiotic conditions in dioecious species, and on the distribution and role of mycorrhizae in determining the abundance and diversity of floodplain vegetation. Greenhouse experiments were conducted to complement field experiments; these used a variety of apparatuses, including rhizopods and rhizotrons, specially designed for controlling water table levels in growing mediums and the associated seedling and root growth.

Installation of hydrological monitoring stations at field sites permitted measurement of river stage and floodplain soil moisture, the latter using a standard form of tensiometer at all sites. Field investigation occurred of patterns of biodiversity and regeneration (at sites where natural regeneration occured) with in some cases, reach-scale analysis of changes in sediment inputs, channel patterns and vegetation cover.

A general analysis was undertaken of river development and management at a catchment scale with a particular view to developing a conceptual model of river types and relationships between abiotic inputs and vegetation response at different spatio-temporal scales.

Throughout the project there has been a particular focus on *Salicaceae* species and some other early successional riparian species. These species are the best indicators of changed hydrological and sedimentological regimes following some forms of river control because the sites and conditions they require for regeneration are no longer provided. At the experimental field site scale, each research group asked distinctive research questions: the Cambridge group focused on sexual variation in the response of *Populus nigra* to water availability and on the impact of sediment burial; the Grenoble and Toulouse groups examined energy allocation to roots and shoots under different abiotic conditions and for different aged seedlings; the Toulouse group also studied water fluxes in the field; and the Umeå group examined mycorrhizal associations and competition. At a river reach scale, the Grenoble group studied longer term dynamics between sediment load in the River Isere, the formation of alluvial bars and the establishment of vegetation. This work has been an excellent bridge between the experimental work and monitoring work carried out at a site scale and the archival studies at a catchment scale.

Two-dimensional hydrological/hydraulic modelling has been carried out by the Cambridge and Grenoble groups, both to simulate recharge of soil moisture in floodplain sediments (by rainfall and through stage rises), and to simulate flow patterns across floodplain surfaces.

Investigations have been carried out into institutional aspects of floodplain restoration using qualitative socio-economic methods. A framework has been devised to classify different types of European rivers and their floodplains, and different categories of restoration schemes (creation, restoration, rehabilitation). This work drew on a review of published studies of floodplain geomorphology and restoration ecology.

3. Results

Field experiments have shown a range of critical relationships linking soil moisture availability, sediment type and vegetation regeneration and growth patterns. For example, at the River Øre site (Umeå, Sweden) mycorrhizal distribution, competition and elevation above river stage have been shown to be important in explaining species distribution and growth along a soil moisture gradient. On the River Ouse site (Cambridge, UK) experiments showed some statistically significant differences in the growth performance of *Populus nigra* males and females in relation to environmental variables but nevertheless, a considerable overlap in habitat requirements between the two sexes. Hydrological monitoring showed clear relationships between river stage and soil moisture availability in floodplain sediments at all sites. On the Garonne River (Toulouse, France) links were found between the origins of groundwater and the use of water by floodplain trees. Greenhouse experiments have added more detailed quantitative information about these relationships.

Field monitoring of vegetation regeneration patterns has shown critical relationships between vegetation management practices, sedimentation rates and vegetation biodiversity. For example, on the River Isère (Grenoble, France) a quantifiable relationship has been identified between bedload transport by the river, the mobility of alluvial islands and the development of vegetation on those islands.

Two-dimensional hydrological/hydraulic models were developed and applied in two ways. Firstly, infiltration into a 2D floodplain cross-section was simulated, following both rainfall input at the surface and lateral recharge through a stage rise in the river. A representation of the River Ouse field site as a digital terrain model (derived from specially flown aerial photography) with subsurface sedimentology then provided the basis for implementation of this model. Secondly, 2D representations of the flow field were simulated provisionally for the Isere field site, to explore the potential for examining spatial patterns of overbank velocity in order to understand the locations in which deposition and surface erosion are most likely to occur on the floodplain surface.

The catchment-scale studies and the institutional studies highlighted the complexities of both the physical and biological responses of rivers to river management practices over time and the responses today by river managers to the dual need to restore floodplain ecosystems and exercise flood control. The pilot institutional study confirmed the importance of institutional factors in determining the feasibility and success of floodplain restoration, particularly 1) the nature of riparian land tenure; 2) the existence of organisations with legal powers and funding to lead initiatives; and 3) the ideas and attitudes of river engineers, particularly about the relations between flood control and ecological restoration. The restoration of floodplain and riparian environments is made more complex by the institutional demands of projects that take account of the upstream-downstream and channel-riparian zone linkages in floodplain function.

4. Discussion and conclusions

The primary focus of the work of all groups has been on the role of water table regimes and available soil moisture in determining the performance of woody riparian vegetation species. Results indicate that for a range of species, water table conditions and available soil moisture have a significant effect on regeneration, survival and growth. These effects are not always direct but can be related to the moisture-holding capacity and hydraulic conductivity of different sediment types, to the availability of nutrients in different sediment types and in different water sources and to the presence or absence of mycorrhizae. Field monitoring, combined with reach and catchment-scale studies of channel change and historical river management practices give a broader picture of hydrological and geomorphological trends and vegetation responses over the decadel time frame. These data have allowed assessment of changes in the rivers under study through time and development of ideas on the appropriateness of different types of river restoration in different types of rivers. An integrated assessment of the importance of hydrological controls on riparian species has allowed the development of preliminary river flow recommendations for the management and restoration of floodplain woodland.

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Johansson, M.E. and C. Nilsson. Performance of two riparian pioneer tree species along a riverbank elevation gradient (*in preparation*).

Winfield, M and F.M.R. Hughes. Variations in the genetic, morphometric and growth characteristics of Populus nigra ssp. Betulifolia clones: implications for river restoration initiatives in the UK (*Submitted to the Journal of Biogeography*).

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APPENDIX 1

FLoodplain Biodiversity And Restoration 2 (FLOBAR2): Integrated natural science and socio-economic approaches to catchment flow management

Introduction

The FLOBAR2 project has grown directly from the work of FLOBAR. It started in April, 2000 and will run until March 2003. The partners involved in the work include:

University of Cambridge (United Kingdom) (Coordinator), Institute for Regional Development and Structural Planning, Berlin (Germany, Université Joseph Fourier - Grenoble 1(France), University of Lethbridge (Canada), Centre National de la Recherche Scientifique -Toulouse (France), and Umeå University (Sweden)

Objectives

FLOBAR2 has four main objectives. The work towards these four objectives has been divided into 7 sub-projects (known as work packages and labelled WP1-7):

Objective 1: To develop scientific guidelines for the application of river flow prescriptions which benefit floodplain ecosystems while maintaining acceptable levels of flood control (WP1).

Objective 2: To quantify aspects of the relationships between hydrological inputs to a floodplain and plant response measured in terms of water consumption, growth and the diversity of regeneration strategies (WP2, WP3, WP4 and WP5).

Objective 3: To investigate the flow resistance associated with woody riparian vegetation using field studies and mathematical and numerical modelling (WP6).

Objective 4: To investigate and compare the effectiveness of selected institutional arrangements for restoring floodplain environments at different spatial scales and in different national/local settings (WP7).

The overall aim of the project is to combine environmental and social scientific perspectives on river management. The project will add to scientific understanding both of the role of hydrology in influencing biodiversity in floodplain environments, and of the role of floodplain vegetation in influencing flood-period water levels. These alternative directions of causal linkage have to be assessed by the agencies responsible for river, floodplain and flow management, and become embodied in the social institutions that inform public opinion about such management. As potentially-conflicting priorities (such as biodiversity enhancement and flood control) change, institutions and agencies adapt, and different aspects of the science become more or less significant. The institutional and agency structures, and the relevant scientific information upon which they draw, thus evolve together. Guidelines for management must make recommendations about both science and institutions, as these have to develop in harmony in order that management strategies are successfully identified and implemented.

Description of the work proposed

Objective 1: To meet this objective it is proposed to write a manual of scientific guidelines which would allow operational water management models to take account of the water needs of woody floodplain ecosystems as well as more traditional water uses. These guidelines will be developed by collating information and expertise from many sources including the scientific community and end-users. Information from the natural science research base of the FLOBAR projects will also make a significant contribution to the formulation of these guidelines. End-user committees will be working with some of the partners in the project and a workshop will be organised to bring together selected interested scientific and end-user groups in Europe to debate applicability of the guidelines.

Objective 2: This objective is in two parts and consists of four work packages: Part A, Field and laboratory experimental studies on floodplains in different bioclimatic regions of Europe will contribute to an understanding of the linkages between variable abiotic (hydrological) and biotic (litter accumulation) inputs to floodplains and the species biodiversity found on floodplains. Part B, Genetic and field studies will determine the relationships between flow regimes and regeneration strategies by studying sex ratios in dioecious species and proportions of trees derived from vegetative and non-vegetative regeneration sources.

Objective 3: Models of flow patterns on floodplains during over-bank flow events still rely on gross empirical representations of flow resistance and the representation of boundary conditions remain crude. Under this objective the fundamental scientific advance will be to improve representation of vegetation roughness associated with changing vegetation morphology in models used to simulate flow levels during floods. This will be achieved through a combination of theoretical and experimental work and numerical modelling.

Objective 4: Work for this objective aims to assess the effectiveness of institutions in dealing with conflicting management objectives, restoring and managing floodplain environments, enhancing floodplain ecosystems, and maintaining flood control, at different scales and in different settings, consistent with the scientific guidelines developed under Objectives 2 and 3.

It is hoped that the work of FLOBAR 2 and in particular the development of the scientific guidelines, can be evaluated informally and at regular intervals by frequent contact with the community of practitioners and scientists involved in river restoration. The process of developing guidelines is seen as an iterative one which will benefit greatly from the contacts established at the River Restoration 2000 workshop in Wageningen, The Netherlands and by continuing these contacts through the European River Restoration Centre and linked institutions.

The main contact points for FLOBAR2 are:

Professor Keith Richards and Dr. Francine M.R.Hughes, Department of Geography, University of Cambridge Downing Place., Cambridge United Kingdom CB2 3EN

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FLOODPLAIN RESTORATION OF THE DIJLE RIVER

W.Huybrechts, P. De Becker, F. Raymaeker, and F. Saey

Abstract

This paper presents a restoration project in the floodplain of the river Dijle upstream of Leuven, Central Belgium. Purpose of the project is the integration of water management and nature management objectives. The water management objectives are mainly related to safety, more in particular to the protection of the city of Leuven against flooding. The nature management objectives are the improvement of ecological values and the creation of large areas of nature in the floodplain of the Dijle. Traditionally, these objectives are considered as a contradiction. However, in recent years a new water management scheme was developed and approved by the water authority, reconciling both objectives.

In the new, integrated approach, the natural hydrological processes of the river system are incorporated in the water management scheme. The discharge of water is slowed down by increasing channel roughness, and delayed by storage of the excess of floodwater in the floodplain. The technical measures to reach these objectives are minimal. The water authority relies on an appropriate management and the functioning of natural processes: sedimentation and erosion processes are allowed, free meander evolution is possible, safe inundation is permitted.

Due to intensive drainage, selective sediment removal in the river channel, mowing of the littoral vegetation and removal of shrubs and trees from the levees, high frequency floods (> 1 per 25 years) did no longer occur. In the integrated water management, all these measures are reconsidered. This offers an excellent basis for a nature restoration program in the floodplain for aquatic as well as water related terrestrial ecosystems. The natural erosion and sedimentation processes gradually will lead to an improvement of habitats for e.g. macro-invertebrates and fish, and offer possibilities for floodplain related birds. The inundation improves the connection between channel and floodplain, sustains abiotic gradients and can become an instrument in the management of the larger areas of nature, allowing the development of typical alluvial floodplain mires.

RESTORATION ALONG THE RIVER SCHELDE

P. Meire

Abstract
The Schelde is a rather small river. It measures 350 km and its catchment is about 21 000 km^2. However, it has a very high population density and hence the river and its tributaries have been subjected to a very heavy antropogenic pressure. Not only water quality was very much deteriorated but also large stretches of the river were straightened and calibrated for shipping.

In recent years, however, much effort is done to reduce the waste load and the first habitat restoration projects are in progress. In my presentation I will give an overview of the problems in the freshwater tidal part of the river and of the present view on management.

To protect the land from flooding an extensive dike reinforcement plan (the 'Sigmaplan') is under construction. This offers many opportunities for restoration. First of all the construction of the dikes can be adapted to allow vegetation growth. Secondly, and most important, the dikes can be located more inland. Finally, coupled with the construction of controlled inundation areas, very interesting opportunities for nature development arise. Based on some examples the rationale of these projects will be discussed.

ARTERIAL DRAINAGE MAINTENANCE IN MOY CATCHMENT

J. Murphy

Abstract

The presentation will elucidate the following subjects:

- *History of OPW arterial drainage programme in Ireland*
- *Description of Moy Catchment and original scheme works carried out 1960–1971*
- *Scheme statistics*
- *OPW maintenance responsibility*
- *Traditional maintenance methods*
- *Changes in maintenance practices in light of increased environmental awareness*
  - *Retention of bank vegetation, one bank method*
  - *Use of natural materials for bank protection, where possible*
  - *Vary bed levels in cross-sections to cater for low flows*
  - *Allow natural sinuosity of channels to develop*
  - *Preservation of attractive bridges, particularly stone structures rather than replacement*
  - *Intervene only where necessary*
- *Importance of Moy as one of the premier salmon fisheries in Europe*
- *Liaison with Duchas and other environmental interests*
- *No direct responsibility for water quality, however*
- *Likely future developments*

RIVER RESTORATION DEMANDS MANAGEMENT TRANSFORMATION

J. van Alphen, and H. Havinga

Abstract

Restoration of a multifunctional use of rivers means adjusting the human use to natural river conditions.

The present river systems are more or less fixed, in order to facilitate navigation and the discharge of water, ice and sediment. Present river management is largely based on restricting natural dynamics by constructive measures, like groins and fixed beds. These measures are mono-functional, disturb natural sediment transports and degenerate natural habitats. In addition they require large investments and maintenance costs.

Restoration of natural conditions means that human activities have to cope with natural dynamics and the delicate balance between natural processes, measures and natural responses of the system. This requires a thorough understanding of margins and scales (time and spatial) of natural river dynamics and the interaction with measures. New fields of interest are the relation of vegetation growth and succession in the floodplain with flow resistance and the influence of secondary flows on bed morphology (water depth!) of the main channel. Constructive measures will give way to a 'building with nature' philosophy, like maintenance dredging.
In addition, online monitoring information has to supply the river managers with accurate information about the status of the river system to warn him for short term critical conditions or long term developments towards critical boundaries of functions or the river system. Much of this information will be accessible on Internet.

To achieve these natural river conditions, co-operation with floodplain authorities and management bodies is inevitable. This requires skills in presentation of knowledge, decision making and negotiating. Decision support systems (DSS) are important tools for the future river manager.

Finally, management actions have to be based (and sometimes enforced) on a sound legal base and maintainable policy. This requires a more active and upgraded role of surveillance in the field.

FLOODPLAIN WATERS AS PART OF A EUROPEAN ECOLOGICAL NETWORK: FISH AND INVERTEBRATES

B.L.W.G. Higler et al.

Abstract

Floodplain waters function as breeding chambers and refugia for riverine fish and macro-invertebrates. Moreover, they contain ecosystems of different composition in relation to the frequency of contact with river water. The question of the importance of isolation and connection of relevant surface waters for aquatic organisms is poorly understood. Migration via the rivers and watershed connecting canals and by air (flying water insects and invertebrates transported by birds) is dependent on many variables such as water quality, migration speed and scale. Watershed boundaries in present Europe are no longer limiting the distribution of aquatic animals and nature development along rivers is a mighty tool to enhance such a distribution.

THE FLOODPLAIN OF THE RIVER IJSSEL (THE NETHERLANDS): HOW TO START COMMUNICATION WITH THE LOCAL COMMUNITY?

G. Kooijman

Abstract

The National Forest Service of The Netherlands presents a project to involve the local community in the nature (and recreation) development plans of the floodplains along the River IJssel.

In order to reach the local community, the communication project is focused on the implementation of the recreational part of the nature development project. The National Forest Service intends to stimulate a larger recreational participation in the nature development in this area. The implementation of recreation in the floodplains of the IJssel is an appealing subject for starting the consultation of the local population. Once the local community is involved in the project, the more technical part of nature development becomes open for discussion too.

A flyer was produced, giving a future vision of the flooplains by a drawing of the area in bird's-eye view. These flyers were distributed during an information evening for the local community. During the evening and afterwards, people could indicate their ideas for the recreational implementation. About 30 reactions came in from the local community, and the same amount from children of the local primary schools. All reactions will be used to work out the final development plans for the area.

This communication project will result in a better understanding between the National Forest Service and the local community, thereby facilitating the implementation of the nature development of the floodplains along the river IJssel.

DEVELOPMENTS IN THE FLOODPLAINS OF LARGE DUTCH RIVERS

J. Kruijshoop

Abstract

The 'NURG Development Plan' was initiated during the 1980s, in line with the government's 'Fourth Document on Spatial Planning' (VINEX). This led to the development of a co-operative association between three ministries and six provinces. In 1993 the Ministries of Agriculture, Nature Management and Fisheries, and Public Works and Water Management began a co-operative nature development projects in the river basins of the rivers Waal, Rhine, Lek, IJssel and Meuse.

High water levels occurred in the rivers in 1993 and 1995. This resulted in legislation assuring accelerated improvements of about 160 km of dikes before 1 January 1997 and of about 600 km of dikes at a later stage. Large quantities of soil were required for the dike improvements and since nature development projects can provide this, it was a logical step to link dike improvement and nature development, leading to obvious win-win situations. The high water levels of 1993 and 1995 stimulated an acceleration of nature development work in the floodplains. The new target was the restoration of initially 4000 hectares by the year 2000 and another 3000 hectares in the period up to 2010. The high waters also led to the formulation of a new policy for the river region. The rivers needed to be given more room by widening of side channels, broadening and lowering of floodplains and removal of obstacles to increase flow. The plans include the creation of unified areas, with a simplified management structure, allowing the river system to function more naturally.

The finance available for NURG, budgeted at 350 million guilders in 1993, is invested in acquisition and execution, including such necessary project-related activities as planning, information, PR and monitoring. As agreed in the covenant between Agriculture, Nature Management and Fisheries, and the Inter-Provincial Council, provincial funds amounting to 50% of the acquisition and execution costs for the projects are transferred to private nature conservation organisations.

THE BORDER MEUSE PROJECT: THE DESIGN OF A NEW RIVER LANDSCAPE

F. Schepers

Abstract
Between Maastricht and Maasbracht, some 45 km to the north, flows the Border Meuse: the only gravel-bedded river in The Netherlands. Its name refers to the fact that it forms the meandering frontier between The Netherlands and Belgium. Abandoned by shipping, which travels between Maastricht and Maasbracht on the nearby Juliana Canal, the river was nevertheless subject to heavy human intervention, mainly during the last two centuries. Frantic attempts were made to confine it within its banks and control the meandering behaviour.

New approaches in water management have not passed this river by. The Border Meuse Project, an ambitious project to give the river new freedom is now approaching implementation. The aim of the Border Meuse Project is to reconcile the objectives of flood protection, gravel extraction and nature development.

The project aims to regain the hydrological, morphological and ecological processes of the river. The way to achieve this is to widen the river bed and to lower the floodplains, in such way that the river is able to reshape itself by means of these processes.

During the last two years, an engineering team of specialists has worked out this new approach into a 'new river design' for the Border Meuse. This design was completed in spring 2000 and is now subject to negotiations with contractors, gravel companies and nature organisations. Extensive effect studies have accompanied the designing process, mainly by means of hydrological, morphological, ecological and groundwater models.

TRANSBOUNDARY CO-OPERATION ON RIVER BASIN MANAGEMENT

H. Zingstra

Abstract
Borders between countries are rarely based on river catchments or river basins. Sound water management and land use planning, however, should be based on a catchment approach. Measures in the field of water quality improvement, water quantity management and groundwater protection are effective only when based on an integrated planning concept for the entire river basin.

River basin wide integrated planning needs to take into consideration the role wetlands play in restoring the natural discharge and recharge patterns of the water system. In addition it needs to acknowledge the role wetlands play to purify water and to trap sediments.

Present day water resources management, however, dramatically conflicts with ecologically desirable approaches to river systems. Dams, reservoirs and interbasin transfers have been constructed to achieve a situation of networks of water bodies benefiting transport of goods and discharge of calculated water flows. But this artificial situation is far away from healthy functioning river systems, benefiting not only transport and water discharge but also biodiversity protection, tourism, flood protection and natural water purification.

Wetlands International strongly promotes the establishment of transboundary co-operation on integrated wetland and water management. River restoration should be an integrated part of river basin wide planning. Planning and execution of river restoration measures for international rivers can only be effective when based on transboundary co-operation on the management of these rivers.

In 1999 Wetlands International has carried out a project aiming to identify transboundary rivers and wetlands significant for biodiversity protection in Central Europe. The main outcome of this project is an overview of rivers and wetlands lacking arrangements on biodiversity protection and on integrated transboundary water management.

PRACTICAL ADVANCES IN RIVER RESTORATION

P.M. Staten, and H. Ellis

Abstract

This paper presents a contrasting picture of river restoration work from over 36 years ago to the present day.

The first case study presented is that of a Half Tide Gabion Wall on the River Humber near Hull constructed in 1964. The structure of Gabions and Reno mattresses was required to protect an eroding estuary foreshore. The wall was designed to overtop regularly, depositing silt behind, in time restoring the eroded salt marshes. Thirty-six years later the structure has been revisited to reveal the long term success of the project both in terms of engineering and ecological benefits to the area.

In the year 2000 we work in a world where river restoration project success should be demonstrated in a relatively short time period. This paper demonstrates that with a carefully engineered integration of traditional construction and bio-engineering techniques the time for successful restoration can be cut dramatically. A series of three recent case studies are presented which demonstrate that with good engineering, bank protection can be achieved with ecological benefit returns in the short term. Each example considers different erosion conditions as the river channel become wider approaching an estuary.

THE NORWICH RIVER VALLEYS STRATEGY

J. Jones

Abstract
Norfolk is a rural county with only 5% of the land area given over to towns and villages. The largest settlement in the county is the city of Norwich, a regional capital of East Anglia since medieval times.

The City is strategically placed at the head of the navigable waters of the River Yare and the confluence of its major tributary the Wensum. Although 47 km from the sea at Great Yarmouth, the tides still reach the heart of the city. Norwich owes its existence and past prosperity to its function as an inland port. It has been an urban entity for over 1100 years and in landscape terms the city enjoys a fortuitous setting. Parts of the steep wooded ridges, which define the natural river valley landscape, still remain.

A record of past achievement makes a compelling argument for the need and value of a strategy offering a vision for the years ahead. A long term strategy is being prepared to help guide the future protection and enhancement of the river valleys in and near the city of Norwich. Using a process of 'Landscape Character Assessment', an Action Plan will identify landscape and habitat values, restoration/management techniques, provision of access and recreation infrastructure and opportunities for local participation, within each of the reaches of the river valleys. Due to its remit across five local authority areas this project has created partnerships – all of whom place great importance on protecting and enhancing the landscape of the river valleys for wildlife, amenity and recreation. Besides, most of the projects proposed around the Norwich area are a direct result of community consultations and therefore reflect their needs.

A feasibility study is complete and a three year program for river dredging on the navigable Wensum within the city has been agreed. The first stage will start this summer in order to prepare for the pilot river bus project. This will continue the process of raising awareness within the community of the value of their river resource and of the plans to restore it as a major artery through the city.

STREAM REHABILITATION IN SWITZERLAND

A. Peter, U. Bundi, B. Kaenel, and H. P. Willi

Abstract

In Switzerland the intensity of human occupation of land and water is very high. Most Swiss rivers are exposed to a variety of impacts. Between 30–40 % of the small streams (1st order streams) were placed into culverts during the last decades. Streams and rivers of higher order are highly canalised and fragmented. In total, only about 5–10% of the Swiss streams and rivers retained its natural or near-natural state. Therefore, the need for stream and river restoration and rehabilitation is very strong in Switzerland. Approximately 15 000 km of streams should be rehabilitated.

The results of rehabilitation projects of streams depend on the stretch of the stream and the amount of riverine land that can be restored. A new statutory basis in Switzerland ensures the importance of the lateral connection between water and land for the natural functioning of streams and favours rehabilitation. Ecological rehabilitation has to be carried out on a whole catchment basis. Therefore appropriate tools for catchment analysis (ecomorphological analysis) were developed.

We will present suggestions for the rehabilitation of small and medium sized streams using a whole catchment approach.

SOUTHERN EUROPE

REHABILITATION OF A RIVER IN AN URBAN AREA, THE JAMOR RIVER CASE

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Abstract
The Jamor River, located near Lisbon, is a small tributary of the Tagus River with a high seasonal flow regime. The Jamor watershed has suffered several modifications since the Roman time, by agriculture and cattle grazing. In the last two decades, urban development has been increased in the watershed. The destruction of natural vegetation and the changing of land use have modified the watershed drainage conditions and augmented flood hazards. On the other hand, the construction of houses and roads on the riverbanks, the loss of riparian trees, damage to the riverbank structure, presence of bridges with narrow sections, erosion, and sedimentation on the river bed and along the riverbank have affected channel morphology and reduced the floodwater discharge capacity. The Jamor River also exhibits water quality problems related to the discharge of untreated wastewater and the disposal of litter in the river. The occurrence of periodic floods causes environmental, social and economic damages to the local population.
The main objectives of the rehabilitation project of the Jamor River are the reduction of flood magnitude and frequency, and the restoration of landscape and ecological values of the river. The recreation value of the river is also considered. The project includes: (i) re-profiling of the longitudinal and cross-sections of the river, increasing the floodwater discharge capacity, (ii) construction of three weirs on the tributaries for sediment retention and peak flow reduction, (iii) restoration and management of riparian vegetation, and (iv) enhancement of cultural values.

1. Introduction

The Jamor River rehabilitation project is integrated in a global programme for flood control in the urban area of Lisbon. The main objectives of this project are the reduction of flood magnitude and frequency, and the restoration of the aesthetic, ecological and recreational values of the river. The *Instituto da Água* is responsible for this project, but the municipalities will also to participate in its implementation. The first studies took place after a great flood that occurred in 1983. The final version of the project plan dates from 1995. Then the project implementation started. The project implementation is being done at reach level, considering the most critical situations and the existence of specific projects.
This project is associated with another one for the cleaning of rivers in the Lisbon urban area. The projects aim at the improvement of water quality and rehabilitation of the Jamor River.

2. The Jamor River

The Jamor River, located near Lisbon, is a small tributary of the Tagus River. The river is 16.6 km long, draining an area of 44.6 km². The source of the river is in the Carregueira Mountain, at an elevation of 310 m. The river discharges into Tagus estuary, near the Cruz Quebrada beach.

According to the Köppen climatic classification, this region is characterised by a temperate wet Mesothermic climate (Csb) with a long, but not very hot, dry season in summer.

The Jamor watershed can be divided in two distinct geological zones. The headwaters and the upper zone are part of a region with calcareous sediments of the Jurassic and Cretaceous, while the lower zone is part of the volcanic complex of Lisbon of the later Cretaceous. Near the river mouth some Miocene deposits and alluvial deposits in the river and its tributaries are found.

Due to the geological situation, soil erosion and slope instability occurs in the Jamor River watershed, mainly in areas where the natural vegetation was removed.

The average runoffl in the watershed of the Jamor River is 250 mm and the mean annual discharge is 0.30 m³/s. The river is characterised by a high seasonal flow regime. From June to October, the mean monthly discharge is lower than 0.1 m³/s, and in January and February the maximum mean monthly discharge can reach 1.20 m³/s.

The landscape in the Jamor watershed has changed several times since the Roman time, due to agriculture and cattle production. In Roman time, the Jamor River was also used for water supply. The Olisipo Roman dam, constructed in one of its tributaries, bears evidence of this river function.

In the last two decades, the urban development in the watershed has increased. The aquatic and riverside vegetation has changed very much. The destruction of natural vegetation and the changing land-use have changed the drainage conditions in the watershed drainage and augmented the flood hazards.

On the other hand, house and road construction on riverbanks, loss of riparian trees and damage to the riverbank structure, the presence of bridges with narrow sections, erosion, and sedimentation on the riverbed and along the riverbanks have affected channel morphology and reduced the floodwater discharge capacity.

There are also water quality problems related to the discharge of untreated wastewater and the disposal of litter in the river. Presently, the water quality is such that recreation involving direct contact with the water is not allowed. The bad water quality is caused by the high values of organic matter and bacteriological contamination.

The occurrence of periodic floods causes environmental, social and economic damages to the local population. This happened in 1967 and 1983. In 1967, the simultaneous occurrence of high water in the estuary contributed to a high water level in the river.

3. Present Situation

Several reaches of the Jamor River can described on the bases of the following principal characteristics: topography, riparian vegetation, and physical and biological features of river cross sections. In some of these reaches some rehabilitation measures were already implemented within the framework of the Jamor River rehabilitation project.

Reach 1 – This reach is still slightly modified by man. It begins at the headwaters on the Carregueira Mountain. The main channel width varies from 0.8 to 5.0 m and its depth ranges from 1 to 2 m. There is no floodplain. The banks are vertical, where some riparian trees, like ash (*Fraxinus angustifolia*), black poplar (*Populus nigra*), and blackberry thicket (*Robus* sp.) grow. Some zones present a good riparian corridor. On the right riverbank, there is a small oak wood very well preserved, with high landscape and ecological values.

Reach 2 - In this reach, the river is channelled over a distance of 650 m under Belas town. The channel was incorrectly designed for a flood with a return period of 100 years, having a discharge capacity of 70% of this flood. Consequently, floods occur very often upstream of this reach.

Reach 3 – This river reach crosses a suburban region with some cultivated lands (*'hortas'*) and ends near the Pendão village. These '*hortas*' occupy the floodplain. The main channel width varies from 2 to 4 m and its depth ranges from 1 to 3 m. The banks are almost vertical and often are rough stone walls covered by blackberry thicket (*Robus* sp.). It is possible to find some riparian trees on the riverbanks.

Reach 4 – The river reach crosses an urban region and ends before the Queluz Palace. The main channel width varies from 4 to 10 m and its depth from 3 to 4 m. The right bank has some rudimental vegetation and the left bank is at some place formed by a vertical rough stone wall. The floodplain width varies from 5 to 15 m and is occupied by houses and '*hortas*'. These houses have suffered several damages during the flood in 1983 (this flood had a return period of 100 years).

Reach 5 – This river reach had the same characteristics as Reach 4 until 1997. In that year, the Amadora Municipality implemented some rehabilitation works. The main objectives were to create landscape continuity with the Gardens of Queluz Palace, the valorisation and enhancement of riverbanks, including the construction of a garden (*Jardim dos Candeeiros*) on the floodplain.

Reach 6 – In this reach the river is channelled and crosses the 18th century Gardens of the Queluz Palace, which used to be the summer residence of the Portuguese Royal Family.

Reach 7 – A semi-natural reach that crosses a suburban region and present an irregular cross-section. The mid-channel river width varies from 3 to 20 m and its depth ranges from 0.25 to 2.5 m. Some river sections have vertical rough stone wall riverbanks, partially covered by riparian vegetation. However, other section show some river bank stability problems. In the riverbed are large stones, aquatic weeds and sediment accumulation. The floodplain width varies and there are houses, industrial buildings, small-forested areas, and cultivated lands. An old church from the 19th century is located in the floodplain. The church has an elevated entry to prevent the inflow of flood water. There were some bridges with narrow sections, which were re-designed for the 100-years flood, after the first studies in1986.

Reach 8 - This reach was integrated in a sport and leisure area, the *Complexo Desportivo do Jamor*, that includes a hippodrome, tennis courts and other facilities, located in the floodplain. The natural channel was realigned and dredged. The old channel was transformed into an artificial lake connected with the new channel. This new channel has trapezoidal sections protected with '*gabions*' and will be used for canoeing. It is a very poor riparian corridor dominated by *Phraghmites* sp. Old farms, almost abandoned, occupy the left bank.

Reach 9 – This last reach crosses an urban area, ending in the Tagus estuary. It was channelled in the period 1930-1940 and the riverbanks were protected by rough stone wall. Two groins were built in the river mouth to protect the two bridges that were built immediately upstream.

4. Future Measures

The Jamor River rehabilitation project includes several futures measures:

1. Re-profiling of the longitudinal profile and re-dimensioning of the cross-sections of the river reach between at the end of reach 2, until the crossing with the A5 highway (at the end of Reach 7). Where the river crosses urban areas, the riverbed and the riverbanks will be protected with '*gabions*'. These interventions will increase the river floodwater capacity and reduce the water velocity.

2. Construction of '*gabion*' weirs with a maximum height of 7 m, one in the Jamor River (immediately upstream at the beginning of reach 2) and two in its tributaries, to allow the retention of sediments and the reduction of peak flow of 62%, 37%, and 42 %, respectively. Other kinds of measures are not possible to implement because of the intense urbanisation in this area.
3. Cutting of the weeds, restoration and management of the riparian vegetation with native species after the end of reach 2.
4. Construction of gardens with facilities for sport activities upstream of the weirs and in the upper part of the *Complexo Desportivo do Jamor* (reach 8).

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IN-STREAM FLOWS IN SPAIN

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Abstract
The intensive use of water resources and fertile lands of floodplains in Spain have given rise to an evident deterioration of the rivers. The Spanish authorities involved in the environmental management have implemented restoration measures for the river ecosystems, but these measures lack sense if they are not accompanied by the establishment of an in-stream flows hydrological regime. The present legal framework of water management, Water Plans, have assessed minimum flows to comply with the environmental demand of rivers. These minimum flows reflect the in-stream flows state of the art at the time when the Water Plans were established. Nevertheless, the Plans recognise their own limitation to comply efficiently with the environmental demands, and include and review of the regulations. At this moment, at least, three methodologies in Spain are in a very advanced stage of development, to establish an environmental compatible flow regime for the use of the remaining water.

1. Introduction

In the last century the regulation of water resources has grown in Spain exponentially, to meet the demands of water users (drinking water, industry and especially irrigated lands). Currently, there are 1024 large operating dams with a total storage capacity of 53 806 hm^3, and a total water surface of 282 445 hectares, which have given rise to an evident deterioration of the different ecosystems related with fresh waters upstream and downstream of dams.
The regulation and diversion of the water resources had a negative impact on the riparian areas. This was further increased by the demand of high quality, intensively, cultivated lands. The cultivated areas are usually found in the fertile lowland of rivers. Vast floodplains are being transformed into irrigated lands (more than 1.5 millions hectares, which is approximately 15% of the total cultivated lands).
The noted deterioration, the growing environmental consciousness raising of the Spanish society, and the growing demands of utilising the rivers and their surrounding areas (fishery, sports, landscape, etc.), has led to the establishment of different administrations involved in the environmental management. These administrations are to legislate and manage the water resources according to the principles of sustainable development.

2. Environmental Management

In the last 15 years the Autonomous Communities or Regional Governments, responsible for the environmental management, have taken specific actions to maintain and restore the gallery forests on riverbanks. The General Administration of the State or National Government took measures to restore the river morphology and protect the banks, because the management of the public hydraulic domain, is an exclusive responsibility of the National Government.
The implementation of all these measures to improve the environmental quality of the rivers and its

adjacent areas, lack sense, if they are not accompanied by the establishment of an hydrological regime with an environmental aim (in-stream flows). This hydrological regime can only be set through the legal instruments to manage the water resources, the Water Plans (*Planes Hidrológicos de Cuenca/PHCs*). The *PHCs*, are the basic planning and management tools for the water resources. In the *PHC* the available resources, the existing demands and the assignment of the available resources of water to present and future demands should be laid down. These Plans are the backbone of the Water Law. The Water Law has been sanctioned by the Water Counsels of each Water Authority (in Spanish, *Confederación Hidrográfica*) after a long process of political discussion. Water Counsels are the planning institutions of the rivers basins, in which the water users, national and autonomous administrations, and technical services of the Water Authorities are represented.
The Water Plans has been legally approved recently (R.D. 1664/1998, of 24^{th} of July of 1998). In the Water Plans rules are laid down for the minimum water flow in the rivers in their watershed. The minimum flow vary from1 to 10% of the annual average runoff (see Table 1).

Table 1. General conditions of flows established in the different Water Plans in Spain

WATER PLAN	GENERAL CONDITIONS
Norte I, II y III	Minimum flow: 10%, with a minimum of 50 l/s.
Duero	Minimum flows are not indicated.
Tajo	Environmental demand: Monthly volume equivalent to the 50% of the non regulated mean summer inflow.
Guadiana I y II	Minimum volume spill over from Dams: 1% of the natural inflow to the Dam.
Guadalquivir	50 l/s as maximum except the flows assigned for the General Exploitation System.
Sur	Ecological Flow: 10% of inter-annual mean inflow.
Segura	Minimum Flow: 10% of inter-annual mean inflow.
Júcar	Maximum Reserve: 1% of the total resources of the watershed.
Ebro	Minimum Flow: 10% of inter-annual mean inflow.
Cataluña	Minimum Flow: 5% of the median inflow of ten consecutive years. Always up to 50 l/s.
Galicia-Costa	Minimum Flow: 10% of annual mean inflow.

3. Environmental Flows

The Water Plans, as already indicated, have been subject of a long debate before their final approval. The considerations about the minimum flows in the rivers are still in its infancy and reflect the state of the art at the moment of editing the Water Plans (late 80s). Methodologies for the calculation of the minimum flow requirements of the Mediterranean rivers (mainly of the Spanish rivers), were not available. The existing methods propose abundant minimum flows that were not able to reflect the hydrological variability (annual and inter-annual) of the Spanish Mediterranean rivers (see Table 2). This limitation has been adopted in the White Book of the Water (*in Spanish LBA*). This book is the analysis document of the Water in Spain, which was edited in December 1998. In the White Book of the Water it is also proposed to restrict the exploitation in a watershed. 20% of the watershed should be kept in a natural state in order to meet the environmental demands of the Spanish rivers and wetlands. The *LBA* has been written with the objective, among others, to serve as a discussion document for the writing of the National Hydrological Plan (*Plan Hidrológico National/PHN*). The *PHN* will coordinate the different PHCs and will lay down the general bases of the water management in Spain. The *PHN*, that has to be approved by the Spanish Parliament, will incorporate the general restriction concepts included in the Law 46/1999 of December the 13th (modification of the Water Law).

This Law, anticipating some aspects of the final version of the Directive Framework of Water, lays down, among others, some interesting and novel aspects, like in art. 38.1, that states:
'the water planning will consider, as a general objective, to obtain the good ecological state of the public hydraulic domain and the satisfaction of the demands of water....listen to reason the different uses in harmony with the environment and the natural resources'.
In relation to the circulation of volumes of water, art. 57.7 states:
'the ecological volumes or environmental demands will not have the character of use....and ...ought to be considered as a restriction imposed with general character to the Systems of Exploitation. and, finally...*ecological flows will be set in the PHC and for their establishment the Waters Authorities will carry out specific studies for each reach of the river'.*

4. In-stream Flows Approaches in Spain

In the last years different approaches for the establishment of an environmental hydrological regime in rivers have been developed in Spain. Mainly three approaches have been developed.

1. The adaptation of the IFIM methodology (Bovee 1982) to the Spanish rivers, carried out by the equipment directed by the Dr. Diego García of Jalón. This adaptation has consisted of the development of flows preference curves for ciprinodontid species of the Spanish rivers, and in the generation of a regime of flows with the hydrological variability of the Spanish Mediterranean rivers (García of Jalón *et al.* 1997).
2. The so called Basque Method (Docampo *et al.* 1995) that estimates the flows required for the presence of bentonic invertebrates. This method uses, as indicator species of the ecological state of the aquatic ecosystem, the species of bentonic invertebrates. The bentonic invertebrates are the bases of the trofic chain that permits the existence of the species that inhabit the whole watershed.
3. The Basic Flow. By means of analysing the daily registered flow series, a minimum flow can be assessed which is required to maintain the existing biological diversity. This method proposes the generation of a flow regime in the studied reach similar to the existing one without regulation (however, at a lower scale), as well as the creation of flushing flows to clean the substrate and maintain the width of the river bed. (Palau *et al.* 1998).

None of these methods has sufficiently been validated in the field. So, the effects of the proposed flow regime on the conservation of the physical and biological diversity of the reach has not yet been assessed. Presently, different projects are being started all over the country, to assess the effects of the proposed flow regimes. Water authorities, universities and water users are actively participating in these projects.

5. Conclusions

From a conservationist point of view, the future management of fresh waters and their associated ecosystems in Spain, that will be clearly laid down in the *PHC* and in the future *PHN*, may be qualified as hopeful, compared to the management to this day. Most of the *PHCs* and the new Water Law emphasise the need to maintain flows in rivers for a sound environment, as well as the need to develop methodologies and tools to estimate the flow regimes for each river. This objective will be achieved, fairly soon, thanks to the development of the mentioned methodologies.

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Table 2. Particular Flow conditions in the rivers, as laid down in the different Water Plans

DAM or RIVER/ WATER AUTHORITY	RIVER/DESCRIPTIÓN	FLOW m^3/s
Riaño dam/Duero	Esla/Spill over from dam	4.0
Juan Benet dam/Duero	Porma/Spill over from dam	3.0
Villameca dam/Duero	Tuerto/Spill over from dam	0.1
Barrios de Luna dam/Duero	Orbigo-Luna/Spill over from dam	2.5
Camporredondo-Comp. dam / Duero	Carrion/Spill over from dam	0.5
Requejada dam/Duero	Pisuerga/Spill over from dam	0.6
Cervera-Ruesga dam/Duero	Ribera/Spill over from dam	0.5
Aguilar de Campoo dam/Duero	Pisuerga/Spill over from dam	2.0
Arlanzón dam/Duero	Arlanzón/Spill over from dam	0.1
Uzquiza dam /Duero	Arlanzón/Spill over from dam	0.3
Cuerda del Pozo dam/Duero	Duero/Spill over from dam	0.6
Linares del Arroyo dam/Duero	Riaza/Spill over from dam	0.1
Santa Teresa dam/Duero	Tormes/Spill over from dam	6.0
Agueda dam/Duero	Agueda/Spill over from dam	2.0
Guadalquivir/Guadalquivir	Downstream Pedro Marín dam/minimum flow	1.6
Guadalquivir/Guadalquivir	Downstream Mengíbar dam/minimum flow	4.4
Guadalquivir/Guadalquivir	Downstream El Carpio dam/minimum flow	7.2
Guadalquivir/Guadalquivir	Downstream Alcalá del Río dam/minimum flow	12.1

Genil/Guadalquivir	Puente Genil city/minimum flow	1.5
Segura/Segura	Reach from Contraparada (Murcia) to S.Antonio (Guardamar)/minimum flow	4.0
Cenia/Júcar	Reach downstream Ulldecona dam to La Cenia diversion/minimum flow	0.3
Sichar/Júcar	Reach downstream Sichar dam to Onda weir/minimum flow	0.2
Guadalaviar/Júcar	Reach downstream Benegéber dam, to Loriguilla dam/ minimum flow	0.7
Guadalaviar/Júcar	Downstream Loriguilla dam/minimum flow	0.5
Cabriel/Júcar	Downstream Contreras dam/minimum flow	0.4
Júcar/Júcar	Downstream Alarcón dam/minimum flow	0.4
Júcar/Júcar	Downstream Picazo Hidroelectric power station/ minimum flow	0.4
Júcar/Júcar	Downstream Tous dam/minimum flow	0.6
Magro/Júcar	Downstream Forata dam/minimum flow	0.2
Serpis/Júcar	In all the river Serpis/minimum flow	0.08
Guadalest/Júcar	Downstream Guadalest dam/minimum flow	0.1
Verdugo/Galicia-Costa	In all the river Verdugo/minimum flow	0.5
Otaivén/Galicia-Costa	In all the river Otaivén/minimum flow	0.5
Lérez/Galicia-Costa	Spill over from dams of water basin /minimum flow in Lerez river	1.0
Umia/Galicia-Costa	Spill over from dams of water basin/ minimum flow in Umia river	1.0
Ulla/Galicia-Costa	Spill over from dams of water basin/ minimum flow in Ulla river	1.5
Forcadas/Galicia-Costa	Downstream Forcadas dam/minimum flow	0.5
Ebro/Ebro	River mouth/minimum flow	100

THE ‘DOÑANA 2005’ PROJECT

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Abstract
The Guadalquivir marshes have experienced a continued transformation and degradation during the last century. Mainly because human of intervention, the surface has been largely reduced and what is left is now threatened by the cutting of the water supply and has lost its original quality. The accident in Aznalcóllar, on the 25th of April 1998, has worsened this situation, by damaging the Doñana National Park environment, although it did not entered into the protected area itself.
The Ministry of Environment had already started a process of reflection and undertook an analysis of the present and future situation of the Doñana National Park area. The result of this process was the ‘Doñana 2005’ project, supported by the National Parliament. Its objective is to recuperate the traditional hydrological dynamics of the marshes by the implementation of a series of actions. The first actions are related to the restoration of the water systems and the next are a following up programme of the project, a research programme and a communication plan, which includes the citizen participation through transparent and clear information. It is an open and participatory project that pursues not only an environmental restoration but creates a common conscience about conservation of the marsh ecosystem.
The actions included in the ‘Doñana 2005’ project are in accordance with other actions in the surrounding area, in particular with the Guadiamar River Green Corridor project, promoted by the Junta de Andalucía.
The ‘Doñana 2005’ project will only be successful if the different organisations and institutions involved will join their efforts.

1. Background and Justification

The Doñana National Park is one of the most emblematic wetlands in Europe. It is integrated in the Ramsar Agreement for the wetlands protection, in the programme of Biosphere Reserves patronaged by the UNESCO and is recognised as a World Heritage Site. The management of the Doñana Park has also been awarded with the European Diploma.

Doñana is located close to the mouth of the Guadalquivir River (Figure 1). Here we find many different ecosystems, of which the marshes are a very weak and vulnerable, and dynamic ecosystem. The marshes are very vulnerable to the changing surrounding conditions, especially to changes in the hydrological function of the marshes. Great ecological value, as habitat of many wild life and floral species, its unique landscapes and its geographical, strategic, important position, are factors that justify its conservation.

Anyway, the Guadalquivir marshes have experienced a continuous process of transformation and degradation during the last century, mainly because of human intervention. Even with all these changes, we still can find a very important wetland in Doñana, although the quantity and quality of

the natural water supply has degraded.
We know already for a long time that the water systems in the Doñana National Park have to be restored. Unfortunately, during the last decades, the need for restoration has been in conflict with the interests of land use. The first restoration try was known as ‘*Doñana´s hydraulic regeneration Plan*’ (1981). Although it was well meant, the plan did not provide a overall solution to the damage done to the marshes in the past and did not consider the whole basin.

The Aznalcóllar mining accident, on the 25th of April 1998, has worsened the situation by damaging the National Park environment although it did not enter into the park itself. Then the *‘Doñana 2005’* project was born. The project was initiated not only because of the mining accident, but also because of the previous reflections about the hydrological functioning and its conservation, which had already started years ago.

2. Reference Frame

After the mining accident the Ministry of Environment took some emergency measures, all related to the Guadiamar River, to overcome this situation. At the same time two kind of actions were taken (mid-term and long-term), with different characteristics but complementary: the *Guadiamar ‘Green Corridor’* and the *‘Doñana 2005’*.

The *‘Doñana 2005’* project looks after the marshes naturalness recuperation and its hydrological functioning. The project also pursues to change the tendency of the last decades. The tendency was to convert the National Park into a completely hydrologically isolated area, managed by very strict models based on dykes and sluice gates.

The directress idea is a new project that will restore all the surrounding river basins providing water, not only the Guadiamar river. An ambitious project, the result of a situation that existed after the mining accident. The aim of the project is to restore not only of the traditional hydro-dynamics in the local river basin, but also in the surrounding river basins.

It is important to point out that the final purpose of the *‘Doñana 2005’* is the restoration of the functions of the water systems. This objective is also included in the ‘Guadiamar Green Corridor’ project. Therefore, we can see how complementary both projects are, not only in their objectives but also in their actions, making an administrative co-ordination between them necessary.

3. Objectives

- Recovering the traditional hydrological marshes dynamics, assuring the water quality and quantity;
- Maintaining continuous interaction between the Doñana marshes and the Guadalquivir Estuary, assuring that the water flows when needed and preventing the flow when not;
- Stopping the degradation and restoring the fauna habitats and landscapes;
- Establishing a follow-up and evaluation system that supports the implementation of the plan and promotes research and dissemination;
- Preventing that polluted water enters into the Doñana marshes or being used for human needs.

4. Characteristics

1. It is an **integrated** project. This means that the Ministry of Environment or the National Park are not the only organisations involved. It must integrate the other administrations involved, like the *Confederación Hidrográfica del Guadalquivir* and the *Junta de Andalucía;*
2. A scientific committee consisting of specialists of international reputation acts as an supervisory/ advisory body;
3. The project has a comprehensive character (**holistic** approach) as it integrates the natural environment with the socio-economic factors. It is also the first time that solutions for the historical damage in Doñana is looked at as a whole;
4. It intends to incorporate suggestions and opinions from the scientific community, the conservationists associations and the social agents involved: it is a **participatory** project;
5. It is an **open** project. It will take a long time till its completion. This makes it possible to incorporate new technologies, the recommendations of the scientific committee, and the contributions coming from the participation programme. It also develops a follow-up and evaluation programme for the appropriate adjustments during the project implementation.

5. Scientific Committee

Due to the dimensions and characteristics, of the *'Doñana 2005'* project, a scientific committee that supervises and evaluates the adopted actions, is essential. The members of the scientific committee have an international reputation, are independent professionals and form a multidisciplinary group. The members are coming from research institutions that are involved, in some way, in the management and conservation of natural areas.
This committee has already been formed but is not yet officially appointed by the Ministry of Environment.

6. Dissemination and Public Participation

The *'Doñana 2005'* project is conceived as an open and continuous process, with citizen participation, and clear and transparent information. It looks for a social consensus that will assure the success of the project. The dissemination and public participation addresses the public in general and the social agents involved in the Doñana´s National Park territory and environment. Among these social agents, the agricultural collective is an important one.

7. Actions Included in the DOÑANA 2005 Project

The *'Doñana 2005'* project must not be considered as just a group of projects or actions. We need a holistic and integrating vision, taking into account the particular characteristics of the marshland ecosystems. The project tries to reconvert, as far as it is possible, the marshland into an open system.

The project proposes to change the management model that has been applied to the marshland during the last fifty years. The new management model does not want to isolate the marsh land, but wants to restore the natural water flow of the ecosystem. Therefore streams must be rehabilitated, the waters must be cleaned and sewage water of cities, like *El Rocio*, must be treated. We will try to recover the hydrological function of the river channels. Also important is the management of the interaction between the river and the marsh, i.e. the *'Brazo de la Torre'* and *'Entremuros'*.

Doñana is not only an ambitious project from the hydraulic point of view. It seems reasonable to consider it as a macro laboratory that can serve as a model for nature restoration in similar areas. The effectiveness of the works and their corrective measures should be evaluated whenever considered necessary. These evaluation programmes provide information and recommendations for follow-up programmes, including the related research.

The proposed actions included in the *'Doñana 2005'* project, are the following:

1 Restoration of the *'Soto Grande'*, *'Soto Chico'*, and the *'Laguna de los Reyes'* streams. It consists of restoring the streams flowing to the Rocío marsh by installing filtering and decontamination structures and sediment traps, if necessary, and eliminating the artificial channels;
2 Treatment of the *'Rocío'* sewage. To avoid the black waters coming into the marshlands;
3 Restoration of the *'Partido'* stream. To stop the progressive sand coming to the marshes;
4 Restoration of the *'Gallega'* marsh. It intends to eliminate the artificial channels and recuperate the original channels pattern;
5 Recovery of the *'Guadiamar'* channel operating capacity. By incorporating the flows coming from the Guadiamar river along watercourses from the *'Cigüeña'* stream. At the same time the project aims at the restoration and environmental recovery of the *'Guadiamar'* river public water supplies and riverbed;
6 Restoration of the *'Travieso'* channel. By stopping the agriculture that has been practised for many years on the *'Caracoles'* land;
7 Restoration of the *'Brazo de la Torre'* operating capacity. Similar to the previous action, this action tries to recuperate the fluvio- tidal movements in this area. This is one of the most complex actions;
8 Restoration and management of water flow in the marsh bordering the river, the *'Brazo de la Torre'* and *'Entremuros'*. It aims at interaction between the Doñana marshes and the river;
9 Monitoring and evaluation;
10 Operational Research;
11 Dissemination of Project Objectives and Achievements.

8. Financing

The *'Doñana 2005'* project is financed by the European Union and the Spanish State Government (regular contribution from the General Budget). The total amount is 86 million Euros, to be spent between 1998 and 2005.

Figure 1. Doñana National Park

RIVER RESTORATION IN SPAIN, CASE STUDY: LLOBREGAT RIVER

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Abstract
Some general remarks and restoration constraints are mentioned for the Spanish rivers, where only rehabilitation projects have been implemented until now. The main characteristics of the Lower Llobregat Rehabilitation project are presented, together with some conclusions. Irrigation is essential to maintain riparian plantations in the dry Mediterranean climate. Lack of execution control or unfinished works do not increase the confidence in bio-engineering techniques and river restoration for river management.

1. Introduction

Spanish rivers are starting to be restored or ameliorated, after some decades of intensive flow regulation (García de Jalón 1987), rural land consolidation and urban channelisation (*CEDEX* 1995). Due to the Mediterranean climate the flow regimes show high fluctuations, including long periods of reduced base flow alternated with big floods. This situation promotes the use of the floodplain during dry seasons and causes great damages during the floods.
In this context, River Restoration projects have to deal with the following :
1. The scarcity of fluvial space where meandering can be redesigned;
2. A permanent threat of flooding;
3. There is still much more confidence in traditional hydraulic engineering projects than on new bio-engineering approaches for river control.

2. Case Study: The Llobregat River Rehabilitation Project

The rehabilitation of the lower Llobregat River is a good example of the river restoration procedures in Spain in the 90´s (González del Tánago and García de Jalón 1996), although river managers have changed somewhat their traditional engineering thinking since this project was finished in 1998.

Geographical description
The Llobregat River has its sources in the East Southern Pyrenees (*Fonts del Llobregat*) at an altitude of 2000 m. With a total length of 156.5 km, it drains a basin of 948.4 km^2, forming a large delta at its mouth, in the Mediterranean sea, after crossing a very densely populated and industrialised region South-west of Barcelona.

The project reach is located in the lower part of the basin, with a total length of 14 km. The mean annual discharge is 21.5 m^3/s and the flood discharge in the project area is 4000 m^3/s. The floodplain in the project reach is intensively used for agricultural, urban and industrial purposes, and the left bank accomodates several transport facilities (motorway to Barcelona, local roads and the rail-road).

New project and river rehabilitation context

A new motorway to Barcelona city was proposed to be constructed along the right bank of Llobregat river, confining definitively its floodplain. The initial project included the channelisation of the river affected reach, dredging the channel to extract gravel for the road construction.

The Environmental Department of Catalonia demanded an alternative, more environmentally friendly, river treatment, which had to be redesigned taking into account many hydraulic constraints but also some ecological issues.

Rehabilitation objectives

The general objectives for the rehabilitation project were:

1. To improve the morphological and biological structure of the river, to assure its ecological functioning;
2. To create a continuous fluvial corridor, allowing aquatic and riparian species dispersion, and recreational and cultural activities for human populations along the valley.

Some specific objectives were taken into account for the project design, like:

1. To assure hydraulic conditions, able to maintain permanent aquatic communities;
2. To stabilise the channel and support woody riparian vegetation, adapted to the frequency and magnitude of river floods;
3. To encourage the use of the river for recreational and cultural activities, promoting its historical, ecological and landscape values.

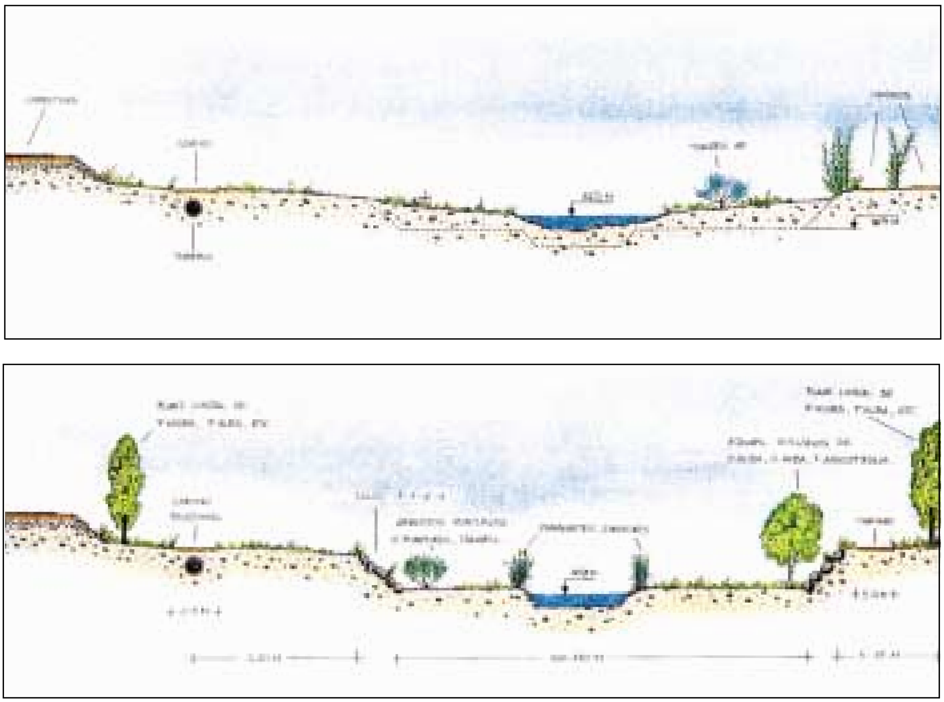

Figure 1. Cross section of river Llobregat before rehabilitation works (showing in doted line the hydraulic proposal) and the project proposal.

Project design

The main measures which were included in the project design were:

- Creation of a multiple cross-section, including low flows channel along the channelised river reaches, with a meandering pattern inside the flood cross section;
- Plantations of vegetation areas along the banks of low flows channel, to stabilise its pattern and create aquatic habitat;
- Plantations of riparian vegetation along the river corridor, for habitat creation, recreational purposes and fluvial landscape enhancement;
- Design of a pedestrian road along the river corridor, to allow walking, cycling and access to the recreational areas.

Some recommendations for the implementations of the hydraulic design were made as well:

- Reducing the length of the channelised reaches as much as possible;
- The depth of rip-rap layer, which was initially proposed to consist of two layers, was finally constructed in a single layer;
- Covering and planting the rip-raped slopes;
- Decreasing the channel lateral slopes to a maximum ration of 3:1.

Figure 1 shows the typical cross section of the river Llobregat (before project and after rehabilitation design). The top view of the plan, including meandering of the low flow channel and different bank and riparian plantations, is presented in Figure 2.

Execution of the project

Although a detailed plantation project was proposed and accepted by managers, only a reduced part was implemented, having serious problems with the quality of plants and maintenance. The low flow channel was not executed correctly, and the new motorway was open to traffic and officially finished without completing the river rehabilitation works.

Figure 2. Plan of the rehabilitation project showing the meandering pattern proposed for the low flow section and the vegetation plantation schemes.

Conclusions

Intensive use of floodplains, together with highly torrential flow regimes, still promote channelisations works in Spanish rivers in the 90s, reducing available space for river dynamics and river restoration. Little attention is paid to rehabilitation works by the traditional hydraulic engineers, specially in the large projects.

Natural recovery of riparian vegetation can take many years under Mediterranean conditions, due to relatively reduced seed production in the areas traditionally overgrazed, with exhausted woody vegetation. Riparian plantations are recommended in these cases, and irrigation during the first summer after planting is considered essential to ensure the survival of the plantations.

Unfinished or not very well executed rehabilitation projects do not increase the confidence in bio-engineering techniques. Good demonstration projects are badly needed in Spain, to initiate proper river management, including ecological processes restoration and flood control.

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THE GREEN CORRIDOR: THE RESTORATION OF THE GUADIAMAR RIVER

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Abstract

The restoration project started in September 1998, with 'The Basic Project'. In this document, the different elements of the work were laid down. They are the following: re-examining the previous studies of the physical environment, studying the vegetation development, determining the boundaries of 'The Green Corridor' concerning the necessary expropriation, developing future programmes for nature recreation. Our aim is to bring about the public co-operation and the money needed to expropriate, and to perform the reforestation of the riverine areas.

Later on, two pilot projects were implemented in order to solve some problems encountered in the restoration process. The study of plant species and their characteristic planting necessities turned out to be time consuming, complicating the reforestation management. Now, instead of performing this extensive study, we select real scenes (places with similar vegetation types), where we examine the characteristics of each plant species: association with other specimens of the same species, associations with different species and location preferences concerning humidity, light conditions, soil conditions, etc. At the same time the soils are analysed and checked on the possible presence of pollutants. The polluted areas were excluded from the data set and the final analysis was undertaken.

The last action was to combine the data on the vegetation with abiotic information, such as edaphology, permeability, elevation and seasonal fluctuation of the water, in a GIS-based vegetation model, which is a useful tool in the restoration projects.

1. Introduction

The mining accident took place in the early hours of the 25th of April 1998. One of the dikes of the tailings pond in the mining installation of *Aznalcóllar* (Sevilla) broke. The consequence of this dam burst was that polluted waters and sludge streamed into the *Agrio* River and the *Guadiamar*.

The dam burst had a width of more than 50 meters. This sludge had an estimated volume of 6 hm^3; 2 hm^3 were made up of sludge with the rest being moderately acidic water with a pH around 5.5 and with a high concentration of heavy metals. The water and sludge spilt caused the overflowing of the *Guadiamar,* which destroyed the riverbanks and the surrounding land.

2. 'The Basic Projet'

The restoration project started in September 1998, with 'The Basic Project', after the sludge was removed. The different elements of the works to be implemented, were laid down in this project document. The following elements were included;

- Re-examining the previous studies of the physical environment;
- Studying the vegetation development;

- Determining the boundaries of the Ecological Corridor, concerning the necessary expropriation;
- Developing programmes for recreational facilities.

Our aim is to bring about the public co-operation and the money needed for the expropriation, and to reafforest the riverine areas.

3. Main Objectives and Justification

The Guadiamar River is of considerable environmental value for our region due to the different characteristics along its entire course. What's more, it represents a clear and notable connection between two great natural systems: the marshland and the Sierra Morena Mountains.
The objectives were to recuperate the viability of the flow in the river, and to restore the riverbed and the adjacent areas. The natural values of the river, lost because of human activities, should be restored. The river and its surrounding areas should be made suitable for recreation.
The first step in the integral ecological restoration is the re-development of riparian and riverbank vegetation and the surrounding areas. The creation of wastewater treatment plants and infrastructures for the treatment of all urban and industrial sewage which flows to the river should not be forgotten.
The plantation activities related to the Ecological Corridor began after the sludge was removed and the soil had been treated. The vegetal species could then be planted without the risk that later works would destroy the plants. To ensure the viability of the plantations, the works will be carried out in the humid season, between autumn and spring.

4. Pilot Projects

Nevertheless, certain restoration activities were started in clean areas as pilot projects. Two projects were prepared for two small areas. These projects had to sort out the development process of the vegetation. The huge amount of vegetal species and its specific planting necessities, make the reforestation management very complicate. All information collected was used to design the restoration project.

5. Selection of Natural Landscapes

For generations the areas adjacent to the river has been used for agriculture. Most of the original natural areas along the river have disappeared. So we selected natural landscapes, sites with similar vegetation pattern, in order to collect the seeds to produce the necessary plants. Besides, we went to the field to test the real characteristic of each vegetal specimen: associations of several species, associations of different species and the natural growing conditions, like humidity, darkness, deep ground, etc.

6. The Initial Situation: The Environmental Study

The affected area after the sludge removal was the starting point. Vegetation in these areas is lacking, and the top layer of the soil has been removed.
Climatological report: according to the classification of Gaussen & Bagnoul, the study zone is included

in the Class IV phytoclimatic subregion: a dry, warm, genuine Mediterranean climate.
Geological report: the materials are mainly alluvial current silts and fossils of the Guadiamar river, and its tributaries; there are also the quaternary silts that form the marsh of the Guadalquivir.
Edaphological report: the main affected units are: *Fluvisoles, Entisoles, Solonchack,* according to the classification of the FAO (ef, ei, ou).
Physiography: the relief of the affected zone is extremely flat, with some small interior hills of 10 m height. The maximum altitude is of 40 m, and the minimum is 2 m, near the sea. The average slope is of 0.20%, although values of 20% occur near the mountains, surrounding the area.
Botanical report: in the study zone there are remains of vegetation, formed by the following species: poplar, ash, elm, *taraje*, and so on, distributed in more or less regular patterns.

A flow chart is presented in Figure 1.

7. Longitudinal Sections

For the restoration project, the Guadiamar River was divided into four sections:
- **High track:** upstream of the mine installations. It is the connection zone with the Sierra Morena Montains. In this track the prevailing vegetation is holm oak *(Quercus rotundifolia)*, cork tree *(Q. suber)* and pine reafforestation;
- **Medium track:** downstream of the mine installations up to the *Vado del Quema*, with moderately slope and a wide riverbed;
- **Transition to the marsh track:** the permeability of the soil is different;
- **Entremuros area:** the river channelised, and the soil is impermeable.

In the first section it is necessary to strengthen the physical connections with the green corridor, but it isn’t necessary to reforest.

8. Cross Sections

The division of the zone to be restored, according to the digital elevation model, and the seasonal fluctuation of the water flow gives us the boundaries of the riverbed, riverbank, ordinary bank, extraordinary bank, and the Mediterranean forest. In this last model, the soil, as well as the exposition, sunny or shady spot, gives us the transition between one or another sub-model.

9. Vegetation Models

The forest system that is sought is associated with the space. There is an area of gallery forest that will reflect along the whole bed, and an area of Mediterranean forest, consisting of autochthonous species adapted to the soil and climatic conditions in the lands adjacent to the river bed; and marsh vegetation in the area of *Entremuros*.
Reforestation actions have not yet been defined for the riverbed and the riverbanks, since they are unstable areas. Once the river ‘speaks’ then they will be implemented.
The characteristics of the different vegetation models are:
- **Ordinary bank**: the plant density is very high in this area, the main specimen would be the white poplar (*Populus alba*) with willows at the medium track, and tarajes (*Tamarix canariensis*) at the

transition marsh track. In areas with seasonal fluctuation of the flow, the adelfa (*Nerium oleander*) appears;

- **Extraordinary bank:** the main species would be the white poplar (*Populus alba*), the elm tree (*Ulmus minor*) and the ash (*Fraxinus angustifolia*), these are the areas where the phreatic level drops to 1-2 m deep, in the vegetative period;
- **Mediterranean limy forest:** the main specie would be the holm oak (*Quercus rotundifolia*). It would live on limy soils in areas with cool winter and dry summer;
- **Mediterranean siliceous forest:** the main specimen would be the cork tree (*Q. suber*). It would live on siliceous sand or clay soils in areas with sub-humid summer;
- **Wild olive tree:** the main specie would be the wild olive tree (*Olea europaea var. sylvestris*) It would live on clay and limy soils in areas with mild winter and sub-humid to dry summer;
- **The pine forest** would stay in transition to another Mediterranean forest or as a secondary form in potential areas of oak, cork tree or olive tree;
- **In the marsh** zone, we can find the salt marsh on high areas and sweet marsh in small depressions.

Figure 2 show the vegetation models for the medium track and the transition to the marsh track.

10. Project Performance

Prior to the reforestation, the soil until a depth of 50 cm will be ploughed with a helicoidal-planting plough to break the plough layer. Large trees will be planted in a pit.
Small plants will be planted manually and large trees will be planted mechanically, using an excavator.
The plant density was designed according to the characteristics of each vegetation model. Therefore, the plantations will be done in an irregular pattern, like they are found under natural conditions.
The plantation will be protected by a fence, and protective tubes will be put around some of the species.

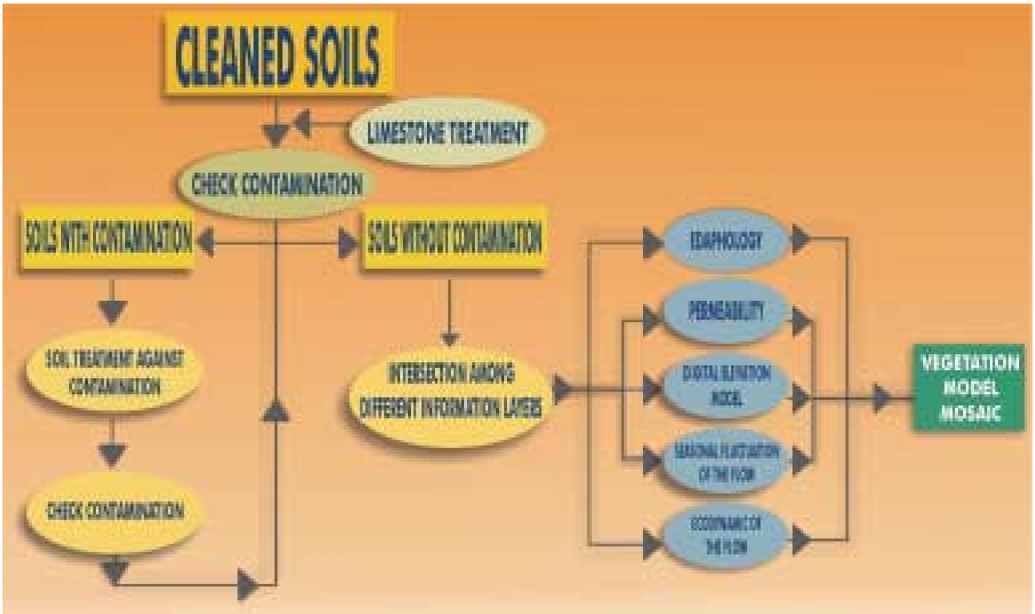

Figure 1.

The plantations will be irrigated after the planting. To ensure a good development of the plantations further actions, like drill-ploughing, weed control and earthing will be implemented.

11. Conclusion

One of the biggest environmental tragedies of the last years, will enable us to make one of the most ambitious river restorations of all times come true.

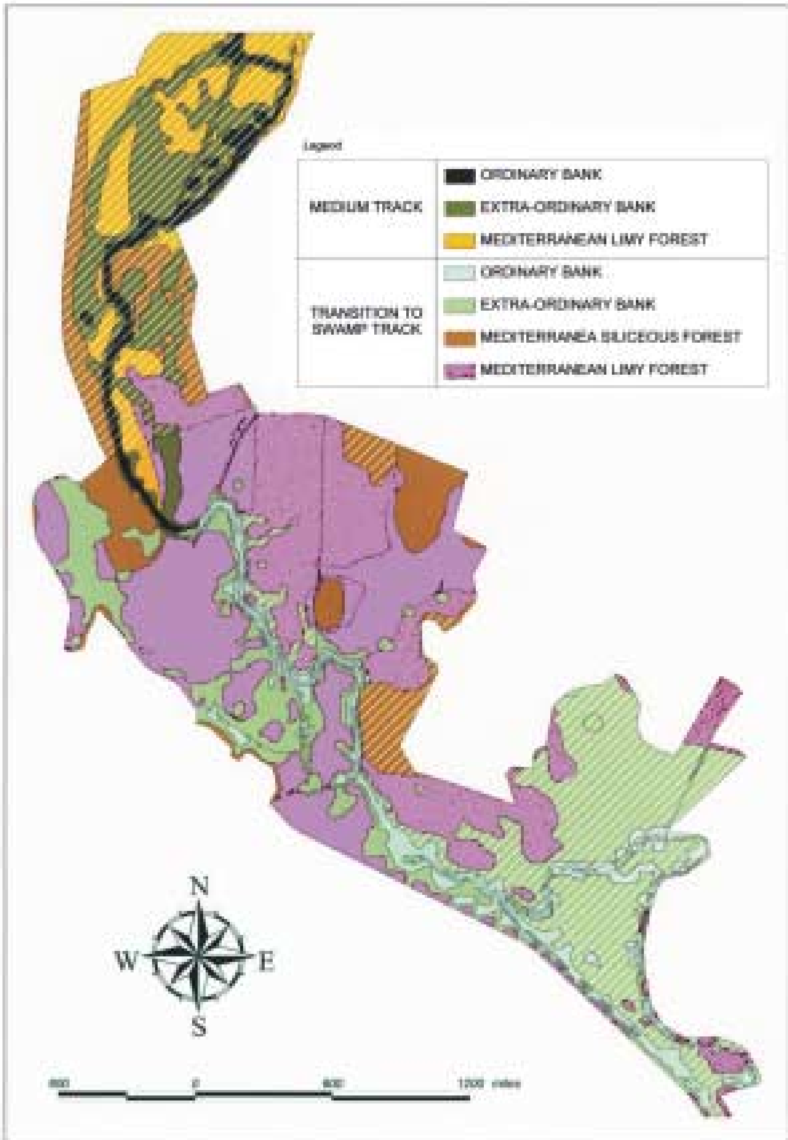

Figure 2. Vegetation models for the medium track and the transition to the swamp track.

AN ALTERNATIVE TO CONVENTIONAL RIVER MANAGEMENT IN GREECE

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Abstract
This work is an introduction to the procedure, used for the conservation of Sperchios river meanders with numerical modelling. In this procedure the MIKE 11 model has been applied. The main problem of the basin is that the river channel is not able to receive the flood flows, which yearly affect rural areas and two villages and which cover the national road, causing serious traffic problems. The study proposed initially had only one scope: the prevention of flooding. The main solution considered was the canalisation of the river into a straight channel, thus destroying the meanders. In this study we examine two alternative scenarios to the flooding problem of the Sperchios River: (1) the use of an existing artificial channel for the flood discharges, and (2) the widening of the riverbanks. The two scenarios have been considered in both environmental and economical terms.

1. Introduction

The basin is located in the NE part of Sterea Ellada in Central Greece. The river catchment covers an area of approximately 1900 km^2. The river length from west to east is 82 km. The mountain fringed valley of the River Sperchios opens only eastwards to a tongue shaped Delta in the Gulf of Maliakos and is characterised by strong morphologic contrasts resulting from a close proximity of the base level and mountainous areas of various levels (Figure 1). The annual runoff to the Gulf of Maliakos is 500 million m^3. Over 2 650 000 m^3 of the detritus eroded from the uplands has been deposited to form the Sperchios floodplain and Delta, which have been extended into the Gulf of Maliakos in historic times. It is estimated that this process is continued today at a rate of 1 100 000 m^3/year. The sedimentation in the delta favours biotopes like beach rocks, islands, marshes. The yearly deposits equal an area of about 140 hectares.

The main problem of the basin is that the river is not able to cope with the flood discharges. The result is the catastrophic flooding of rural areas and two small communities Anthili and Kompotades. There were no victims in the past, but the floods created loss of properties and social problems in the villages. The extend of the destruction depends on the rivers flooding discharges and the season of the year. The floods repeat yearly and the main destruction take place near the railway station, the national road and eastwards. This causes many problems for the traffic in the country. Greece is then divided in two parts and there is no transportation possible between them. The flooding of the River Sperchios is not a local problem but a national one and has a negative effect for the EC countries. The proposed construction works have only one objective, i.e. the prevention of flooding. One of the main solutions considered is the widening of the Tafros Lamias, a channel to drain the flood waters before reaching the meanders. In this paper we consider the role of the Tafros Lamias in solving the flood problems in the Sperchios river basin.

Figure 1. The cathment area of the River Sperchios.

2. Methodology

The Sperchios river basin covers an area of 1900 km^2 .The main branch of the river has 63 tributaries, with permanent or non-permanent flow. The sources of the main streams are in the high mountains in the southern part of the basin. The streams flow from south to north. The northern streams are crossing mainly hills and agricultural areas. The main river basin can be divided in 24 sub-basins. The main river bed has a length of 82.5 km. Near the village of Komma, the river branches out, one branch is the canal constructed in 1945 to prevent the village of Anthili from flooding, and the other one is the old river bed called Alamana. The main section of the river flows through mountainous area with very small meanders and steep slopes. In the last section of the river (1/3), the slope is very flat and the river starts to meander. To be more specific, east of Kompotades the river meanders very much, due to the flat slopes.

For the grid of the main river bed a lot of data had to be collected because of the complexity of the river's morphology:

- *Layout 1:2000:* the river bed of the main branch, from Kompotades to Maliakos estuary;
- *Slopes:* the total length of the river;
- *Cross sections:* From Kompotades to Maliakos, every 500 m the cross-sections of the river has been measured exactly.

The discharges of the River Sperchios and its tributaries are highly variable. In winter and spring the discharges are high, and in summer and autumn the discharge is less than 10 m^3/s and in some streams there is no flow. Since 1932 the discharge and water level of the River Sperchios are measured daily at two stations near the bridges of Kompotades and Kastri.

The River Sperchios river has the lowest discharges in the summer months, less than 10 m^3/s. The only available measurements of maximum discharges are the measurements of *DEB* (Ministry of

Agriculture) at Kompotades and Kastri stations. Up to now there has been no serious report and study of the flooding of the Sperchios river basin. Data on flood discharges and flooded area are only estimations. Satellite images helped a lot in the estimation of the flooded area by previous floods. From the study of these images the following results appear to be the most convenient: The flooded area from the '1981 floods' is approximately 3500 hectares of agricultural land. The areas remain flooded for 4 to 5 days, with a maximum of 8 to 10 days, in depressions.

According to local measurements, the total sediment transport from 1960 -1970 was 1 000 000 m^3/year. Today, the total sediment transport is up to 300 000 m^3/year (Daoulas 1981). Kakavas in 1988, in a sediment transport study, using aerial pictures and in situ measurements, concluded that the amount of sediment transport presented in the study by Daoulas was very low. Kakavas estimated that the total amount of sediment transport was 2 655 909 m^3/year. The largest amounts come from the following streams: Bistriza:1 700 000 m^3 /year, Roustianitis:190 000 m^3/year, Louggies:160 000 m^3/year.

There are two scenarios which have been considered in more detail:
1. Draining the flood waters through the Alamana and Ektropi branches;
2. Draining through the Tafros Lamias channel and check if there are appropriate slopes and cross-sections to safely drain the flood water to the Maliakos estuary.

From previous studies (Daoulas 1981 and Kakabas 1988) the flood discharges for Tafros Lamias were: Westwards of Ksirias Lamias Q_{50}= 170 m^3/s, Eastwards of Ksirias Lamias Q_{50}= 370 m^3/s. The construction team suggested to widen the Tafros Lamias up to 20 m. This suggestion is going to be considered in the model's simulation. Topographical elements have been used in the simulation study: Map of the region in scale 1:50 000. Topographical diagrams 1:2000. Horizontal sections of the river 1:2000 and 1:100. Cross-sections 1:200/1:100 of the river and related streams. Horizontal layout 1:200. All the cross-sections has been designed according to Daoulas study of 1981. The river slopes are taken from the study of Maroukian *et al.* in 1995.

The river simulation network includes the following streams: Sperchios from Kastri to Kompotades, Mpekiorema, Tafros Lamias, Ksirias, Gorgopotamos, Asopos, Ektropi, Alamana. In scenario 1, the Tafros Lamias is not connected with the River Sperchios. In Scenario 2 the Tafros Lamias canal is connected to the River Sperchios before the river starts to meander, near the Kastri Bridge. The boundary conditions have been set at the source of the streams and time-series of measured discharges have been used as input for the models. The boundary conditions of Alamanas and Ektropis delta have been collected from gauges of the local port authorities. Boundary conditions for the river springs are discharges and the rivers delta surface elevations. For the simulations the time step was set up to 2 minutes for the time of 24 hours. A grid system of 500 m was used for better resolution and least simulation time. To satisfy the Courant number and limit it up to 10 the simulation time step was estimated to be up to 5 minutes.

3. Results

In scenario 1, Tafros Lamias is not connected with the Sperchios River. This is the current situation. The scope of this scenario is to identify areas where the water overflows the riverbanks and floods the nearby sub-basins. This study will help the engineers to construct and rebuild at the right points.
In a second run of the first scenario, the effect of widening the river bed up to 500 m was simulated.

Daoulas 1981 suggested this solution. New river banks are proposed to be constructed along the river over a distance of 14.8 km from Kastri to Kompotades. The simulation showed that this proposal can be an excellent solution; the river can drain the flood discharges to the Maliakos estuary without flooding the adjacent areas. This solution is considered successful except for the high cost of construction and the environmental damages to the river system.

In scenario 2, the Tafros Lamias channel is connected to the Sperchios River at a point close to Kastri. This connection can be a solution for the flood problems. In this simulation a part of the flood discharges of the river are drained through the Tafros Lamias channel and then to the Maliakos estuary. The simulation model tried to figure out if the existing slopes and cross sections are able to handle a part of the rivers flood discharges. The simulations showed that the existing Tafros Lamias is not able to contribute sufficiently in safely draining the flood discharges. The Tafros Lamias can discharge only up to 150 m^3/s from Kastri to Ksirias and 350 m^3/s from Ksirias to Maliakos estuary. This scenario is not acceptable without widening the Tafros Lamias channel.
A second run simulated a widening of the Tafros channel up to 50 m and a depth of 3 m. The simulation showed that it is then possible to discharge 500-600 m^3/s through the Tafros without flooding problems. However, this proposal will create social problems, since the Tafros Lamias flows very close to the city of Lamia. Also the costs are of such solution are really high. But, environmentally this solution is acceptable since there is not any ecosystem disturbance.

4. Conclusions

The simulation of two scenarios for solving the flood problems in the Sperchios river basin came up with the following results:

1. Scenario 1: The existing channel is not able to discharge a flood with a return period of 50 years, which is approximately 2000 m^3/s. The river basin would be flooded. The simulation shows that a numerous points constructions have to be made, to safeguard the riverbanks. This is a very temporary solution.
2. Scenario 2: The flood problems can be solved without any other construction in the Sperchios river network, except for the Tafros Lamias channel. Because of the flat slopes in the region, the Tafros will need a very wide channel to carry the flood discharges. The width of the channel depends on the discharges to be drained by Tafros Lamias.

The preferable cross-sections from Daoulas study can receive up to 400 m^3/s. Widening the cross-sections even more would mean that a second stream will have to be created, but citizens of Lamia don't want such a channel.
Both scenarios are environmentally acceptable. Form the hydraulic point of view it is better to create wider riverbanks, parallel to the channel. Such a solution is more expensive.
Finally, it has to be mentioned that there is a need for integrated water management of the river network, and there should be no separate actions that would destroy the river ecosystem.

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RIVER RESTORATION PRACTICE IN SPAIN

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Abstract
As part of an overall European process in the last four decades, Spanish rivers have suffered from land-use intensification and pollution of waters, changing their physical structure, chemical components and biological communities. Nonetheless, the European trends towards river restoration and minimising of environmental impacts have not been assumed by the Spanish Water Basin Authorities (Confederaciones Hidrográficas), which continue their public works programme, including channelling and dredging of rivers with strongly damaging techniques.

Since the late 1980s, under these adverse conditions, some Regional Environmental Bureaux and different Non-Governmental Organisations/NGOs (especially AEMS-Ríos con Vida and WWF/Adena) have started river restoration projects with bio-engineering techniques. Our recent review analyses 53 projects and demonstrates positive results in 33 projects, although financial support and technical knowledge are insufficient. Only 7 projects have failed completely. Generally, the projects cover short river stretches (average 1100 meters), and have no watershed approach. Concerning the recent trends, the heavily polluted Guadiamar River (Doñana, Andalusia) is worth to be mentioned due to the development of a dynamic 'Green Corridor'.

The study shows the positive results of live stakes, live cribwalls, wing deflectors, weirs and boulder clusters in Mediterranean rivers, but demonstrates that live fascines and brush mattresses have not been useful due to drying-out. Aspects that deserve special attention are the lack of following-up projects, dissemination of results and participation of local people.

THE 'GUADIAMAR CORRIDOR PROJECT'

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Abstract

When in the early hours of 25 April 1998 the dike of the tailings pond broke at the pyrite mines of the Boliden Apirsa Company, in the municipality of Aznalcóllar, the Agno and Guadiamar rivers were flooded by about 6 hm^3 of sludge and water contaminated with heavy metals. This became known world-wide, because the mining accident was very serious. Moreover, the Guadiamar river is one of the most important waterways into the marshlands of one of the most emblematic parks among the protected natural areas in the world arena of conservation: the Doñana National Park.

The administration's major concern was to immediately take efficient emergency measures aimed at reducing and avoiding the propagation of the spill effects both at environmental and socio-economic levels.

More than one year after the accident, the first phase, i.e. the 'Emergency Measures Scheme', has been concluded. Under this Scheme, a series of very important actions have been carried out, such as sludge removal, water treatment, cleaning of 'Entremuros', restoration activities for controlling soil acidity, etc. Besides, many control and following-up measures have been undertaken concerning the quality of water, air, soil, sediment and plant and animal life, that have led to a significant progress with regard to the environmental recuperation of the affected area.

The aim of the 'Guadiamar Corridor Project' is not only the removal of the contamination, but also the re-establishment of the ecological function of the Guadiamar River and its watershed to create an ecological corridor between the Sierra Morena mountains and the Doñana coastline. Furthermore, the project intends to implement an alternative and sustainable development strategy, based on new economic activities and opportunities created by the corridor.

NORTHERN EUROPE

FINLAND - PROBLEMS AND POSSIBILITIES OF LOWLAND RIVER RESTORATION IN BOREAL CIRCUMSTANCES

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Abstract

The northern climate with six months of ice and snow poses problems but also special possibilities for river restoration. Thick ice blocks floating with the spring floods, caused by suddenly melting snow, bring about a flood danger, but are also a stress factor to the vegetation of the river banks. On the other hand the ice forces, together with the melting of the frozen soil, reform the banks and are of help in natural recovery. On lowland rivers the erosion processes by the streaming water itself are limited and the eroded material is mostly clay or silt, causing a certain problem for water quality.

Flood control works luckily have not lead to severe river degradation in Finland, but on wide floodplains flood embankments are a problem for the river landscape. New methods in flood control projects by riverbank formations, flooded side arms and the creation of wetlands are investigated to maintain the natural river landscape. A more comprehensive flood control policy is being developed, consisting of the use of buffer stripes and wetlands for water protection.

Timber floating along the rivers has caused a severe damage for small rivers in northern forest areas. During the last 20 years most of the rivers used for floating have been restored by removing stones back to the rapids, widening the streams and by creating fish habitats.

Power plants cause a problem for natural salmon and trout migration. In smaller rivers old mill dams have been demolished. As fish stairs did not have proven to work, new examples of more natural bypasses have been built.

RIVER RESTORATION IN BØRSELVA, NORTHERN NORWAY

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Abstract
Since 1914, after the regulation of Lake Børsvann in the northern part of Norway, the water flow has been strongly reduced in the River Børselva. Hydropower production was the purpose of the regulation, and the water was taken to a power plant outside the catchment area. The catchment was reduced from 85 km^2 to 5.5 km^2 , and up to 1970 there were no instream flow requirements in the river. Overflowing of water from the dam was only seen in periods with great floods. During the years of low flow the river has developed into an eutrophicated river overgrown with water plants, and fish has ceased spawning in the river.

When the local authority took over the power plant in 1986, a new flow regime for the river was developed, with a small base flow, and some artificial floods to ensure satisfactory quality in the watercourse. At the same time instructions were given for clearing the river to restore the free passage of fish and to improve the self-purification of the river. However, little has been done to improve the conditions of the River Børselva since 1986. The new flow regime, which has been operating since 1986, has not shown to be satisfactory for the ecosystem in the River Børselva.

A project running for five years was started in 1997/98 to fulfil the limitations set by the government in 1986. The project aims at rehabilitating the river through various types of restoration measures combined with a new flow regime. River restoration of this kind is relatively new in Norway. The variety of interests connected to the river makes the planning for a healthy, multi-functional river system an important opportunity to gain knowledge of river restoration in this region. Among other topics, the project will include research work, which combines hydrologic and hydraulic modelling with full-scale tests of effects of different discharges.

The problems of the River Børselva are of general interest for the future handling of regulated rivers, both to optimise the hydropower generation, and at the same time to be able to take care of the natural values of the river and its neighbourhood.

STAKEHOLDER ATTITUDES TO RIVER MODIFICATION AND RESTORATION

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Abstract
Norwegian rivers have been modified by hydropower development, flood protection efforts, and agricultural use, during the last century. Vital river functions have been affected. Simultaneously the number of river stakeholder interests and the demand for river restoration efforts have increased. The power of different stakeholder groups have changed considerably. Accordingly, new conflicts have arisen and river managers recognise a need for better knowledge of stakeholder attitudes as a fundament for the planning and implementation of new river restoration projects.

Attitudes to different types of river modification and river restoration measures have been investigated among river owners, river recreants and river managers in four river areas in Norway. River Maana in Telemark county is heavily modified by hydropower development and restoration measures are being implemented. River Smalelva in Oestfold has been canalised for agricultural purposes and crayfish habitats have been rehabilitated. River Glomma at the settlement of Kirkenaer in Hedmark county have experienced several flood protection measures. River Moelva in Hedmark county has been canalised and flood protected and several weirs and current deflectors for Brown Trout (Salmo trutto fario) habitat improvement have been constructed. 80 members of the three stakeholder groups in the four river areas have been interviewed. Photos have been important elements in the interview process and methods and scales from psychological research have been applied.

Preliminary results reveal important differences between the stakeholder groups both in affective and cognitive attitudes to the different types of river modifications and river restoration measures.

OUTSIDE EUROPE

RESCUING A FRAGILE RIVER FROM OVER-EXPLOITATION – AUSTRALIA'S RIVER MURRAY

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Abstract

The River Murray drains a huge area but has a typically low, highly variable flow. 80% of its water is now taken out, mainly for irrigation, but also for urban supply. Salinity is increasing so that in 20 years the water may be undrinkable half the time. Surrounding wetlands are drying out (or being flooded at the wrong time), and native fish, birds, frogs and vegetation are in serious decline.

Problems have been tackled bit by bit over the last 20 years. Each of three States is responsible for its own impact on the River's salinity, and must pay for salt-reduction schemes to offset any increases that State causes. A cap on water taken out of the River and its tributaries has been put in place, but water can trade to its most economic use. Wetlands are being nourished by saving up water for several years, and then making big releases.

There is still a long way to go, but some lessons are evident. Community ownership of solutions is critical. So too is a computer model showing the River's behaviour over 100 years of weather records, under different options. 'Win-win' ideas have been important, e.g. the water saved up for wetlands is available to be borrowed by irrigators in droughts.

1. Introduction: A Fragile River

The River Murray ranks among the top rivers in the world in terms of length and catchment area. Counting the Darling tributary, it is 3750 kilometres long, nearly three times as long as the Rhine. Its catchment covers over a million square kilometres, a seventh of Australia, or an area bigger than France and Spain together.

The River Murray, however, carries a relatively low, and highly variable, volume of water. Under natural conditions the average annual flow out of the mouth would have been just 14 000 GL a year, or about 4000 m^3/s, not much more than the flow in the Rhine. Every dozen or so years it would stop flowing altogether.

It gets most of its inflows from a small area of mountains in the south-east, but runs inland through flat, semi-arid country. The Darling tributary drains over half the catchment, but receives little rain apart from the odd monsoonal downpour – which often spreads into ephemeral wetlands and does not reach the Murray.

Ecosystems evolved to suit the harsh environment. Thus along the main River were redgum forests which liked to be flooded in most springs. Birds such as egrets and herons bred whenever the conditions were favourable, as did fish like the big Murray cod.These wetlands were linked to the River in ways which were crucial in sustaining the River's health.

Further away from the River were drier eucalypt forests, and towards the west, stunted Mallee trees growing slowly to about 8 metres tall. These efficiently captured almost all the scarce rain that penetrated the soil, so only 1 to 2 mm a year percolated through to the highly saline groundwater that lurked below.

2. Exploitation

In 1915, Victoria, New South Wales and South Australia signed an agreement on the development of the River Murray for navigation and for irrigation. In doing so, they had to agree on how to share not only the costs of the structures, but also the available water.

The agreement gave the two upstream States, Victoria and New South Wales, the right to half each of the water entering the Murray in the hilly uplands, above Albury. They were also entitled to all their own tributary inflow below Albury. However, they were each required to supply, out of these resources, half of a specified entitlement for the downstream State, South Australia.

This agreement has worked very well in underwriting the building of four large storages on the Murray, with total capacity almost as much as a typical year's flows, and the massive expansion of irrigated agriculture that has occurred, on both the Murray and State tributaries.

In recent years the agreement has been amended so that Victoria and New South Wales can manage their half shares of inflow and storage quite independently, carrying over unused water to the following year. This has helped them to run very different reserve policies, one suited to permanent plantings (horticulture and dairy farming), the other to annual crops (rice and cotton).

Use by both farmers and townspeople is mostly metered. Entitlements of farmers and of urban authorities are well enough defined for water trading to be blossoming. The arrangements have been good for development.

3. Adverse Consequences

The agreement on managing the River was struck prior to consciousness about the needs of the River's environment. It provided for about 5% of average natural flows to be kept as a 'dilution' entitlement to the downstream State, but otherwise contemplated no limit on the water taken out.

By 1995, typical flows out of the Mouth were down to about 20% of what they had been under natural conditions. Barrages just above the Mouth to prevent sea water intrusion are now kept completely shut most of the time: the bottom of the River is a pond.

With the barrages shut, the Mouth itself relies on tidal flow to stay open. It closed in 1981 for the first time in recorded history, reopening a few months later. Since then it has been chronically close to closure, threatening the rich ecology of a Ramsar-listed estuarine lake which runs for over 100 kilometres inside the coast.

The River has increasingly been managed to transport water for consumptive use. Flows are unseasonable, too steady, and too cold because they come from the bottom of large storages. Fish passage is blocked not only by the large dams but by a series of small weirs built for navigation. Wetlands along the River are being flooded less frequently, or in a few cases at the wrong times. Much of the redgum vegetation along the River now looks to be in jeopardy. Native fish, birds and frogs have been in serious decline, while European carp exist in plague proportions.

In 1991 there was a bloom of poisonous blue-green algae which stretched for 1000 kilometres along the Darling, giving people a jolt. But most alarming of all, salinity levels in the lower Murray are now expected to increase such that in only 20 years the water is likely to be undrinkable nearly half the time. The 1 million residents of Adelaide rely on this water for 40% of their supplies.

The challenges for river and catchment managers, and indeed for the community at large, are great. The remainder of this paper outlines the solutions that are being developed on three different fronts.

4. Putting a 'Cap' on water taken

By 1995 Governments were so worried about the deteriorating health of the river systems, and also about the threat that continuing growth of extractions posed to the reliability of existing users' water supplies, that they agreed to establish a limit, or 'Cap', on water taken from all of the streams in the Murray-Darling Basin.
By and large the Cap has been set at the level of water that was being taken in each State at the time (see Figure 1). That is, the *underlying* level in the 1993/94 irrigation season; the actual level varies dramatically from year to year depending on how dry and hot it is, and what water is in storage.

It is hard to see how, politically, the States could have reached agreement to a Cap on any other basis than this one. But the Cap has fundamentally changed the water entitlement of each State.
Thus on the River Murray itself, New South Wales' usage was 25% higher than Victoria's when the 'whistle blew'. Victorian water users have felt uneasy about the Cap for them being lower than the one on the other side of the River. They have hesitantly accepted it as being a result of the more reliable supplies provided to them.
Each of the States is responsible for implementing the Cap within its borders. Implementation has often proved to be a tricky task, because:

- The volume of water allowed to be taken varies enormously from year to year. Under the Cap, a State can take the volume that would have been taken if there was no growth in extractions – as calculated from a computer model. This isn't known until the end of the year, so overruns are possible. The rule is that accumulated overruns, net of underruns, must not rise above 20% of average volume taken (see Figure 2);
- The Cap could not have been implemented simply be stopping the issuing of new rights. Already by 1995 it was largely the case in most States that a new water user was required to buy an existing right from someone else. The growth in extractions was occurring because of take-up of existing rights that were not fully used (including over-allocation water);
- Existing rights had not always been clearly defined. A right might consist simply of an approval to have a certain-sized pump. Some farmers believed they had a legal right to whatever their crops needed, or cited promises that their rights would never be cut back even in the worst drought. It was necessary to reach agreement about a fair way of sharing water in the light of the various claims.

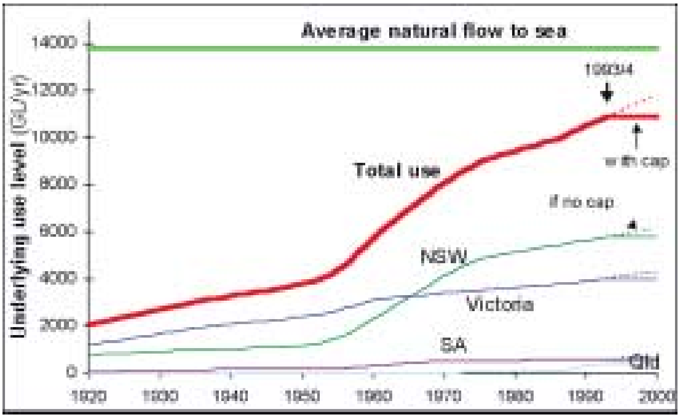

Figure 1. Growth and capping of water use in Murray-Darling Basin.

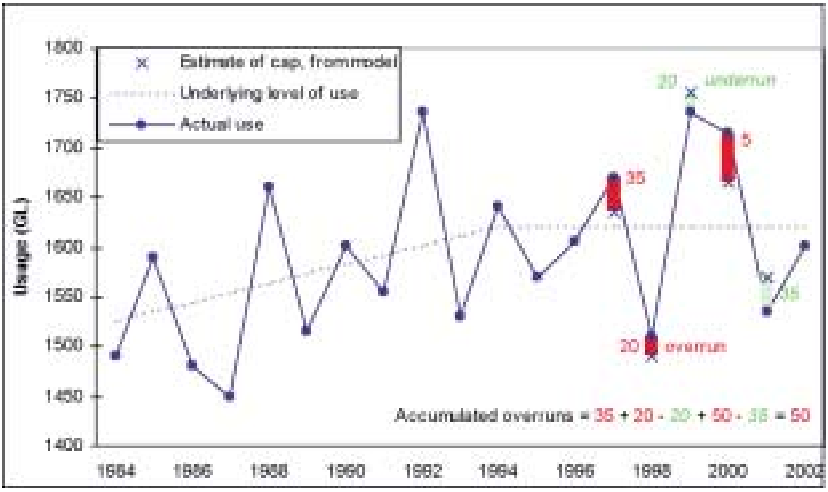

Figure 2. Illustration of how the Cap works

Implementing the Cap on Victoria's use from the River Murray, for example, involved a three-year process of negotiation and balancing, backed up by much technical work. The outcome of the process has been implemented through clear, tradeable entitlements held by authorities, that include obligations to meet well-specified users' rights (see Table 1).

Table 1. Distribution of the water available to Victoria from River Murray (extract)

Authority	**High-security rights**		**Off-take commitments, for high-security allocation of:**					
			50%	**60%**	**70%**	**80%**	**90%**	**100%**
G-MW: Torrum -barry	403.052	At farm:	201.5	241.8	282.1	322.4	362.7	403.1
		Losses:	**141.3**	**144.5**	**147.7**	**150.9**	**154.0**	**157.2**
			346.0	**390.1**	**434.3**	**478.4**	**522.4**	**566.7**
Diverters, Dart. -Nyah	83.099		**41.5**	**49.9**	**58.2**	**66.5**	**74.8**	**83.1**
FMIT	73.027	At farm:	36.5	43.8	51.1	58.4	65.7	73.0
		Losses:	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**
			48.5	**55.8**	**63.1**	**70.4**	**77.7**	**85.0**
Lower	19.913	River	**10.0**	**11.9**	**13.9**	**15.9**	**17.9**	**19.9**
Murray W	2.033	Channel	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**
Etc.			...	...	...	...	...	...
Total	1192.932		**852.9**	**977.1**	**1101.8**	**1226.1**	**1350.0**	**1474.7**

With the Cap firmly in place, water trading has grown in significance. Moreover, the entitlements allow for 350 GL of delivery losses, which provides strong incentives for efficiencies. Provision is made for increasing the water set aside for environmental purposes if this is required in the future.

A five-year review of the Cap is currently being undertaken. This is showing that:

a) The Cap is crucial to protect reliability of water supplies, and it has accelerated the definition of rights and trading in water;

b) No Cap has been determined yet for Queensland, and this is a problem – use there has grown by 50% in the last five years;
c) Farm dams should be under the Cap, and maybe also tree plantations (these reduce run-off by 2 ML per ha), and groundwater;
d) To halt degradation of riverine ecosystems, the Cap may need to be set at a lower level: it is too early to tell;
e) Other measures like stopping tree-clearing and actively managing water left in the River are needed as well as the Cap, and will make it less likely that the Cap has to be lowered.

5. Managing Water Left in the River to Benefit Wetlands

The Cap is the major, critical step that had to be taken to ensure the environmental health of the river system, but it is not enough by itself. There is now so little water left in the River Murray that what remains needs to be actively managed to maximise environmental benefits.
A major concern has been the loss of the natural spring-flooding regimes for redgum forests and other wetlands along the River. These wetlands are vital to river health, because they play a major role in absorbing nutrients, and provide crucial habitat, breeding grounds and food chain links.
Modelling over 100 years shows that, under levels of use now, Barmah forest (also Ramsar-listed) has four-month floods high enough to cover half the forest in less than 20% of springs, compared with in more than 60% of springs under natural conditions. There are periods of up to 13 years without such floods, compared with never longer than five years before irrigation (Figure 3).

In discussion with New South Wales, Victoria developed a proposal to protect this forest. This took the 50 GL a year from each State previously agreed on, saved it in not-otherwise-needed airspace in storages, and released it every few years in spring on top of a flush in the River Murray, so it flooded into the forest.
However, periods between adequate watering of the forest were still too long. Moreover, when this initial forest provision was put into the model, plus take-up of unused rights and other pressures, over 100 years the lowest seasonal allocation or water rights (in February, $^3/_4$ of the way through the season) dropped to 30%, unacceptable in traditionally reliable Victoria.

Eventually we were able to find a way of protecting both the forest and irrigators' supplies.
After trying all sorts of approaches, it was concluded that proper watering of the forest needed an extra 25 GL of lower-security water from each of the two States. This was provided for, but at the same time water being saved up for the forest could be lent to water users in bad droughts, when their seasonal allocations would otherwise be less than 100% of water right (see Figure 4).

6. Combating Salinity

Much of the Murray-Darling Basin was an ancient sea. Perhaps more importantly, 1 million tonnes of salt per year is carried in rain and deposited across the Basin. The Basin's low rainfall, flat landscape, and high evaporation have concentrated salt in the soil. Native vegetation has transpired pure water, leaving salt to be leached down to the groundwater, much of which is saltier than the sea.
In the 1970's and 80's increased salinity in the River became a concern. This salinity was coming about as a result of all the water being taken out of Basin rivers, but also leaky irrigation developments producing mounds in the highly saline groundwater.

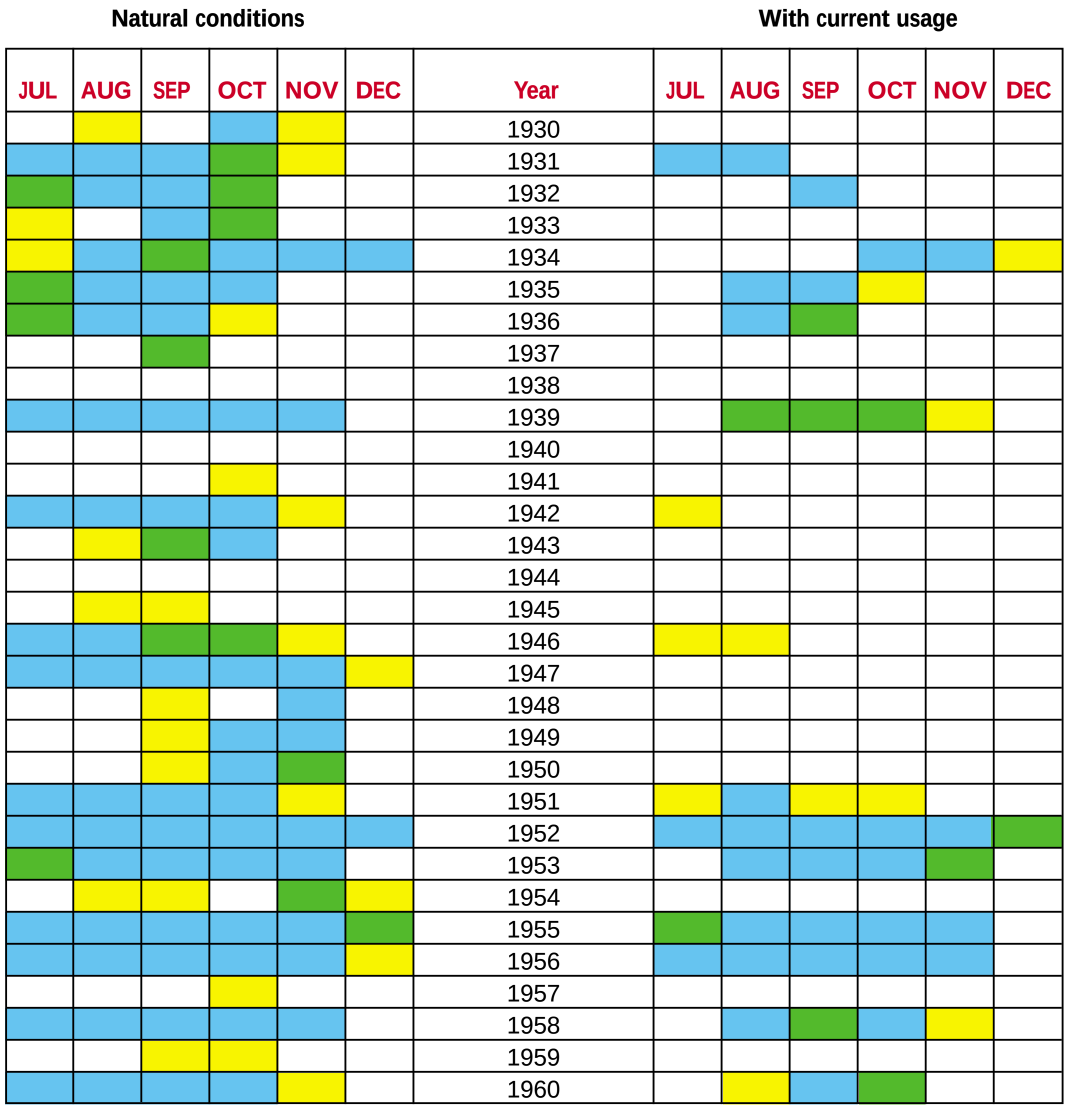

Figure 3. Wetlands in trouble: Barmah forest floods 1930-60. Blue = high floods, green = medium floods, yellow = low floods.

In 1988 a salinity strategy was put in place by the three southern States. Through this they:

a) Agreed on changed river operations and some joint works (bores/pumps to intercept groundwater and take it away to evaporation basins) to reduce salinity by 80 EC, plus a further 30 EC as credits to cover new irrigation drainage;

b) Made each State accountable for its future actions causing river salinity: these must be offset by credits the State has earned, e.g. through further salt interception works.

This strategy has been very successful in holding down or compensating for salinity from irrigation and drainage developed since 1988. The strategy has promoted least-cost measures, almost a market in pollution rights.

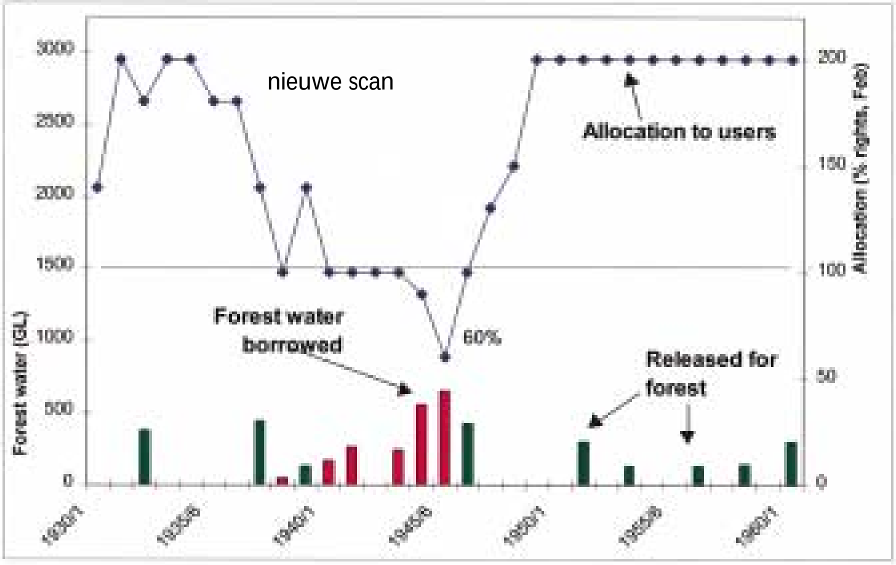

Figure 4. Barmah water released and borrowed 1930-60

But recently it has become clear that the strategy deals with only a quarter of the problem. The delayed effects of pre-1988 irrigation developments are ignored. But 90% of the remaining problem comes not from irrigation at all (relatively manageable!), but from hard-to-counter activities on the dry catchment land.
Native trees have been replaced by grass and grain crops over a vast proportion of the Basin. Leakage rates to groundwater are now up to 10 times what they were historically. The level of often highly saline groundwater has been rising by as much a meter per year in some parts.

A recent audit has found that by the year 2050:
a) The salt mobilised each year will double to 8 million tonnes, of which a bit under half will be exported down the River and the rest will accumulate in irrigation areas and wetlands;
b) The average daily salinity of the lower Murray (at Morgan) is likely to be up nearly 40%, from 573 EC to 791 EC (World Health Organisation desirable drinking limit is 800 EC);
c) In several tributaries and wetlands, the salinity will go over 1500 EC (harmful for the environment as well as for irrigation);
d) Million hectares, or 5% of whole Basin, will be salinised (10 times the current area);
e) Annual damage to agriculture and roads, buildings, etc. could reach $1 billion.

What else must be done to combat salinity? Here is current thinking:
- Introduce lucerne. This could be effective in <600 mm rainfall, sheep/wheat country;
- Replant trees. This is *the only effective option* in >600 mm rainfall, grazing country, **but** up to 70% coverage is required especially of winter-rainfall land. It is only semi-commercial in terms of timber production on <800 mm rainfall land, and it reduces run-off into rivers.

We don't have all the answers yet. But it is clear that a new accountability framework is needed, extending the 1988 strategy, to promote least-cost, market-based steps that deal with the problem.

7. Conclusion: Some Lessons

Here are some general comments about things that have proved valuable in tackling the challenges presented by the River Murray:

a) Community involvement in developing solutions is crucial;
b) A what-if computer model is essential to assess the impact of different options;
c) It is important not to handle lots of things together, but to focus on a manageable task;
d) Resolving problems sometimes requires creative, win-win ideas or 'sweeteners';
e) Clearly defining people's water rights is comforting and encourages investment.

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HISTORICAL CHANGES TO THE SAN FRANCISCO BAY-DELTA WATERSHED: IMPLICATIONS FOR ECOSYSTEM RESTORATION

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Abstract
The Sacramento and San Joaquin Rivers (and their inland delta) provide water for agriculture and urban uses throughout central and southern California, through an elaborate inter-basin transfer via diversions and canals. Historically, the system also supported large populations of anadromous fish. Prior to 1850, spring, fall, and winter runs of Chinook Salmon (Oncorhynchus tshawytscha) numbered an estimated 3–4 million annually. After 1850, the abundance and distribution of these fish underwent a severe decline as a result of human activities like hydraulic mining, canalisation, pollution, and over-fishing. Spring-run Chinook Salmon were extirpated from the San Joaquin system by the 1940s and their present distribution is confined to three small tributaries of the Sacramento River. Winter-run Chinook Salmon are threatened with extinction.
The ability of water users to divert water from these rivers and the delta is threatened by protections for these fish that may be imposed under the 'US Endangered Species Act', so there is considerable motivation to restore the ecosystem such that fish populations are considered to be out of imminent danger. Important stakeholders include the urban areas of southern California, agricultural interests, and environmental groups.
Considerable funding is available under the 'Central Valley Improvement Act' and under the 'Calfed Bay-Delta Programme' (a consortium of state and federal agencies that are undertaking an ecosystem restoration programme for the San Francisco Estuary-River system), making this the second largest ecosystem restoration programme in the US. The main objectives are to restore habitat for and populations of wild Chinook Salmon and other endangered fish species, and to improve water quality for human consumption. Restoration activities include additions of gravel to improve spawning habitat, purchase of lands along rivers to permit active channel migration and flooding of the river banks, riparian plantings, and screening of diversions. A recently adopted 'Strategic Plan' for the restoration programme calls for an adaptive management framework in which scientific information is explicitly used to refine restoration goals, select projects, and evaluate success.

1. Introduction

The Sacramento and San Joaquin rivers drain over 160 000 km^2 (over 40% of the land area of California), receiving most of their runoff from tributaries draining the Sierra Nevada and Cascade ranges. The mainstem Sacramento flows southward and San Joaquin northward along the axis of the Central Valley of California, meeting in an inland delta (The Delta) and then flowing westward through the San Francisco Estuary and debouching into the Pacific Ocean through the Golden Gate of San Francisco. Over the last century and a half, the estuary, delta, river channels, and catchment have been altered to an extent not commonly appreciated. Populations of native fishes that formerly inhabited the system have declined, with many races extinct or nearly so. Most notable among these native fish were the Chinook salmon (*Oncorhynchus tshawytscha*), of whom an estimated average of 2-3 million ascended the Sacramento-San Joaquin River system to spawn in freshwater stream gravel prior to the beginning of extensive European settlement about 1850. Since then, populations of these fish have declined precipitously, such that many runs are now extinct, and others are listed as threatened or endangered under federal and state legislation to protect endangered species (Yoshiyama *et al.* 1996).

Over-fishing and competition from introduced species have been important factors in the declines. In addition, the geomorphic, hydrologic and ecological processes in the watershed that formerly supported these native fish species have been fundamentally changed by human activities. This paper reviews the effects of these human activities affecting ecosystem, such as dams, diversions, groundwater pumping, conversion and filling of floodplain and inter-tidal wetlands, gold and gravel mining, levees, artificial bank protection, pollution, and land-use changes in the watersheds draining to the rivers, Delta, and Estuary.

Two parallel, large-scale ecosystem restoration programmes are now underway in the Sacramento-San Joaquin River system: the Anadromous Fish Restoration Programme of the US Fish and Wildlife Service and the Calfed Bay-Delta Programme. From the mid-1990s through 1999, these programmes spent USD 394 million and 284 million respectively on restoration projects, not including administrative expenses. However, most of these restoration projects were selected on an ad-hoc basis, not based on a larger, system-wide ecosystem model as a basis for prioritisation. An overarching framework for prioritising restoration actions is being developed, and standards for proposals have been raised to increase the likelihood that lessons learned from restoration projects can inform future restoration planning, through an explicit adaptive management approach (Healey *et al.* 1998).

It is essential that we understand the nature and extent of the historical changes to the ecosystem if we are to develop sound restoration goals and understand constraints upon what we can realistically achieve, even in a massive restoration programme (Kondolf and Larson 1995).

2. Hydrology, Dams, and Native Fishes

The flow regimes of the Sacramento-San Joaquin River system reflect the prevailing Mediterranean climate and elevation gradient of the Sierra Nevada range from sea level to well over 4000 m, resulting in a combination of winter rainfall runoff and spring snowmelt. The largest floods were generated by winter rains, especially warm rains falling on a snowpack. Less extreme high flows resulted from spring snowmelt in late spring and early summer. High winter flows were essential for maintaining the open, active channel form, for flushing fine sediments from gravels needed by salmon for spawning, and providing the intermediate disturbances that maintained the structure of the food chain. Spring snowmelt flows were important for seaward migration of juvenile salmon, which as poor swimmers, depended upon the downstream current to take them to the open ocean where they spent their adult lives,

The salmon came upstream in several *runs*, each timed to take advantage of certain parts of the hydrograph. The fall-run migrated in October-November (after temperatures cooled off) up as far as the wide, gravel-bedded reaches in the valley or foothills, and spawned shortly after arriving in the spawning reaches. With this strategy, the fall-run adults spent little time in the freshwater habitat (where they would be vulnerable to predation or high water temperatures), but in dry years they might encounter difficulties in passing shallow reaches and other barriers in their upstream migration. By contrast, the spring-run took advantage of the reliably high snowmelt flows for their migration, moving farther upstream into mountainous reaches with cooler temperatures year-round, where they passed the summer, spawning in September and October. The young of both spring and fall runs emerged from the gravel in the spring and migrated downstream in late spring-early summer with the spring snowmelt flows. (Genetically-distinct winter- and late-fall runs also occurred.) The spring-run were formerly the most abundant in this system, supporting numerous canneries in the Central Valley in the 19th century (Yoshiyama *et al.* 1996).

Dams constructed in the late 19th and early 20th centuries blocked access to natal spawning grounds of the spring run, exterminating most of these runs by 1945. The remnant runs are on small tributaries that would have seemed inconsequential in 1850 but are now highly treasured. Healthy runs of wild spring run salmon persist on Butte Creek, Deer Creek, and Mill Creek. Fall-run still occur in the habitat remaining in some channels downstream of dams, but their numbers have declined in response to habitat losses, changes in flow regime, and reduced gravel supply from upstream (discussed below).

Besides blocking access to upstream habitats, dams, the reservoirs they impound, and their associated diversions, substantially alter the downstream flow regime. Relatively small reservoirs built prior to 1940 have since been replaced and supplanted by massive reservoirs, generally located in the foothills transition. These reservoirs impound varying percentages of the rivers' annual runoff, with corresponding ability to regulate seasonal and inter-annual variations in flow (Figure 1). Reservoir storage capacity in the Sacramento-San Joaquin system now totals about 3.5 billion m^3, with storage in the Sacramento River basin equivalent to over 80% of the annual runoff and in the San Joaquin River basin equivalent to over 80% of the annual runoff. As a result, frequent floods (important for maintaining channel form and habitat) have been eliminated or drastically reduced on most reaches (Figure 2). In addition, the annual snowmelt peak has been largely eliminated, as this water arrives at a time when it can be stored in the reservoirs, i.e. after the flood season and at the beginning of the irrigation season. Loss of frequent floods eliminated the frequent, intermediate disturbances that maintained channel form and gravel quality in many downstream channels, allowing fine sediment to accumulate in spawning gravel and changing the aquatic trophic structure by favouring predator-resistant macro-invertebrates over scour-resistant forms (negatively affecting food availability for young salmon) (Power *et al.* 1996).

3. Habitats and their Direct Alterations

The assemblage of native species depended on a mosaic of habitats, including extensive tidal wetlands in the estuary and delta, which provided a wide range of habitats of various life stages of many species. Species such as Chinook salmon utilised habitats throughout the river system, from cold mountain streams (for spawning) to seasonally inundated floodplains and delta channels (for juvenile rearing). Unfortunately, we lack good information on how many habitats were utilised by various species and their life stages, but more research is now being undertaken to provide insights into the role of these habitats. For example, recent observations of use of inundated floodplains by juvenile Chinook salmon and other species during floods in 1997 on the Cosumnes, the last non-dammed river in the system, has demonstrated the critical role of these habitats in development of juvenile salmon, resulting in greater growth rates than for salmon without access to the floodplain resources, and presumably increasing their success as adults.

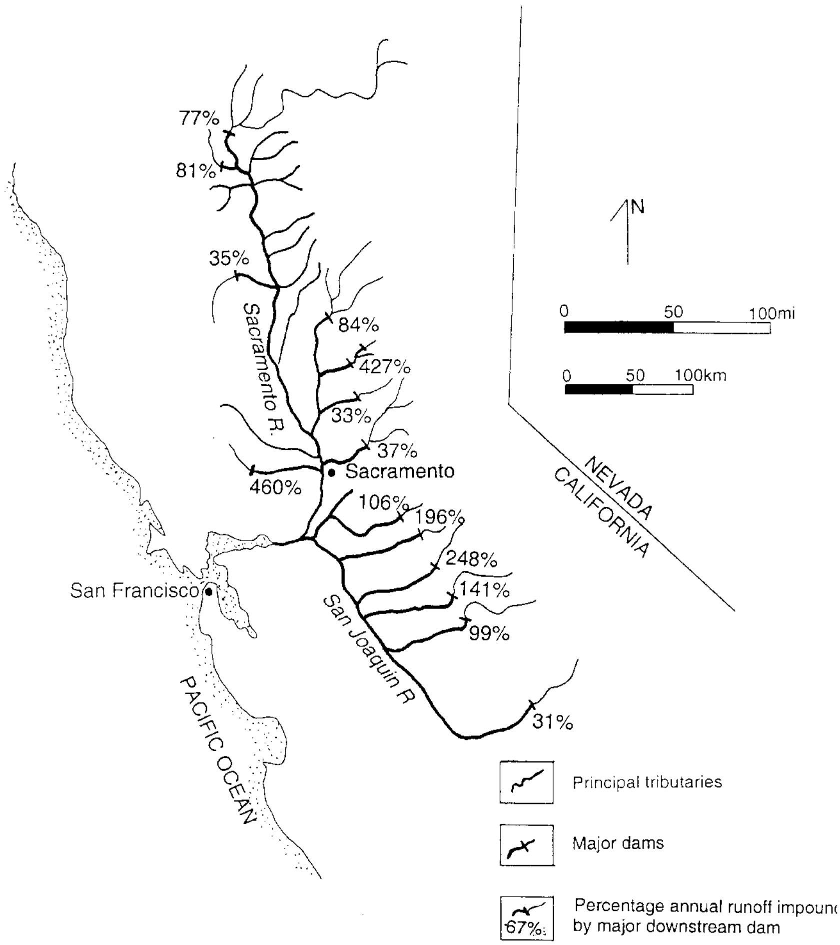

Figure 1. Capacity of large foothills reservoirs as percentage of mean annual runoff for selected tributaries to the Sacramento-San Joaquin River system.

These wetland habitats have been variously filled, drained, dyked, levelled, and converted to other uses, notably agriculture. Riparian floodplain forests have been reduced in extent by 90% since 1850. Of the estimated 160 000 ha of tidal wetlands in the Delta, all but 2% have been dyked off since 1850. And of the inter-tidal wetlands in the San Francisco and Suisun Bays, only 8% remain (Bay Institute 1998). In the Delta, the so-called ' islands' protected by dykes are now typically 2-5 m below sea level because once dried out and exposed to the atmosphere, the organic-rich soils oxidised and

shrank. This complicates attempts to restore inter-tidal habitats. It is not enough to simply breach the offending dykes, as has been successfully done in deltas that have not subsided such as the Danube River delta (Danube Delta Biosphere Reserve Authority 1997), because in the Sacramento Delta this would simply create open-water lakes with little chance of filling up with sediment or establishing inter-tidal vegetation.

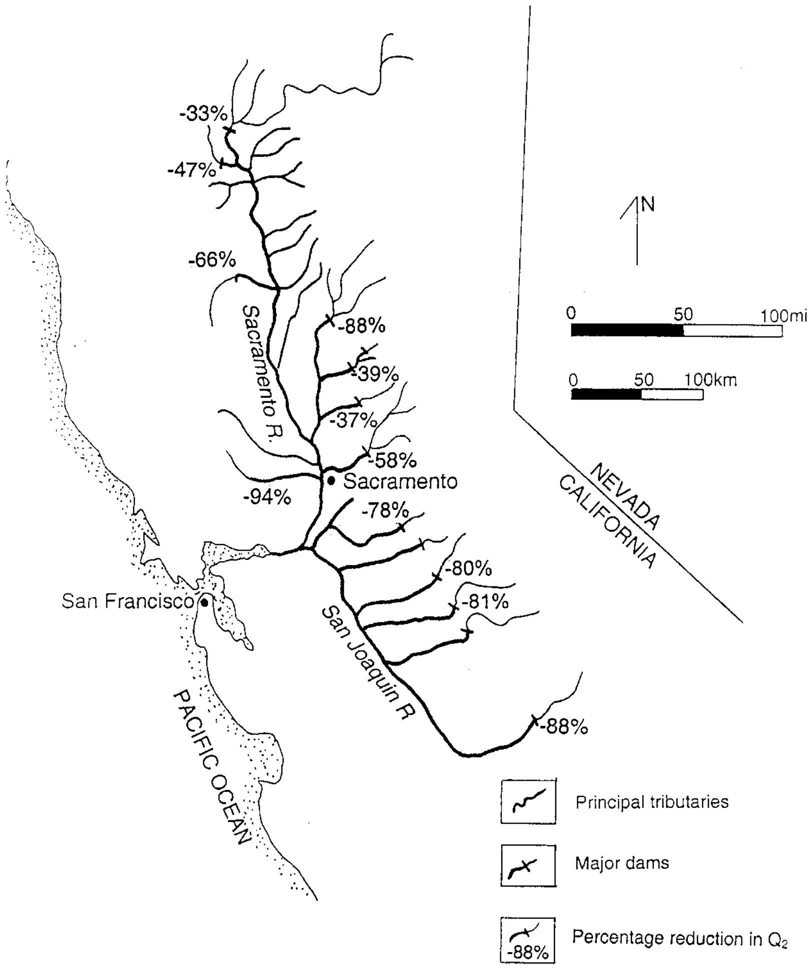

Figure 2. Reduction in the two-year flood, Q2 (i.e., the flood occurring as an annual peak flow once every two years on average) for selected tributaries to the Sacramento-San Joaquin River system.

Even where wetlands have not been physically altered, their hydrology typically has. For example, the Delta experienced enormous seasonal and inter-annual fluctuations in salinity. During large floods, the estuary system was fresh all the way to the Golden Gate, while during the fall of dry years, saline water intruded up delta channels nearly throughout the Delta. Native organisms were adapted to these salinity variations. However, with reductions in flow variability caused by dams and diversions, the saline-freshwater boundary is controlled and kept downstream of the Delta (through reservoir releases during dry months) to maintain water quality in the large diversions from the Delta. The loss of salinity fluctuations has probably facilitated establishment of exotic organisms. A number of pilot projects have been undertaken using fill to recreate inter-tidal habitats in the Delta and San Francisco Bay, but it is still unclear to what extent physical habitat creation benefits native species or simply provides more habitat for exotic species (many of whom prey on natives), and these projects are typically expensive (in excess of USD 100 000/ha).

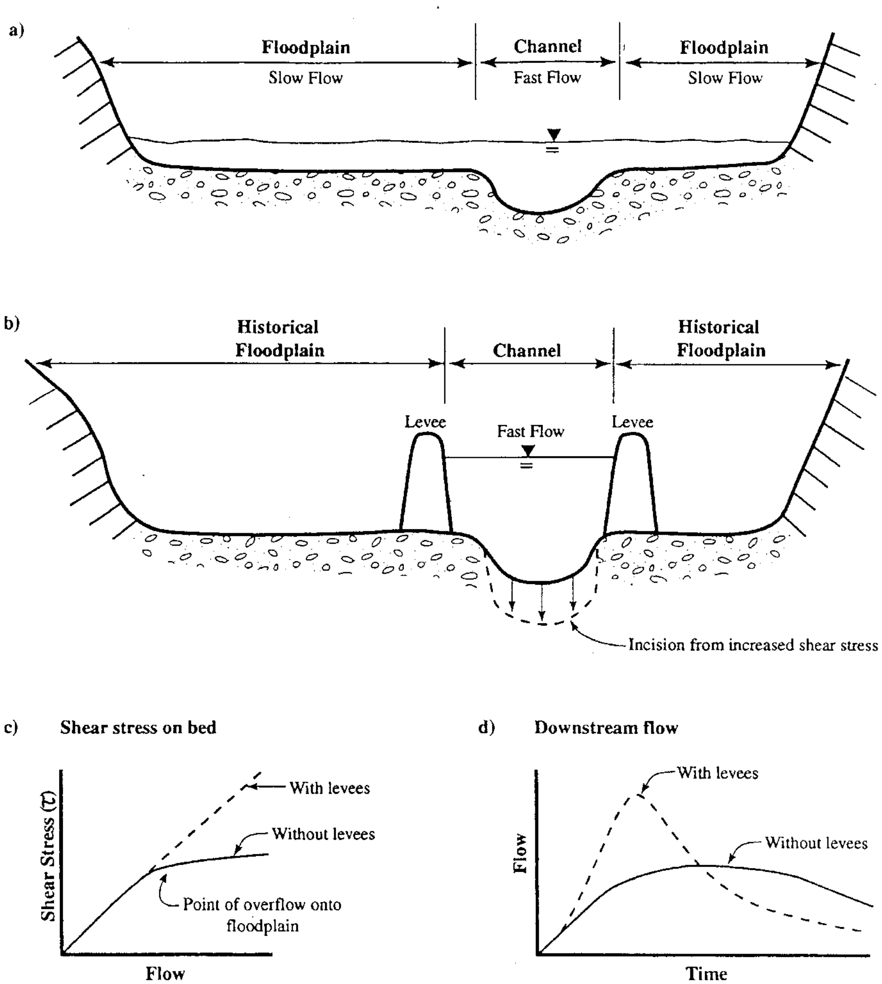

Figure 3. Effect of levees (dykes) on flood flows. Natural flows on the riverbanks (a) accommodate much of the flood flow, attenuating peaks in a downstream direction (d). Elimination of flooding of the riverbanks concentrates flow in the channel (b) leading to more rapid translation of flood peaks and without attenuation (d). Within the levees, increased depths and velocities result in higher shear stress on the bed (c), which can lead to channel incision and less frequent flooding of the riverbanks.

4. Levees and Flood Control

Most river floodplains have been isolated from the channel by levees (dykes). The hydrologic connectivity between channel and floodplain is thereby lost, reducing ecological complexity (Ward and Stanford 1995). Elimination of flooding the riverbanks and storing floodwaters on the floodplain eliminates the downstream attenuation of flood stage, and flood peaks are translated downstream rapidly and without attenuation (Figure 3), typically resulting in greater flood damage downstream. The increased depths contained within the levees also increase the bed shear stress, and tend to cause

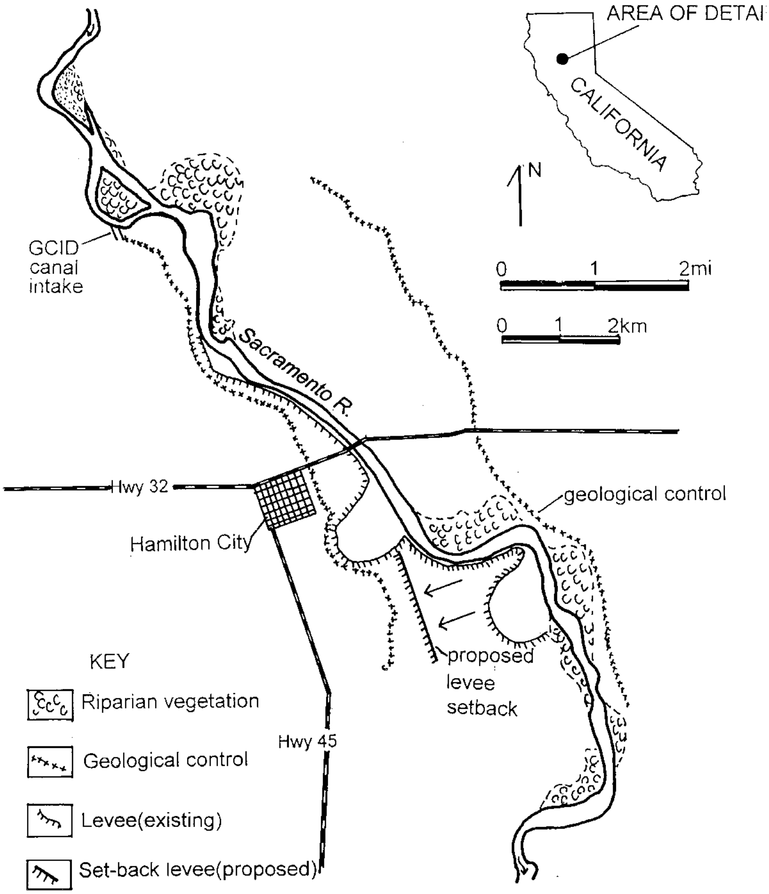

Figure 4. Proposed setback of the 'J Levee' along the Sacramento River near Hamilton City.

channel incision, which in turn increases the channel capacity and makes flooding of the riverbanks even less likely (Figure 3).

One of the main restoration actions frequently discussed is levee breaching or setback, to permit floodplains to flood once again. Levee breaches have been effected on the Cosumnes River, San Joaquin River, and a levee setback on the Sacramento River near Hamilton City (about 100 km north of Sacramento) to permit a large area of floodplain to flood each year is now being considered (Figure 4). Levee setbacks are among the most promising options for restoring the physical processes that in turn can be expected to restore the habitats needed by native organisms, although it requires purchase of fee title or flood easements to floodplain lands formerly protected from frequent flooding.

5. Changes in the Sediment Budget

The supply of sediment to the bottomland of the Sacramento-San Joaquin Rivers has changed substantially since 1850. This has been most noticeable in the coarse fraction of the sediment load, the

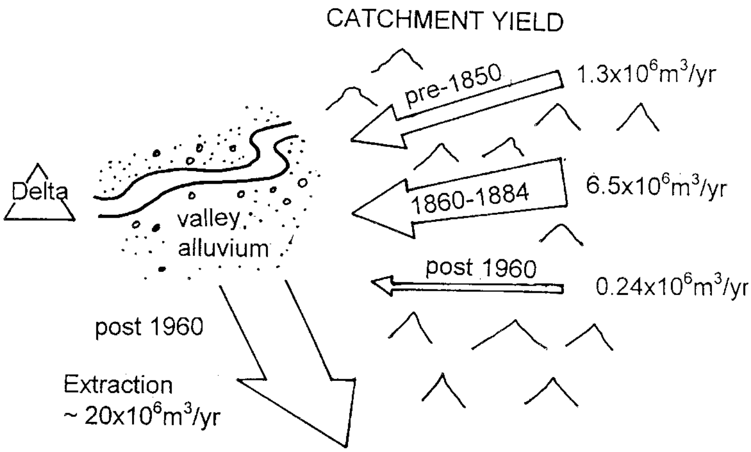

Figure 5. Sediment budget for sand and gravel, showing net supply of sand and gravel from the catchment to the Sacramento-San Joaquin valley prior to European settlement (1850), during the hydraulic mining era (1860-1884), and after completion of dams on virtually every tributary (post-1960). Also shown is the approximate extraction of sand and gravel from river channels and floodplains for construction aggregate.

sand and gravel that move mostly as bedload (Vanoni 1975), because 100% of this fraction is trapped by dams, even those impounding relatively small reservoirs and so effecting only modest changes to the flow regime. The discovery of gold in the Sierra Nevada in 1848 triggered a gold rush, which led to extensive landscape alterations. A major impact on rivers was increased sediment supply from hydraulic mining for gold, which produced an estimated 1.3 billion m^3 of sediment (mostly to the Yuba, Feather, and American Rivers) from about 1860 until 1884, when hydraulic mining (without retaining the sediment thereby produced) was outlawed. Upon reaching the valley floor, the sand and gravel portion of this hydraulic mining sediment resulted in massive channel aggregation and instability. Since the late 19^{th} century, however, a larger human effect on the sediment budget has been the dams that have been built on most tributaries to the river system. Coarse sediment was trapped behind the dams, causing a reduction in coarse sediment supply. The pre-1850 rates of sand and gravel supply (estimated from reservoir sedimentation rates), the five-fold increase in sediment yields during the hydraulic mining era, and the post-dam yield of sand and gravel (from the remaining non-dammed tributaries), reduced to about 20% of the pre-dam yield, are displayed for the entire river system in Figure 5. This figure also includes an estimate for what is now the largest component of the coarse sediment budget: extraction of sand and gravel (for construction aggregate) from the channels and adjacent floodplains.

The net effect of these changes has been to create a substantial sediment deficit in the Sacramento-San Joaquin Rivers and Delta. Sediment starvation downstream of dams is recognised as a significant limitation on salmon spawning success, and projects to artificially add gravel to rivers below dams and/or to construct riffles with imported gravel have been undertaken on18 rivers within the system (Figure 6).

6. Transformation and Restoration of the Sacramento-San Joaquin River System

A broad historical and geographic perspective yields a number of insights for restoration planning in the Sacramento-San Joaquin River system. For example, the magnitude of change in the ecosystem implies that restoration of all reaches is simply not possible given fiscal and political constraints. Political considerations create a tendency for restoration funds to be distributed more or less equitably across the geographical region affected, but this means a little bit of restoration in each of many rivers and reaches.

The effectiveness of this allocation of restoration funding is highly questionable, and even if a positive effect is achieved, it will probably not be possible to detect in a measurement programme. An alternative is to concentrate funding in selected tributaries such that processes and habitats can more effectively be restored and ecosystem response detected. This is an option because the channels of the Sacramento-San Joaquin system are laid out as a system of parallel channels. The geological setting, an alluvial valley ringed by mountains, meant that dams were built on the tributaries in the foothills upstream of the alluvial valley floor. Thus, though the tributary branches are dammed, there is no master dam downstream that controls the entire river system, and individual tributary reaches are still connected to the ocean up to the foothills dams. This implies that it should be possible to restore anadromous salmon habitat in individual rivers below dams, even if neighbouring rivers are not restored. Thus, restoration investments are not wasted if the entire system is not restored.

Before the European settlement, the Sacramento-San Joaquin River ecosystem was characterised by pronounced longitudinal connectivity, with the flow of water, sediment, and nutrients downstream, and the movement of anadromous fish up and downstream (as adults and juveniles respectively) (Figure 7).

The net effect of the historical changes described here has been to reduce or eliminate the longitudinal connectivity, natural dynamics of the river system through reduced high flows, sediment load, and flooding of the riverbanks (Figure 8).

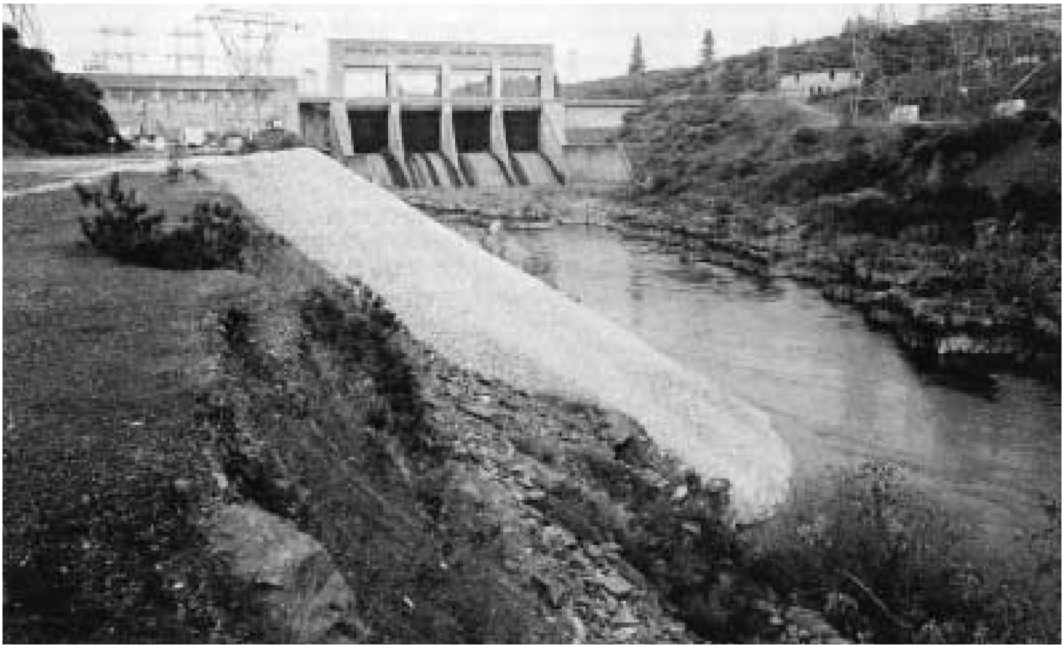

Figure 6. Gravel augmentation below Keswick Dam (the re-regulating dam below Shasta Reservoir) on the Sacramento River. Gravel has been injected or riffles constructed with imported gravel at numerous sites on this reach of the Sacramento since 1979 (photo by Kondolf, January 1991).

Some restoration projects in the Sacramento-San Joaquin river system to date have been unsuccessful because they did not adequately take into account geomorphic processes (Kondolf *et al*. 1996). In evaluating proposed restoration actions, a hierarchy of actions can be described, with the most sustainable and ultimately most effective generally being the cases in which ongoing physical and ecological processes can be maintained (such as through purchases of flood-prone lands to eliminate conflicts between flooding and human occupancy). Cases in which the process has been modified but can be restored (such as through re-operating reservoirs to pass or release higher floods) would be the second priority, while projects that preserve relict habitats no longer supported by physical processes or attempt to physically create habitats not maintained by current processes would receive a lower priority.

For example, we understand that extensive flooding was an important process in maintaining habitat for salmon and other native fish, but we cannot realistically move large cities from the floodplain, nor is it likely that we will remove most existing dams. However, it may be possible to restore floodplain flooding along some rivers and streams, permitting natural processes to shape channel and floodplain habitats. This implies that we should prioritise acquisition of land or flooding/erosion easements along rivers that still flood (i.e. rivers that have not been so dammed that they no longer have high flows), or below dams where restoration of a flooding regime may be possible. Restoration of floodplain functions in these reaches can also reduce flooding pressure downstream (Healey *et al.* 1998).

To be effective and sustainable, restoration must be based on a real understanding of geomorphic and ecological processes, which can inform restoration goals and choice of implementation strategy. Recognising that uncertainty is unavoidable in light of our limited understanding of the functioning of the system, an adaptive management approach has been adopted by the CALFED ecosystem restoration programme, emphasising that restoration actions can be taken that serve to increase our understanding of the system's responses (Healey *et al.* 1998).

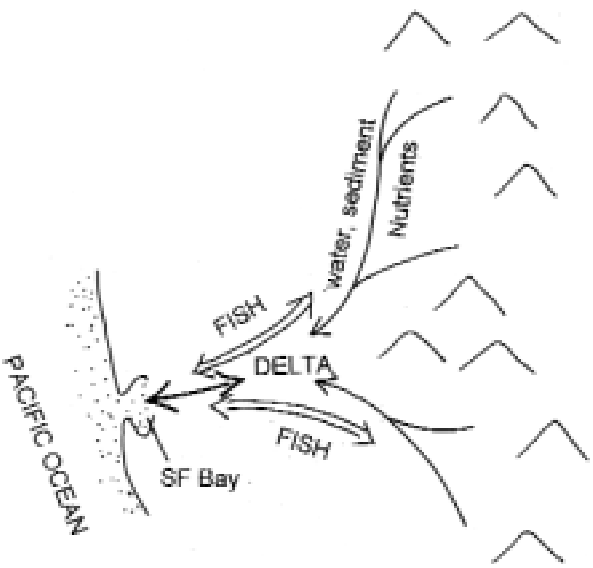

Figure 7. Fluxes of water, sediment, and nutrients from the catchment downstream through channels in the Sacramento-San Joaquin River system. Anadromous fish moved in both directions: adults migrated upstream, juveniles downstream.

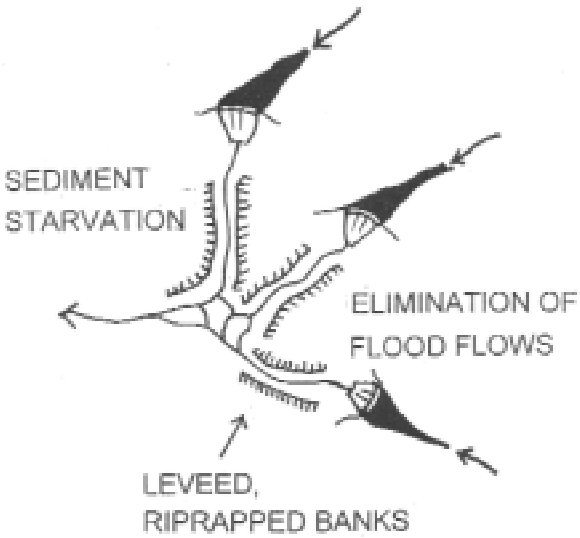

Figure 8. As a result of dams, reduced flows, sediment starvation, and levees on channels in the Sacramento-San Joaquin River system, channels of the lower rivers and delta are isolated from their floodplains, sediment starved, and largely immobile due to reduced flows and bank hardening, reducing ecological complexity and ecosystem productivity.

Acknowledgements
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GIS-BASED MANAGEMENT STRATEGY FOR THE YELLOW RIVER

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Abstract

The Yellow River, the second largest river in China, passing through nine provinces with 5500 km river length and 753 000 km² basin area, is facing four major problems:

1. *Lack of water resources in the upper reaches;*
2. *Soil erosion in the middle reaches;*
3. *Sedimentation in the river bed which causes floods threatening the lower reaches;*
4. *Seasonal drying up of the river and flooding in the lower reaches and delta area.*

To solve these problems, we need an advanced management system. This paper is focusing on the management of Yellow River basin by Geographic Information System/GIS, remote sensing and network system. Its consists of five parts:

1. *Historical change of Yellow River since 1940 and its present situation: describing changes in water resources, water demands, climate, vegetation cover and population;*
2. *Water resource management: describing the ecosystem of the river source area, the influx of melting water to the river, the hydro-power system and the water diversion system;*
3. *Soil erosion management: describing models of soil erosion, land productivity and economic and environmental benefit;*
4. *Flood monitoring and evaluation: describing flood management, monitoring and disaster evaluation;*
5. *Sustainable development of Yellow River Delta/YRD: describing the wetland system, the interactions between soil, water and vegetation and the decision support system for sustainable development.*

The Yellow River has its special characteristics of high sediment contents and seasonal differing water quantities, caused by monsoon climate and seasonal water diversion. The high sedimentation causes suspension of the course of the river and extension of the river mouth. The seasonal water quantities cause flooding in summer and drying up of the river in spring and early summer. By integrated management of the whole basin, optimal allocation of water resources, increasing the vegetation cover, reducing the soil erosion, controlling the river flood and wise use of land resources in the Yellow River Delta, the goal of river restoration may be achieved.

ABBREVIATIONS

AAD	Anthropogenically Added Dynamics
ALRD	Association for Local and Rural Development
AWZ	*Afdeling Waterwegen Kust* (Department of Waterways, Coastal Zone, Belgium)
BBI	Belgian Biological Index
BI	Biotic Index
BCF	BioConcentration Factor
BCM	Billion Cubic Metres
BOD	Biochemical Oxygen Demand
CBS	Central Sava Basin
CBS PRP	Central Sava Basin Preservation and Restoration Project
CEDEX	*Centre de Estudios y Experimentacion de Obras Publicas*, Spain
CGP	Channel Geomorphology Profiler
CIMP	Coefficient of Indicator of Mark Pollution
COD	Chemical Oxygen Demand
COST	CO-operation in the field of Scientific and Technical research
DDBR	Danube Delta Biosphere Reserve
DM	*Deutsche Mark* (German currency)
DPRP	Danube Pollution Reduction Programme
DSES	Development Scheme for Europe's Space
EA	Environmental Assessment
EBRD	European Bank for Reconstruction and Development
EC	European Community
ECRR	European Centre for River Restoration
EEA	European Environment Agency
EEC	European Economic Community
EIA	Environmental Impact Assessment
EPDRB	Environmental Programme for the Danube River Basin
EU	European Union
EURONATUR	European Nature Heritage Fund
EWN	Eurowaternet
GEF	Global Environmental Facility
GL	Giga Litres
GLOBE	Global Learning and Observation to Benefit the Environment
GREEN	Global Rivers Environmental Education Network
ICOLD	International Commission on Large Dams
ICPR	International Commission for the Protection of the Rhine
ICPDR	International Commission for the Protection of the Danube River
IFIM	In-stream Flow Incremental Methodology
IKSR	*Internationale Kommission zum Schutze des Rheins* (ICPR)
IMP	Indicator of Mark Pollution
Interreg	Inter Regional Programme of the EU
IPPC	Integrated Pollution Prevention and Control
IRMA	Interreg Rhine Meuse Activities
ITC	Index of Tropic Completeness
IUCN	International Union for the Conservation of Nature (World Conservation Union)

LIFE	*L'Instrument Financier pour l'Environnement*
MATRA	*Maatschappelijke Transformatie Programma* (Support Programme for Eastern Europe, The Netherlands)
ML	Million Litres
MPC	Maximal Permissible Concentrations
MUV	*Ministerium für Umwelt und Verkehr* (German Ministry for Environment and Transport)
NCR	Netherlands' Centre for River Research
NERI	National Environmental Research Institute, Denmark
NGO	Non-Governmental Organisation
NOEC	No Observed Effect Concentration
NURG	*Nadere Uitwerking Rivieren Gebied* (Detailed Planning of the River Basin, The Netherlands)
PCA	Principal Components Analysis
p.e.	population equivalents
PHARE	Support Programme for Central and East European countries
PHC	*Plan Hidrológico de Cuenca*
PHN	*Plan Hidrológico National*
PIN	Programme International Nature Policy (The Netherlands)
PIP	Public Investment Programme
PPA	Post Project Appraisal
PSI	Performance Since Installation
RAP	Rhine Action Plan
RIZA	Institute for Inland Water Management and Waste Water Treatment, The Netherlands
R&D	Research and Development
RosNIIVKh	Russian Research Institute for Integrated Water Management and Protection
RRC	River Restoration Centre, United Kingdom
RWS	*Rijkswaterstaat* (Directorate General Public Works and Water Management, The Netherlands)
TACIS	Technical Assistance for the Commonwealth of Independent States
TEV	Total Economic Value
TON	Total Oxidised Nitrogen
TRP	Total Restoration Potential
TU	Toxic Unit
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UWWT	Urban Waste Water Treatment
WCD	World Commission on Dams
WFD	Water Framework Directive
WWF	World Wild Life
WL	*Waterloopkundig Laboratorium*/Delfts Hydraulics, The Netherlands
WPI	Water Pollution Index

Colophon

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