

Internationale Kommission für die Hydrologie des Rheingebietes

Commission internationale de l'Hydrologie du bassin du Rhin

**Contributions to the
EUROPEAN WORKSHOP**

**ECOLOGICAL REHABILITATION OF
FLOODPLAINS**

**Arnhem, The Netherlands
22-24 September 1992**

Report no. II-6 under the auspices of the CHR



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Report no. II-6 under the auspices of the CHR

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ISBN 90-70980-15-0

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CIP-GEGEVENS KONINKLIJKE BIBLIOTHEEK, DEN HAAG

Contributions

Contributions to the European workshop ecological rehabilitation of floodplains, Arnhem, The Netherlands, 22-24 September 1992 / [comp./ed. by A. Wagenaar-Hart]. - Lelystad : CHR/KHR. - Ill. - (Report / International Commission for the Hydrology of the Rhine basin. II under the auspices of the CHR ; no. 6)
Met lit. opg. - Met samenvattingen in het Duits, Frans en Nederlands.
ISBN 90-70980-15-0
Trefw.: ecologie ; uiterwaarden.

PREFACE

Over the centuries the area of the large rivers in the Netherlands has changed considerably in character because of human intervention. The twentieth century in particular is distinguished by a decreasing role of natural river dynamics in the floodplains of the large rivers. This resulted in harm to biological values and landscape and geological structures.

In reaction to this and within the framework of the Eo Wijer foundation competition, the Stork Plan was developed. In this plan the possibilities for the rivers area, with regard to agriculture as well as the ecological system, are exploited to the full. The floodplains become nature areas and agriculture is intensified in the hinterland between the age-long inhabited river embankments. River management and the extraction of surface minerals will be directed towards the natural functioning of the rivers area. In this view the extensive nature areas and a large number of smaller nature centres will be strung together through the floodplains like beads. Recreation, living and working can be acceptably fitted in.

The Stork Plan has not passed unheeded. In the Fourth Report on Physical Planning, the further detailing of a developmental perspective for the rivers area is announced. Policy plans for the floodplains have been drawn up. Public discussion, cooperation and administrative coordination are necessary to further concretize and realize these ideas.

The energetic approach to implementation of design plans may, however, cause problems in the future, because a number of aspects has not been elaborated adequately yet. The following problems have been insufficiently studied:

- a. To what extent can river management anticipate the possibilities of nature development in floodplains?
- b. To what extent can other management measures contribute to the possibilities of nature development?
- c. Which nature development schemes are ecologically feasible?
- d. How to weigh nature values against economically based interests, such as shipping, safety and agriculture?
- e. Which existing nature values will be lost when river dynamics in the floodplains is increased?
- f. Which areas offer perspectives for nature development in view of the freedom that is given there to the processes driven by the river (flooding, erosion and sedimentation)?

In order to gather knowledge rapidly on the rehabilitation of floodplains, the Netherlands authorities decided to study this subject in international cooperation. RIZA, for example, is involved in a joint study with VITUKI in Hungary concerning ecological rehabilitation of the Danube, and the Gemenc area in particular. An exchange of information is also taking place within the framework of the CHR.

The aim of the workshop was to stimulate exchange of applied-scientific experiences on the relation between the possibilities for ecological rehabilitation, revitalization and the hydrological properties of rivers and their riparian land.

I hope that this workshop will enlarge the knowledge and experience on river systems with respect to the reinforcement of characteristic landscapes and ecological communities in the rivers of Europe.

dr.ir. J. Leentvaar

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1. AUSTRIA

THE RIVER LEITHA - REHABILITATION FROM 0.0. KM to 15.0 KM

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GENERAL

The Leitha originates in Haderswörth, at the confluence point of the two rivers Schwarza and Pitten. Both of these rivers have their source at the eastern edge of the Alps. The Leitha consequently flows through parts of Southeast Lower Austria and North Burgenland and finally, after a stretch of 118 km, into the Mosoni-Duna (Kis-Duna) in Mosonmagyaróvár (Hungarian territory). The total catchment area of the Leitha up to the Austrian-Hungarian border covers approx. 2,150 km², 1,140 km² of which is formed by the source rivers (The source rivers and their affluents are of special interest when studying high water and flooding along the Leitha). There are hardly any significant affluents along the whole course of the Leitha itself.

Along the Leitha and its source rivers, a variety of water types can be determined. In the upper reaches of the source rivers the water resembles a 'wild stream', in the middle and lower reaches, a greatly meandering lowland river can be determined.

One special characteristic of the Leitha is that almost the whole river is accompanied by a man-made ditch, used for waterworks purposes. On account of the water extraction (from the upper reaches) used to feed this ditch, a stretch of 25 km along the main river contains no water for approx. 200 days of the year. The ditch is used for power stations or for irrigation purposes.

Despite a relatively long period of observation, there are still no exact details available of high water levels. The HQ 100-levels at Haderswörth (the confluence point Schwarza-Pitten) range from 250-400 m³ per second. Running retention plays a significant role along the Leitha, as this river - due to a lack of larger affluents - does not increase, but, on the contrary, the waves reduce in size. At the Austrian-Hungarian border, an HQ 100 level of approx. 140 m per second is reported.

HISTORY OF THE REGULATION OF THE LEITHA

There is evidence that measures taken to regulate the Leitha go back to Roman times. Maintenance measures were taken by Roman soldiers along the course of the river.

There is documentary evidence of various regulatory measures from the Middle Ages and in more recent times. Dams, discharge flumes and irrigation channels were constructed during these periods. The essential regulatory measures were taken in the middle of the 19th century. Approx. 150 years ago, quite large-scale regulatory measures were taken throughout the lower reaches of the Leitha.

Following the catastrophic flooding of 1965-1966, a general regulatory project was set up for the Austrian part of the Leitha. The principal aims of this project were:

- the prevention of flooding in residential areas (HQ 100);
- stabilization of the course of the river and the inclusion of natural retention areas;

- setting up of emergency water storage basins (storage capacity approx. 9 million m³);
- division of the river area into 4 administrative authorities, (foundation of the 'Leitha-Wasserverbände' or water authorities nos. 1-4. As far as administration is concerned, Burgenland is responsible for the authorities nos. 1 and 3 and Lower Austria for nos. 2 and 4).

CURRENT POSITION

Upon completion of the 'general Leitha regulation project', several detailed projects were set up to ensure the safety of the residential areas. These projects have been successfully carried out during the past 20 years. By setting up flood dams, an HQ level of 100 has been achieved, thus ensuring the safety of the residential areas.

On the whole, the regulatory measures which were taken between 1969 and 1985 were only protective ones. Ecological aspects, such as the inclusion of surrounding land, were hardly taken into consideration.

Regulatory aims were reviewed to include the straightening of the course of the river (by cutting off meanders, bank stabilization by using stone pitching and an expansion of the river's profile. The essential criterium was the erection of flood dams on both sides of the river.

The result of these measures was that the river was cut off from the surrounding land. However, after completion of these linear measures and the setting up of an emergency water storage basin (storage capacity approx. 3 million m³), it was established that the assumed HQ safety level of 100 for the residential areas had not been reached.

Due to a lack of exact hydrographic data at the planning stage, calculations had been made on the basis of levels which were too low.

It is now necessary to take action, not only with regard to rehabilitation (river regulation which is as natural as possible and a reversion to the original course of the river), but also with a view to flood protection.

REORIENTATION OF MEASURES TAKEN ON THE RIVER SYSTEM (FROM 1991)

In 1991, the water authority Leitha 1 was assigned by the Federal Ministry of Agriculture and Forestry to prepare a water management concept. This concept was chosen by the Ministry as a pilot project for the type of water known as 'lowland river'. The area covered in the plan ranges from the Austrian-Hungarian border at Nickelsdorf to Gattendorf. The area is otherwise contained by the 'Wiesgraben' (a man-made irrigation ditch) in the north, the 'Kleine Leitha' and the 'Komitatskanal' (the discharge flume of the Leitha) in the north-east and the Leitha including the adjoining flat areas in the south. The area covers a total surface of approx. 40 km² and the total stretch of water measures approx. 45 km (Leitha 15 km, Kleine Leitha 16 km, Komitatskanal 4 km, Wiesgraben 10 km).

The original dynamics of the river were hardly taken into consideration in the regulatory measures of the past 20 years.

The remaining floodplains or parts of them have lost the natural flooding and all connection with the river. The size of ecologically significant areas has been continually reduced by intensive

agriculture. To achieve an immediate improvement in the overall ecological situation, the maintenance measures which were in effect at the time were restructured. Mowing of the banks was reduced to a minimum. At the same time, suitable trees and bushes were planted on the outer embankments and at the points of fluctuating water levels. Breaks in the banks are now repaired only in residential areas and by using natural materials as much as possible. These measures should be regarded as part of the actual water maintenance plan. Subsequently, the work of the overall water maintenance concept was started.

APPROACH

The first step is a general survey (and evaluation) of the whole area under observation. This survey comprises the following points:

- recording of morphological data found in the running waters, establishment of suitable reference points;
- compilation of available data on fishing, limnology, (implementation of test fishing, recording of macro-invertebrates);
- mapping out and evaluation of the floodplains and their waters (vegetation, amphibia);
- recording of the structure of the water;
- inclusion of the area division plans (including changes in usage);
- presentation of ecological deficiencies.

In conjunction with the survey, all offices responsible are involved in setting up an ecological model. This model includes a catalogue of aims for the further development of the area under observation.

The catalogue of aims includes the following areas:

- water-connected area (forming of bank structure, vegetation);
- surface area (examination of flood areas, additional man-made supply areas);
- overall area (biotope integration with the surrounding land).

The catalogue of aims must be approved by the authorities responsible for agriculture, forestry, conservation and fishing. However, the development of area division (building areas, creation of industrial areas, transport developments) must be considered an important criterium.

On the basis of the survey and the resulting model, the concept of necessary measures for these waters, known as the 'Gewässer-pflegeplan' (water maintenance plan) is to be set up. This concept presents a catalogue of measures showing short-, medium- and long-term measures. It deals with water maintenance, conservation and rehabilitation.

SHORT-TERM (IMMEDIATE) MEASURES IN AND BY THE RIVER

- restructuring of the river bank and bed areas (the bank lines, which were extremely geometric up till now, are being structured), creation of slip banks and escarpment banks, removal of berms - changes in the river's profile;
- planting out on the outer banks and in the inner areas (plants and trees suitable to the habitat);
- inclusion of those blind river branches and tributaries which were cut off by the former regulatory measures.

MEDIUM-TERM MEASURES AROUND THE RIVER

During a period of 5 - 7 years, all waters in the area concerned are to be linked up. In addition, the irrigation of remaining floodplain forests and parts of them is planned. Careful land acquisition is planned to ensure that areas which are valuable, both for the water economy and for the ecology, become public property.

LONG-TERM MEASURES IN THE SURROUNDING AREAS

The regulatory measures of the past 20 years were not able to achieve all their aims. During the phase of long-term measures, the creation of natural retention areas is absolutely necessary. This will be achieved by changing those areas which are currently used for intensive agriculture back into meadows. A time span of approx. 15 years is planned for these measures.

In 1991, an emergency water storage basin of natural design over an area of 160,000 m² (storage capacity approx. 320,000 m³) was set up in Zurndorf as a model for this water management concept. During this operation, a stretch of approx. 650 m on the right bank of the Leitha dam was removed and several blind river branches and parts of them were joined to the Leitha river system. A dam was built at a distance of 150 m (on agricultural land). An expansion of the river's profile was attempted, to retain the natural dynamics.

One year later, we can see that natural conditions (formation of sand banks, bank structure) have returned to the river area.

FUTURE ASPECTS

The water authority Leitha 2 has now also been assigned by the Federal Ministry of Agriculture and Forestry to prepare a water maintenance concept. The area covered by this authority covers a stretch of water of approx. 50 km. The implementation of further measures is expected to begin within 2-3 years and will then cover a total stretch of approx. 65 km.

The whole project can only be realized by progressing step by step. Constant observation of the river system (and of the surrounding land) will be necessary, to make any possible adjustments. Implementation is only possible by including the elements of population, agriculture, forestry, fishery and conservation.

We must also aim to include the Hungarian stretch of water, from the Austrian-Hungarian border to the mouth of the river into the Kis Duna, in our water management concept.

2. BELGIUM

RESTORATION OF FLOODPLAINS ALONG A FRESHWATER TIDAL RIVER: THE SCHELDT

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INTRODUCTION

Man has always used estuaries: initially for food, then for transport and most recently as a site for industry and development. These developments resulted in a decrease in both water and structural quality of the estuaries. The deterioration of the water quality was so bad that in some estuaries even anoxic conditions prevailed throughout the year, making all life impossible. Furthermore estuaries form sinks for several pollutants, but also represent a most important source of pollutants for the seas [McLusky, 1990]. On the other hand embankments, reclamation, dredging activities etc. severely affected the habitat diversity or structural quality of the estuary.

The problem of the water quality has received quite a lot of attention and by now several examples exist where a drastic improvement in water quality is achieved (e.g. the Thames). Much less attention was given to the restoration of the structural quality of the estuary. The influence of channel normalization, deepening and reclamation has received thus far less attention than the pollution problem, since the effects are perhaps less conspicuous on the short term. On the long term however, the consequences may even be more dramatical than the former, and involve also the safety of the surrounding areas against floodings [Pieters et al., 1992]. Therefore improvements of the structural quality of the estuary should be an essential part of each management or restoration project. In this paper we want to present some plans which are being developed for the estuary of the river Scheldt. The main focus will be on the Belgian part of the estuary.

THE ESTUARY OF THE RIVER SCHELDT: AN INTRODUCTION

The river Scheldt rises in Saint-Quentin (France), passes through Belgium and the Netherlands and flows into the North Sea after 350 km. The influence of the tide is perceptible up to Ghent, where it is stopped by a sluice. The total length of the Scheldt estuary between Ghent and Vlissingen amounts to 160 km. The width varies between ± 50 m at Dendermonde, 250 m at Temse, 500 m at Antwerpen and 4.5 km at Vlissingen; the maximal width amounts to 7.8 km. The mean tidal amplitude increases from 3.82 m at Vlissingen, 4.5 m at Hansweert and 4.9 m at Antwerp, to a maximum of 5.2 m at Kruikeke. More upstream it decreases to about 2 m near Ghent.

The freshwater input of the Scheldt is on average $100 \text{ m}^3/\text{s}$. Seasonal fluctuations in drainage range from high values during winter (average $180 \text{ m}^3/\text{s}$, maximum $500\text{-}600 \text{ m}^3/\text{s}$) to low values during summer (average $50 \text{ m}^3/\text{s}$, minimum $10 \text{ m}^3/\text{s}$ or less). In the Scheldt estuary the tidal volume ($> 100,000 \text{ m}^3/\text{s}$) largely exceeds the freshwater load (average $100 \text{ m}^3/\text{s}$), resulting in a measurable dilution of the seawater and a relatively large transition zone from salt to freshwater. This is reflected in the chlorinity gradient. Chlorinity decreases from $\pm 16.6 \text{ g Cl/l}$ near Vlissingen to $\pm 4.5 \text{ g Cl/l}$ at the Belgian-Dutch border and near the tributary Rupel the water becomes fresh ($< 0.3 \text{ g Cl/l}$). Generally spoken, the whole estuary can be divided into three main zones: a marine (polyhaline) zone between Vlissingen and Hansweert, a brackish (mesohaline and oligohaline) zone between Hansweert and the tributary Rupel, and a freshwater zone (limnetic zone) more upstream (fig. 1). The fresh and brackish part of the estuary will be the focus of this paper.

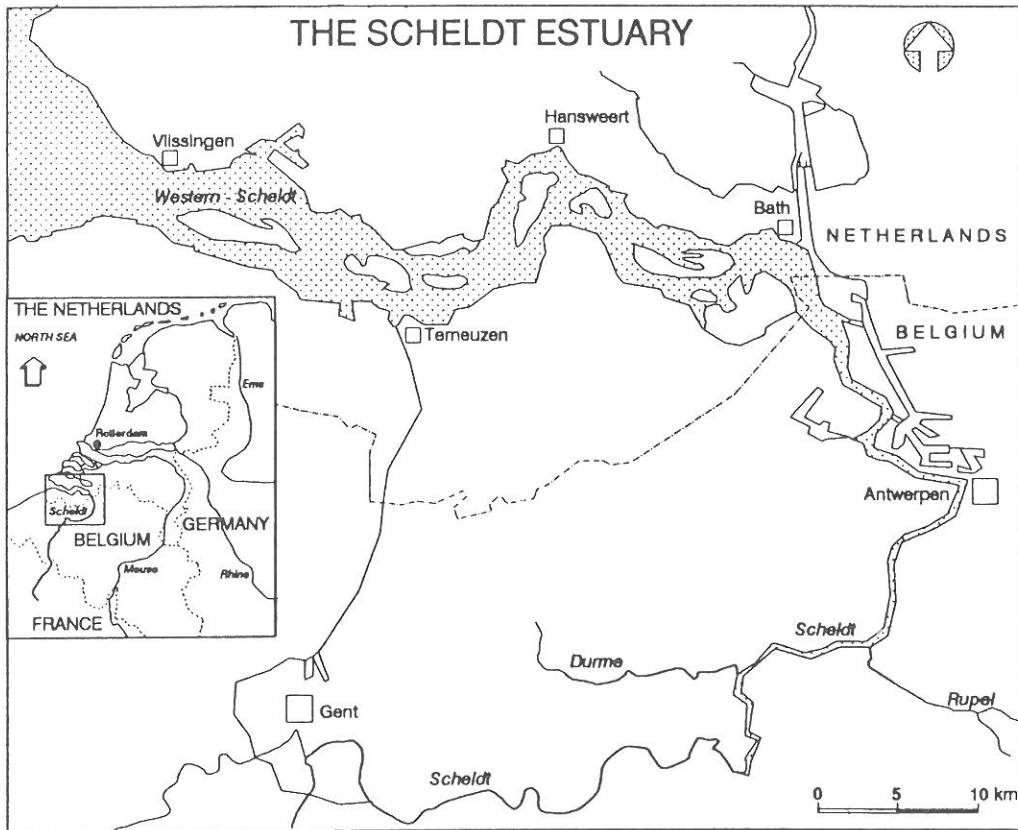


Figure 1 The Scheldt estuary

Upstream from the Dutch-Belgian border, the upper estuary (called Zeeschelde) is characterized by more or less a single tideway. Brackish water and freshwater tidal marshes and mudflats are distributed along the dikes. However, the width of the intertidal area is generally less than a few dozens of meters. Only at some locations there are larger mudflats. The total size of the Zeeschelde is 4000 ha of which more than 1200 ha is intertidal. The presence of 484 ha of fresh water tidal marshes is a unique ecological feature. Along the freshwater tidal part grasslands adjacent to the dikes were regularly flooded in winter until recently. During high water at spring tides water entered the polder through sluices in the dike. At low water the water flowed back to the river. During each tide a little amount of mud was deposited on the agricultural land which made these sites very productive.

Just downstream from the Dutch-Belgian border, the estuary is called Westerschelde and measures about 31,000 hectare of which about 11,000 ha is intertidal. In the brackish part is situated the largest brackish tidal marsh of Europe (2800 ha): "Het verdronken land van Saeftinge" ("The drowned land of Saeftinge"). In between the tidal channels several large sand and mudflats occur. Along the dikes small mudflats are found. In the marine part only some 200 hectares of saltmarsh is present.

During the last century about one third of the intertidal area was lost due to reclamation [Meire et al., 1992]. The wet grasslands along the freshwater tidal part of the estuary are not flooded anymore in winter, which means that the relation with the river is broken. Due to dredging activities the depth of the channel near Zandvliet increased by more than four meters. The total amount of dredged material increased from 5 to 15 million m³ per year between 1960 and 1990 [Belmans, 1988]. This resulted in an increased sedimentation of the intertidal areas. This, together with the reclamation, reduced the tidal prism of the estuary. The tidal amplitude on the other hand increased.

WATER QUALITY OF THE SCHELDT ESTUARY: BAD BUT IMPROVING

The Scheldt estuary is heavily contaminated with heavy metals and organic micropollutants and suffers a huge organic matter input. Most of the pollutants behave conservatively and concentrations generally decrease when salinities increase, as a result of the mixing of riverine and marine particulates [Zoest, van & Eck, van, 1990; Eck, van et al., 1991]. The large organic matter load causes oxygen depletion in the Scheldt river and in the upper estuary. The upper estuary is often anoxic. These (near-) anoxic conditions may prevail as far as the Dutch-Belgian border.

PROTECTION AGAINST STORM SURGES: DELTA AND SIGMA PLAN

After the disastrous storm surge of 1953 the Netherlands government approved the so-called Delta Plan which included the closure of all estuaries in the Delta area of the Southwest Netherlands with the exception of the Westerschelde and the Nieuwe Waterweg, as these are the entrances to the ports of Antwerp and Rotterdam respectively. Along the Westerschelde the plan foresaw in strengthening and heightening the dikes. After the storm surge of 1976, when dike bursts occurred along the Zeeschelde, the Belgian government approved the so-called Sigma Plan. This plan consists of three parts. The first is strengthening and heightening the dikes. Secondly at several places along the river controlled inundation sites are planned and thirdly a storm surge barrier should be built just downstream from Antwerp [Casteleyn & Kerstens, 1988]. By now the Delta Plan has been carried out. More than 70% of the dikes have been adapted within the framework of the Sigma Plan, and most of the controlled inundation areas have been realized.

CONTROLLED INUNDATION AREAS

Controlled inundation areas are sites next to the river which are enclosed by two dikes. The dike along the river is lower than at other sites. A second, higher dike, is situated more inland. As the water rises during a storm surge it will reach the crest of the dike and start to flow over in the controlled inundation area. At that time, upstream of the inundation area, the water will not rise any more as most of the water is entering the polder and only a much smaller amount is moving upwards. By using these inundation areas the dikes upstream can be lower than without inundation areas, to reach the same level of safety. At low tide the water flows again to the river through sluices in the dike. These areas are agricultural land.

The height of the dike in such an inundation area may not be too low, because otherwise the polder will be flooded too often (e.g. also in summer which might cause agricultural damage). Additionally if there are successive storm surges, which happens often, the polder may not be inundated during the first high water. Indeed under these conditions the low water levels are also much higher than normal and it may be impossible to drain the polder at low water. Therefore at the next high water the capacity of the polder to take water is much smaller and hence also its effect on the water level more upstream. For technical details on the construction of the dikes and

the calculation of the water levels we refer to Casteleyn & Kerstens [1988] and Taverniers [1988].

Controlled inundation areas are planned where there is no or nearly no population. In total some 2600 hectares are suitable as controlled inundation area and by now they have been realized in more than 500 hectares scattered along the river.

SUSTAINABLE MANAGEMENT OF THE ESTUARY

As described above different activities resulted in the deterioration of the ecological value of the estuary. By now this has reached a level that it even hampers the economic development. Indeed the storage of heavily polluted mud is a drag on the dredging activities. Therefore the improvement of the water quality is a crucial point in the future management of the estuary. Serious efforts are done now to improve the water quality. Sustainable management however also includes an improvement of the structural quality of the river. According to Pieters et al. [1991, 1992] this includes a) a development of an integrated dredging-extraction-dumping strategy b) the restoration and creation of floodplain areas and c) selected measures to enlarge rare habitat types. The increase of the floodplain areas has several advantages. Tidal volume and current velocity will increase, which will increase the erosion in the main channels, reducing the dredging activity. Furthermore the high water levels will be lower and the sedimentation rates will decrease. The new floodplains can also develop as very valuable new habitats and form a substantial increase of the fresh and brackish water tidal area.

ECOLOGICAL POSSIBILITIES WITHIN THE FRAMEWORK OF THE SIGMA PLAN

Up till now only few ecological considerations have been taken into account when planning and carrying out the Sigma Plan. Safety against storm surges was the main consideration. As the water quality of the river was very bad, the interest of nature conservation in the whole area was rather small.

As the quality of the water starts to improve and huge investments in water treatment are foreseen for the near future, as new ideas are growing on the possibilities of nature development [Baerselman & Vera, 1989; De Bruijn et al, 1987], based on the idea of sustainable management, investigations into the possibilities of ecological rehabilitation of the estuary of the River Scheldt were started [Meire et al., 1992]. The major point is the restoration of river floodplains. The Sigma Plan gives some important possibilities. First of all the management of the existing controlled inundation areas could be changed, so that ecological values predominate over agricultural use. This includes raising of the water level all year round and increasing the frequency of flooding of the site by the river, especially in winter. This can be achieved through the sluices as was the case earlier this century. Increasing the frequency of flooding by the river is only acceptable when the water quality is good enough. Reducing the runoff of the water from the polder itself can already improve greatly the ecological value of these areas. The management of these sites should be oriented on the one hand towards hayfields and on the other hand towards floodplain forests. This is entirely compatible with the role these sites play in flood protection in the Sigma Plan. More drastic is removing the low dike of present controlled inundation areas, thus creating a large intertidal area.

Additionally, where the Sigma Plan must still be carried out, the new dikes could be put further from the river than the present dikes, again increasing the area of intertidal land. In this way there are possibilities to create several hundreds of hectare of intertidal land. This not only increases the volume of the river, but also the surface of freshwater tidal marshes, a very rare

habitat. Preliminary calculations have shown that the increase in intertidal areas has positive effects on the erosion of the main shipping channel to the harbour of Antwerp [Pieters et al., 1991]. Therefore this plan offers a possibility to manage the whole estuary in a way which is beneficial to the safety of the area, the economic values (shipping channel) and the ecosystem itself, the aim of integrated water management.

POSSIBILITIES TO REALIZE THESE PLANS

Giving back land to the river is breaking with a habit of many centuries where man has always tried to reclaim land from the estuary. Therefore these plans cannot be carried out within a short time. However by now for some smaller sites concrete plans have been made. These plans will be realized as experiments. For the completion of the Sigma Plan an environmental impact assessment study will be made in which all possibilities for nature development and for increasing the tidal volume will be considered. Furthermore the Zeeschelde and its valley have been appointed as an ecological impulse project by the Flemish Minister of the Environment. This means, that within this area measures must be taken to realize the ecological main head structure. This encompasses the estuary itself, the intertidal areas and the valley of the river. Within this impulse project the several administrations responsible for the area join and much will be made available to realize the plans. Therefore we are confident that we will be able to start to realize these plans in the near future.

Also in the Netherlands the policy is aimed at improving the structural quality of the estuary. Here already a new intertidal area of about 120 hectares has been created. During a severe storm in February 1990 the dike of the so-called "Selena polder" broke. It was decided not to repair the dike and to convert the site from polder into brackish marsh.

CONCLUSION

If the water quality of the Scheldt improves as foreseen and we can improve the structural quality of the estuary as described in this paper, we are convinced that the Scheldt estuary will become a very unique ecosystem in which there will be an intact gradient from marine to fresh water tidal areas, with all habitat types present at all salinities. This gradient is very rare in Europe. What is more, the realization of these plans would not conflict with the economic function of the estuary, it could even improve it. The challenge for the future will be to further develop a management plan in which the interventions are beneficial to the different functions of the system and not oriented towards one function.

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3. FRANCE

MITIGATION OF THE IMPACTS OF HYDROELECTRIC SCHEMES: AN EXPERIMENT IN THE RHONE FLOODPLAIN, FRANCE

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INTRODUCTION

The present-day hydroelectric schemes as well as the old embankments have fixed the river beds, and thereby impeded fluvial dynamics, namely their lateral shift. Meanwhile, the ecological successions still go on, leading the aquatic ecosystems of the dead arms and the oxbow lakes as well as the floodplain wetlands, to change into terrestrial ecosystems. In the Rhone floodplain the completion of successions needs more than one century for the former meanders, and only a few decades for the shallower former braided channels [Bravard et al., 1986]. Because the fluvial dynamics can no longer rejuvenate these ecological successions by creating new side-arms, the challenge is to preserve these water bodies by slowing the ecological successions or better by arresting them. Our aim was to use a hydroelectric construction in the Upper Rhone River, France, as an experiment to instigate an arrest of the ecological succession in former braided channels by way of the increase in their seepage supply. Those former braided channels that are cut off at their upstream end but still connected downstream to the river, and supplied by seepage water that instigates a slow flow or at least a renewal of the water, are called 'phreatic streams' ('Brunnenwasser' in German). Through that flow, these former braided channels export dissolved organic carbon and dissolved total phosphorus, and may compensate for eutrophication that is due to nutrient uptake from sediment by rooted aquatic plants, then nutrient release by their decomposition to overlying water [Godshalk and Wetzel, 1978; Carpenter, 1980]. Any increase in seepage supply is expected to preserve the water level in these former channels but also to increase the export of nutrients, and thereby to slow down both the eutrophication and the terrestrialization.

STUDY SITE

The studied floodplain of the Rhone River is located at about 80 km downstream from Geneva, near Brégnier-Cordon, France. The hydroelectric scheme ($H=11.4$ m; $Q=700$ m³s⁻¹) was built from 1982 to 1984. The water is diverted by a head race towards the power plant, and returns downstream through a tail race (fig. 1). In that reach of the river the average discharge is 450 m³s⁻¹ ($Q_{10}=1800$ m³s⁻¹). In the by-passed section of the river, the minimum discharge is 80 m³s⁻¹ in winter, and 150 m³s⁻¹ in summer, much more during floods when the discharge entering in the scheme exceeds 700 m³s⁻¹. In 1985, a weir was constructed in the by-passed section of the river for sustaining the water table in the upstream part of that by-passed section.

In this ecosystem experiment, the comparison of any change with the previous stage is not sufficient to assess the effects of any increase in seepage supply, because the former channels experience very active vegetation dynamics due to both successions and fluctuations (seasonal and annual changes in hydrology). In order to cope with any interference between natural vegetation dynamics and experimental effects, we have to compare the actual trajectory of the vegetation dynamics submitted to the experiment (i.e. vegetation changes during several years after the completion of the hydroelectric scheme) with a reference trajectory. That is the reason why we chose two former braided arms whose aquatic vegetation was the most similar [Balocco-Castella, 1988], indicating that they were at about the same successional stage. One of them was located upstream from the power plant, in the area where the water table was expected to rise after the

completion of the scheme (fig. 1C & 2C); this impacted former arm was considered as an experimental site. The other one was located downstream from the power plant where no change in the water table was expected (fig. 1B & 2B), and so it was considered as a reference site. The lower part of the impacted arm was destroyed during the construction of the scheme. The water table was expected to rise in the area of the floodplain located upstream to the power plant, because of the alluvial porosity and the relatively high groundwater flows that were previously indicated by the terrestrial vegetation (communities characterized by *Alnus incana* and *Equisetum hyemale*) surrounding the braided former channels [Pautou, 1984].

MATERIAL AND METHODS

The aquatic vegetation was surveyed during summer in 1981 (before the construction of the scheme), in 1985 (after the completion of the scheme), in 1986 (after the construction of the weir), in 1987 and in 1989. 12 sampling plots (2m-wide strips crossing the channel, i.e. 16 to 30 m²) were regularly distributed along the impacted arm, which is 450 m long, and 19 along the reference arm, which is 1100 m long. The large number of sampling spots compensates for their small size, and permits statistical analysis in non-homogeneous distributions [Bigwood and Inouye, 1988; Bornette and Amoros, 1991]. In each sampling spot, the aquatic vegetation was surveyed using the double Braun-Blanquet [1932] cover and sociability scales. The cover index records the species abundance. The sociability index focuses on the patchy vs regular distribution of the species within each sampling spot. Then, each data couplet was converted into a single value for statistical analyses [Balocco-Castella, 1988; Bornette and Amoros, 1991].

Data sets were analysed using the ADE version 3.1: Hypercard c Stacks and Quickbasic Microsoft c Program Library for the Analysis of Environmental Data (D. Chessel and S. Dolédec, Ecologie des Eaux Douces et des Grands Fleuves, University Lyon I, France). Floristic data were analysed using between-classes Correspondence Analysis (CA) [Dolédec and Chessel, 1992].

According to the longitudinal zonation of the aquatic vegetation and its differential changes [Bornette et al., submitted], the impacted arm was divided into 3 floristic zones, and the reference arm into 4 floristic zones. So, each floristic zone at each sampling date was considered as a class in the between-class CA.

RESULTS

Firstly, data from the two former channels were processed together into between-class CA (fig. 3). The greatest change since 1981 is exhibited by the downstream part of the reference arm (zone Ma). Till 1981 this zone was very similar to the upstream zones Mb and Mc, but since 1985, this zone has become highly related to *Potamogeton lucens* and *Potamogeton pectinatus*, which are species of nutrient-rich water [Wiegand, 1978; Haslam and Molitor, 1988]. That species were the dominant species recorded previously by Balocco-Castella [1988] in the Gland River downstream from the arm confluence. The floristic change in the downstream part of the arm results likely from more eutrophic water backflowing from the Gland River. This backflow was probably instigated from 1981 to 1985 by a slight increase in the Rhone River level while the water table, therefore the seepage supply, remained unchanged (fig. 2). Such backflows were documented by Juget et al. [1979] in another former braided channel of the Rhone River, and by Ortscheit [1985] in the Rhine floodplain. Whereas the medium zones of the reference arm (Mb and Mc) do not exhibit any clear change, the upstream zone (Md) changes from 1987 to 1989 due to terrestrialization. As expected, the water table close to the reference arm did not show any sustainable change after the completion of the hydroelectric scheme till 1987, but during the 1988 and 1989

droughts this water table as well as the river level decreased (fig. 2B and 2C), allowing the continuation of the ecological succession.

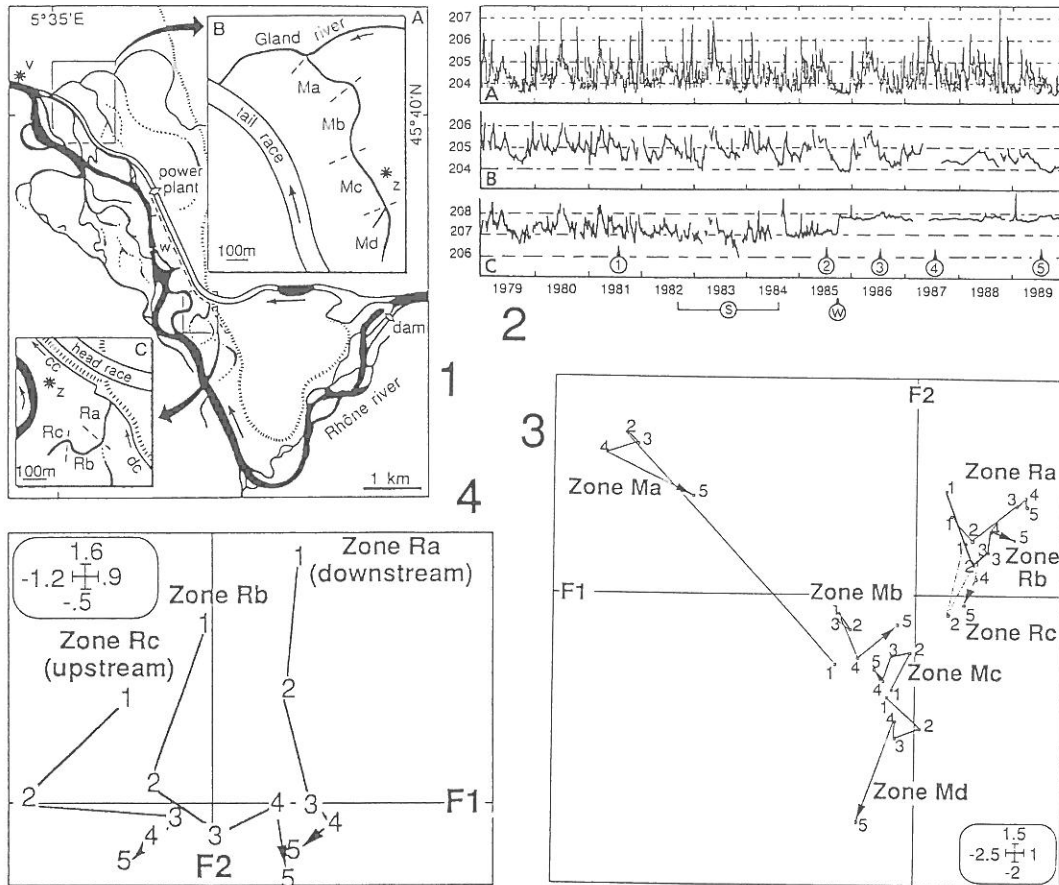


Fig. 1 A: the hydroelectric scheme of the Rhone River in the Brégner-Cordon plain (riv. km 91 to 103 upstream from Lyon); B: detailed map of the reference arm (floristic zones Ma-Md); C: detailed map of the impacted arm (floristic zones Ra-Rb) (cc=counter-canal, dc=drainage canal; v=limnigraph on the river bank, w=weir in the by-passed river section; z=water table recorders).

Fig. 2 Water levels (m above sea level according to NGF marks of the Institut de Géographie National, France) from 1979 to 1989; A: daily levels of the Rhone River downstream from the hydroelectric scheme; B: water table close to the reference arm; C: water table close to the impacted arm (1-5=dates of vegetation surveys; S=duration of the hydroelectric scheme construction; W=weir construction).

Fig. 3 Changes of the floristic zones of the two arms analyzed by between-classes correspondence analysis of the whole data set (F1x F2 factorial map; inertia percentages: F1 21.7%, F2 15.9%; dates: 1=1981, 2=1985, 3=1986, 4=1987, 5=1989).

Fig. 4 Changes of the floristic zones of the impacted arm analyzed separately by between-classes correspondence analysis (F1x F2 factorial map; inertia percentages: F1 27.5%, F2 20%).

In comparison with the changes occurring in the two ends of the reference arm, the changes appear very reduced in the three zones of the impacted arm, suggesting the stabilization of the succession. However, because the greater changes in the reference arm may hide the lower changes in the impacted arm, then floristic data from the impacted arm were processed separately (fig. 4). This data analysis ranges the three zones along a gradient. From 1981 to 1985 the trajectories of the three zones exhibit both a general trend towards the negative values of the F2 axis, and a divergence on the F1 axis. In 1986, after the construction of the weir and the subsequent rise of the water table, the medium and upstream zones (Rb and Rc) converge towards the downstream zone (Ra). In 1987 and 1989, the upstream zone exhibits again the successional trend observed before the construction of the weir. The upstream zone of the impacted arm is related to helophytes (*Polygonum hydropiper*, *Myosotis scorpioides*, *Berula erecta*, *Mentha aquatica*) indicating both the terrestrialization process and the low nutrient content of the water [Kohler et al., 1974; Carbiener et al., 1990]. Terrestrialization increases in the upstream zone in 1985 (negative values on F1 axis) because of the effects of the drainage canal and the lowering of the mean water level of the by-passed river. After the construction of the weir, the water-table rise induced an increase in seepage supply, whose effects are demonstrated by the shift of both upstream and medium zones towards the positive values of F1 axis. This increase stopped the terrestrialization and led to the development of a new group of helophytes that are tolerant to periodical submersion (*Alisma plantago-aquatica*, *Phalaris arundinacea*, *Galium palustre*, *Lysimachia nummularia*) associated with hydrophytes (such as *Myriophyllum verticillatum*). After 1986, terrestrialization slowly proceeds again in the upstream part of the impacted arm together with a regression of the nutrient-poor water species *Berula erecta* and *Mentha aquatica*. The two other zones shift towards negative values of F2 axis that are related to eutrophic species (e.g. *Potamogeton pusillus*, *Ceratophyllum demersum*, *Lemna minor*). The occurrence on the same place of eutrophic and oligotrophic species (*Chara globularis* and *Riccia fluitans* that developed after the completion of the hydroelectric scheme) results from two combined effects: 1) the eutrophication due particularly to organic matter in the sediment; and 2) the nutrient-poor groundwater supply, induced by the water-table rise. Such a co-occurrence of eutrophic and oligotrophic species has been observed on former Rhine River channels by Klein and Carbiener [1988] and by Robach et al. [1991]. In the present study, neither the flood scouring nor the flow resulting from groundwater supply removes the organic matter efficiently: the development of *Ceratophyllum demersum* clearly indicates that the organic matter content is not decreasing.

CONCLUSION

In the reference arm, as expected, the ecological succession was not stopped by the effects of the hydroelectric scheme, and terrestrialization was particularly obvious in 1989 at its upstream part. In comparison, the impacted arm exhibited fewer changes particularly in its upstream part. The effects of the increase in seepage supply in the impacted arm, resulted in the establishment of the oligotrophic species *Chara globularis* and *Riccia fluitans*, and the changes in the trajectories of the vegetation dynamics of the upper parts of the arm, which converge towards the trajectory of the lower part. A successional pause was observed at the upstream part of the impacted arm after the construction of the weir in the by-passed section of the river, but since 1987, a slight trend to terrestrialization and eutrophication has appeared again.

ACKNOWLEDGEMENTS

The present study was partly granted by the Compagnie Nationale du Rhône and by the Program for Interdisciplinary Research on Environment (PIREN-CNRS). Vegetation was surveyed

in 1981, 1985, 1986 and 1987 by C. Balocco-Castella. G. Bornette made the vegetation survey in 1989 and data analyses. P. Leroy provided fieldwork assistance.

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THE RHINE-MEUSE WATER AGENCY'S PROGRAM FOR THE PROTECTION OF AQUATIC ECOSYSTEMS

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A GENERAL OBJECTIVE OF PRESERVATION

The Rhine-Meuse Water Agency has decided during its 6th Action Plan to reach a general objective of preservation of aquatic ecosystems. This political goal necessarily complements the recovery of water quality, and results in a large financial outlay of 500 million francs for the period 1990-1996.

Rivers and their floodplains (swamps, old beds, peat bogs...) make up an everchanging system. The optimum functioning of this system depends on its diversity and its cohesion.

The upholding of the biological dynamics and particularly of the connection between the various ecosystems guarantees the durability of self-purification; floods can be spaced out this way, supply of groundwater reservoirs with 'clean' water during impoundments can be guaranteed and resistance to aggressions, as well as possibilities for sport and tourism generally increase.

Management, preservation and restoration of the diversity of freshwater mediums enable us to maintain quality and efficiency of ecosystems.

In this context, the Rhine-Meuse Water Agency disposes of some financial and technical means that enable it to assert its eco-system preservation goal the same way it asserted traditional hydraulic objectives.

OUTSTANDING ECOLOGICAL SECTORS

Given this general context the Water Agency decided in particular to implement a policy of preservation and management of *outstanding ecological sectors*. Those sectors are the natural habitat of noteworthy species or are characterized by juxtaposition or diversity of noteworthy ecosystems. An outstanding sector may be, for example, a part of the river bed, several humid meadows, ancient river branches.

Thanks to the work of voluntary naturalists most of those sectors have been already listed particularly as far as ZNIEFFs ('Zones Naturelles d'Intérêt Ecologique Floristique et Faunistique', Natural zones of particular ecological interest with a great diversity in the vegetable and animal world) are concerned. The durable preservation of those eco-systems is fundamental because of the important part they play in the general dynamics of floodplains.

The Rhine-Meuse Water Agency is now engaged in various financial or managerial transactions of those zones. These transactions are selected according to priority criteria, as for instance:

- *Financial aid for the supplementary budget necessary to the application of article 19 of the Community rule.*

A compensation will be paid to farmers who maintain extensive farming in Meuse floodplains

of particular ecological interest.

- *Preservation of the Moselle floodplains between the towns of Bayon and Grippont*

According to the Management Scheme of Meurthe and Moselle Quarries, some discussions are held, in the way to decide to buy all pieces of land in the valley (between Bayon and Grippont). Purchases and further management of the area might be committed to an independent institution, the Conservatory of Lorraine Sites.

Beyond these examples it will be necessary to implement an ambitious environment policy including all these aspects.

The Rhine-Meuse Water Agency as well as several Conseils Généraux (local political assemblies) of the river basin (Meuse, Meurthe-et-Moselle, Bas-Rhin, Haut-Rhin) already made official their teamwork policy in this field. All partners involved are convinced of its great importance for the years to come.

4. GERMANY

CHANGES IN HYDRO- AND MORPHODYNAMICS DUE TO REOPENING OF SIDE ARMS OF A RIVER

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INTRODUCTION

The River Danube and many of its tributaries were trained and dammed up for hydropower use. Erosion of the untrained river bed downstream between Vienna and the March estuary occurred as a consequence of these training measures (straightening of river course and retention of sediments). The mean annual erosion is assumed to be 10-15 mm/year [Kresser, 1988]. This would have led to no negative influences on the river bed if the planned complete training of the Danube for hydropower would have been carried out. As, however, the remaining large wetland forest areas are considered to be extremely worthy of protection, the creation of a national park ('Nationalpark Donau-Auen') was proposed, which presumes the abandonment of further river barrages construction.

Thus the question of the future retrogression of bed levels is gaining more importance. A too strong bed erosion would result in a lowering of the groundwater level and in a further reduced flooding of the wetland forest areas. Measures for the stabilization of the river bed are therefore indispensable, particularly because after the completion of the river barrage Vienna-Freudenau (under construction) the tendency to erosion downstream will increase rapidly.

On behalf of the 'Nationalparkplanung Donau-Auen', Vienna, the Institute of Hydraulic Structures of the University of Karlsruhe prepared two studies regarding these problems [Anonymous, 1987, 1990]. A possible solution was proposed which provides besides local training measures (scour protection, ford stabilization) an artificial addition of coarse sediments for the degradation of the river bed; the reopening and reconnection of old side arms was integrated as an important ecological component [Anonymous, 1990].

With the reconnection of presently cut off side arms to the main river a part of flood discharges can flow in the wetlands. This results in a reduction of the tractive force and consequently in a reduction of sediment transport in the main river. It had to be verified therefore, which portion of the floods can be diverted and which improvement for the main river can be achieved in this way.

For these investigations two river sections - in the vicinity of Haslau-Wildungsmauer (km 1903+300-1894+800) and in the region of Hainburg (km 1886+000-1882+500) - were selected. Figure 1 and figure 2 show the general situation in both river stretches.

The main topics of the study can be described as follows (more detailed information is included in [Anonymous, 1990]):

- computation of water level longitudinal sections for the present situation (without consideration of the reconnection of side arms for the calibration of the mathematical model and for comparison with the results achieved for the future situation after reconnection)
- computation of discharge distribution between main river and reopened side arms (the reopening can be achieved by lowering the banks of the main river)
- influence of flow diversion into side arms on tractive forces in the main river (changes of critical grain diameters are taken as assessment).

investigated system of side arms

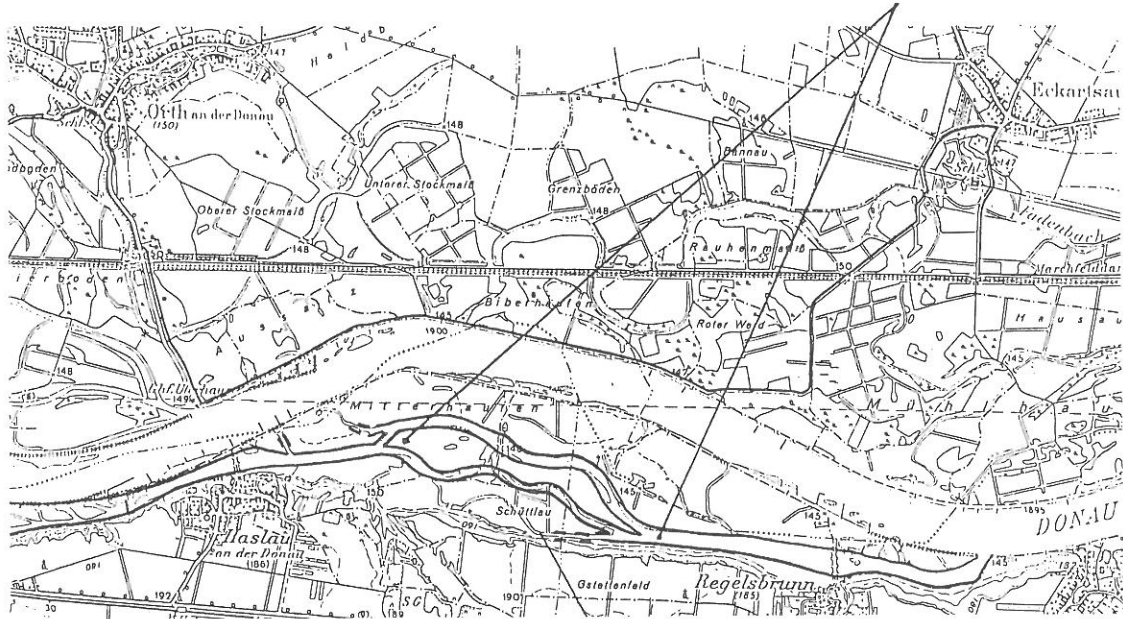


Fig. 1 System of side arms in the vicinity of Haslau-Wildungsmauer

investigated system of side arms

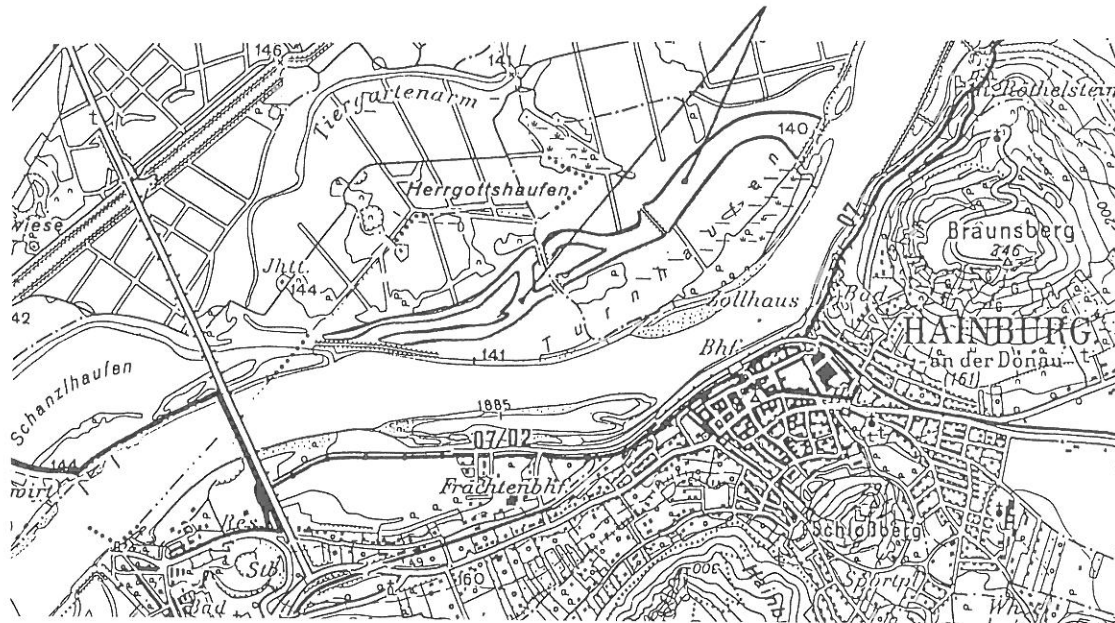


Fig. 2 System of side arms in the floodplains of Stopfenreuth (Hainburg)

MATHEMATICAL MODELLING

The mathematical model used for the computations proved effective for many similar hydraulic problems without bifurcations and branchings. To solve the questions under discussion the existing model was developed and improved to enable the computation of any branched river system. For the execution of the investigations the 'Wasserstraßen-direktion Wien' made available cross sections of the river at distances of 100 m. For calibration of the model water levels registered in 1985 were taken ('KWD 1985'; editor: 'Wasserstraßendirektion Wien').

Concerning the morphological development of the river bed, discharges in the reach of bank-full discharge or more are relevant (bed forming discharges). These discharges were chosen for the judgement of changes of critical grain diameters: in the region of Haslau-Wildungsmauer the flooding of the forest areas begins at about $3800 \text{ m}^3/\text{s}$ and in Hainburg at about $3400 \text{ m}^3/\text{s}$; for comparison: the mean discharge is $1900 \text{ m}^3/\text{s}$ and the discharge of $5200 \text{ m}^3/\text{s}$ corresponds to the maximum navigable water level ('HSW 85').

As the floodplains are strongly overgrown, only a rather small portion of these discharges can flow there (the dense vegetation in combination with the small water depths gives a very high flow resistance). Hence the flow in the forest areas could be neglected in these computations. The results shown in the diagrams are related therefore only to those parts of the total discharge flowing in the river bed or side-arm bed sections.

The side-arm systems shall be reconnected by lowering of bank roads formerly constructed parallel to the embankment of the main river (towing-paths). To improve the rate of discharge of the side arms, existing traverses crossing the side-arm systems and cutting them in single sections, have to be lowered too or completely removed. The actual distribution of discharges between main river and side arms depends then on the amount of lowering of the river bank roads and traverses. Out of a number of possible combinations the following variants were chosen for the investigations (compare fig. 3):

- all traverses and both river bank roads - at the outlet section into the side arms and at the place of reconnection - are lowered by the same amount: 1 m, 2 m or 3 m
- only the river bank roads are lowered whereas the traverses remain unchanged.

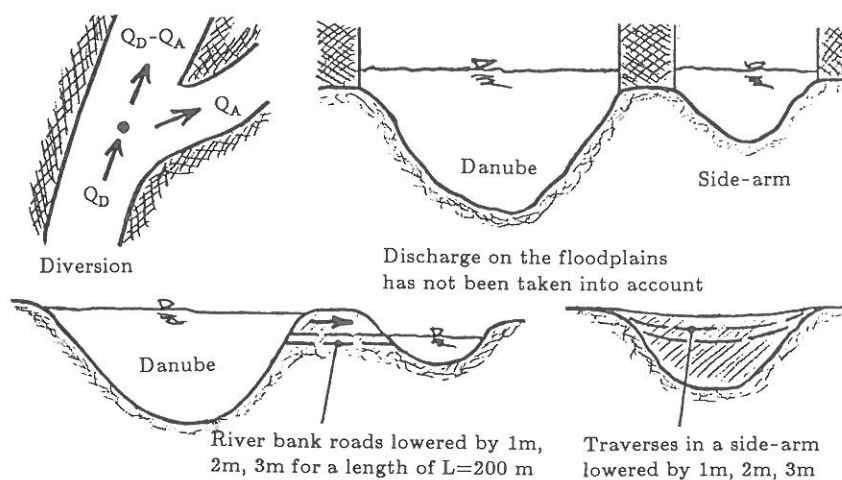


Fig. 3 Assumptions for computation

DISTRIBUTION OF DISCHARGES

The diagrams in fig. 4 show the portion of discharges flowing in the side-arm systems as function of the total discharge in the Danube. With a lowering of all traverses and both river bank roads by 2 m (upper diagrams) - this value seems to be a suitable one - the flow through the side-arm systems starts already at discharges of about 1500 m³/s. At a total discharge of about 4000 m³/s, nearly 600 m³/s (Haslau-Wildungsmauer) and about 400 m³/s (Hainburg) respectively flow through the side arms, whereas at the present situation the diversion of flows starts only at the above-mentioned total discharge.

If only both river bank roads are lowered, the traverses take over the flow control resulting in smaller discharge portions flowing in the side-arm systems. Nevertheless, this measure alone could bring already a remarkable improvement of the present situation (see lower diagrams).

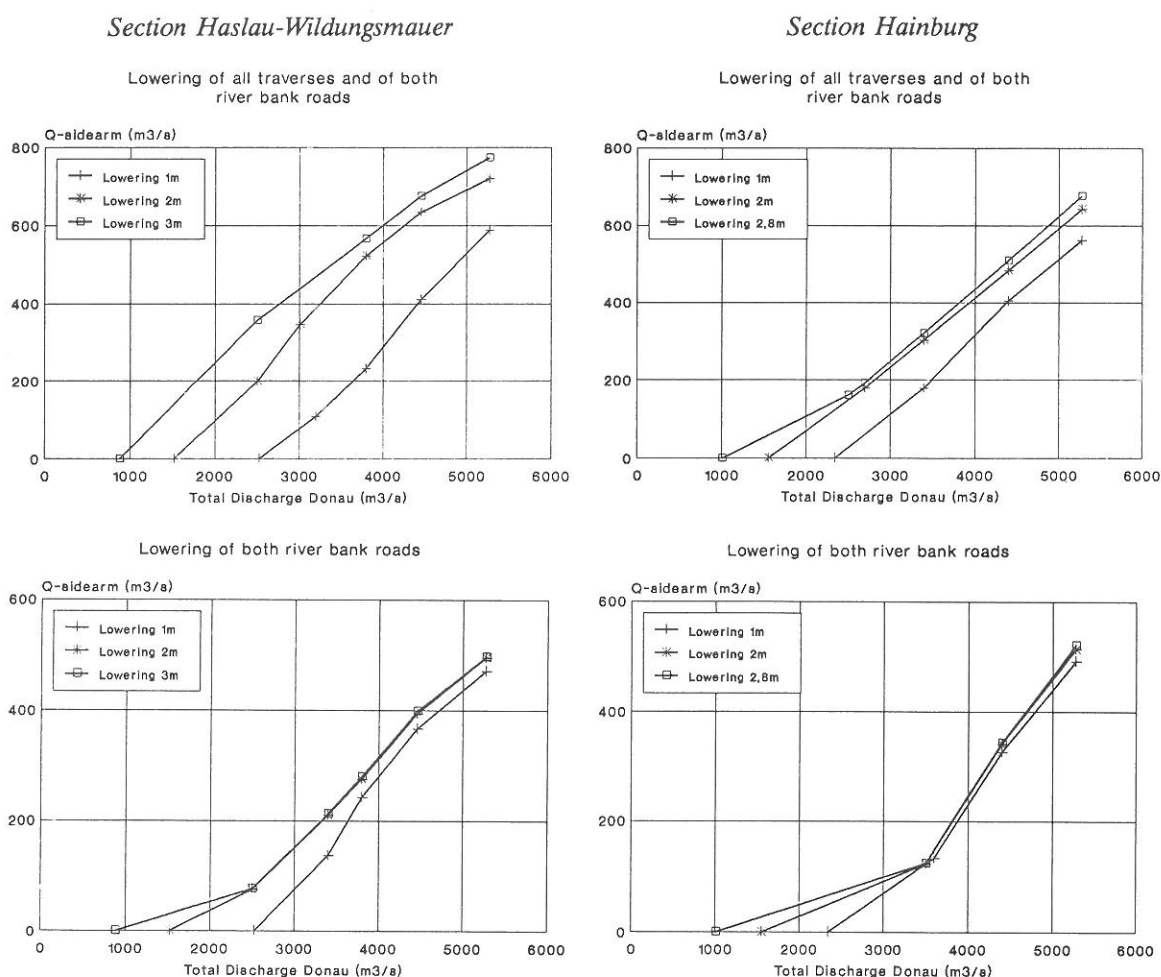


Fig. 4 Discharge in the side-arm systems as a function of the total discharge in the Danube respectively by lowering of the river bank roads and all traverses in the side arms, or river bank roads only

The reduction of the discharge in the Danube due to the diversion results obviously in lower water levels in the main river and brings therefore the envisaged relief for the river bed. In the diagrams in fig. 5 the longitudinal water level sections for the bank-full discharges at the present situation are compared with the situation after reconnection of the side arms to the main river. The influence on the sediment transport capacity of the river and the resulting relief for the river bed will be discussed in the following chapter.

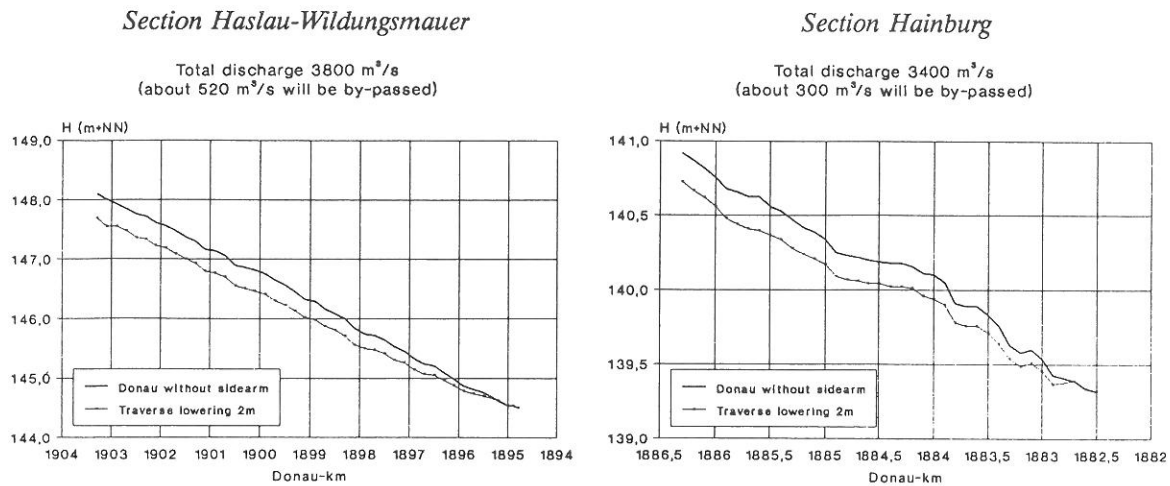


Fig. 5 Change of water level in the river bed of the Danube by lowering of the river bank roads and all traverses in the side-arm systems

RELIEF FOR THE RIVER BED

Each critical grain diameter corresponds to a certain discharge at which the movement of sediment is initiated independently of the actual prevailing grain distribution at the river bottom. The change of critical diameters can therefore be taken for comparison of measures. The computation of these critical diameters was based on the diagram of Shields with an approximation function by Zanke [1982].

Exemplary results for a discharge of 3 800 m³/s (Haslau-Wildungsmauer) and of 3 400 m³/s (Hainburg) are presented in fig. 6: the upper diagrams show the absolute values of critical grain diameters for the lowering of both river bank roads and all traverses in the side-arm systems by 1 m or 2 m respectively; the lower diagrams show the reduction of critical grain diameters due to the diversion of flows (difference of the upper values). The irregular course of the shown lines is explainable by the different geometry of the wetted cross sections: for example the mean flow velocity reaches at a discharge of 3 800 m³/s a value of 2.1 m/s at Danube-km 1897+700, as here the cross section is relatively wide; at profile 1900+500, however, the mean velocity reaches 2.5 m/s resulting in a larger critical grain diameter.

The comparison of results for both river sections reveals the influence of the different morphology of the river bed: at the river section between km 1884+000 and 1882+500 at Hainburg the wetted cross section is narrow and the ford and erosion sections are more distinct than at the river section of Haslau-Wildungsmauer.

For the most stressed section in the Hainburg region the critical diameter is 40 mm at a discharge of 3 400 m³/s compared to 30 mm at Haslau-Wildungsmauer at 3 800 m³/s. The reduction of critical diameters comes to 20% proving that in both river sections a remarkable reduction of tractive forces and of the tendency to erosion would occur if the cut off side arms can be reconnected to the river regime.

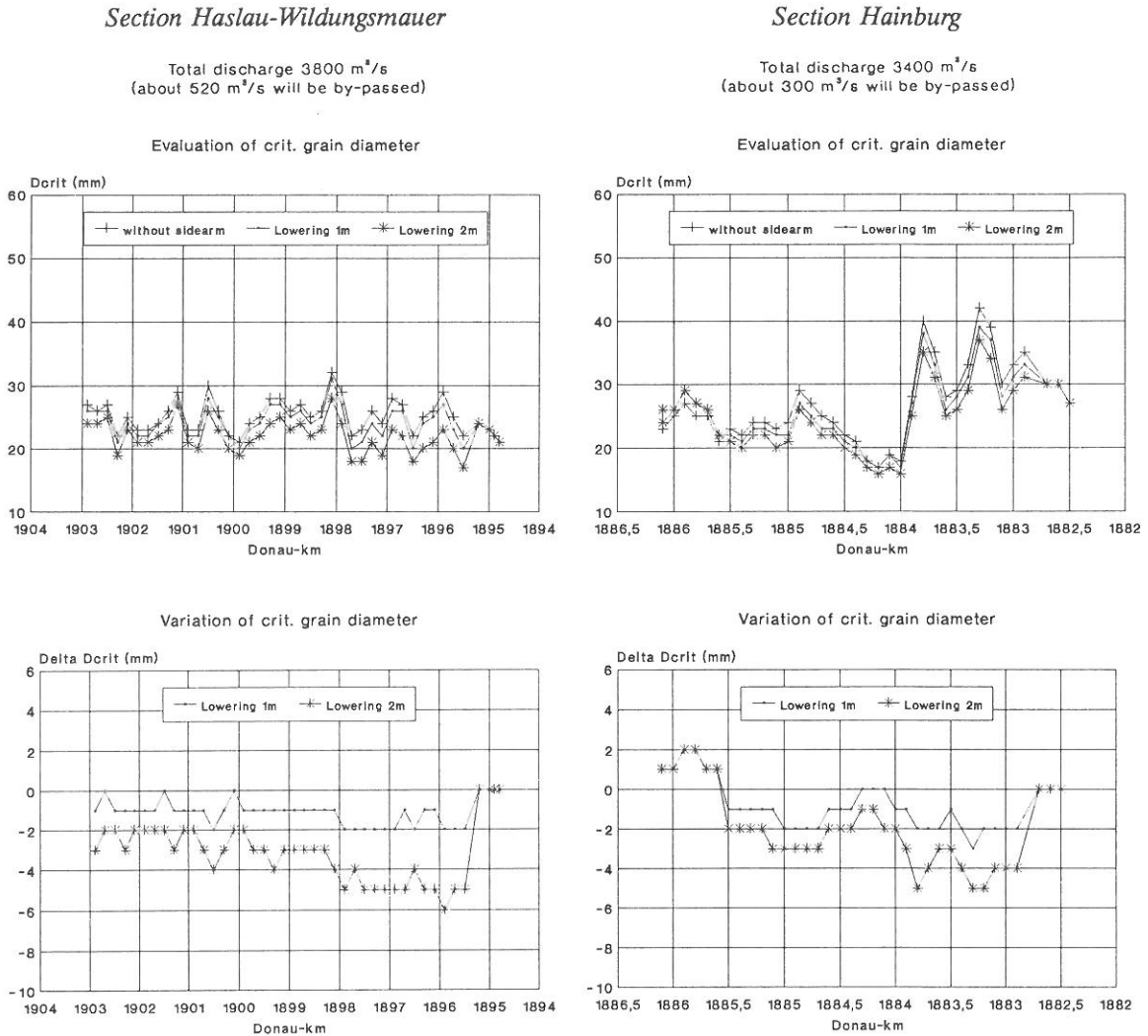


Fig. 6 Influence of the lowering of the river bank roads and all traverses in the side-arm systems on the critical grain diameter

SUMMARY

In the Danube river section east of Vienna natural dynamic flow conditions still prevail: the investigated sections show different characteristics with partly distinct ford and erosion sections. The river bank roads parallel to the main river are presently cutting off the flow into the side arms so that

the former wetland forest areas are rarely flooded. The situation could be improved considerably by reactivating the side-arm systems.

Lowering of river bank roads and traverses would considerably increase the flow dynamics in the floodplains. Since this, however, is the precondition for the preservation of typical wetland forest habitats and therefore for the preservation of the most endangered wetland fauna and flora species, the reconnection and opening of the side arms is strongly recommended.

Depending on the variant chosen, remarkable portions of the flow can be diverted into the side-arm systems at mean high floods already (fig. 4): lowering of all flow hindering structures (river bank roads and all traverses) by about 2 m initiates the diversion already at discharges of about 1500 m³/s. At a discharge of 4000 m³/s nearly 600 m³/s (Haslau-Wildungsmauer) respectively 400 m³/s (Hainburg) are diverted into the side-arm systems whereas at present the diversion starts only at this high discharge (for comparison: the mean discharge corresponds to about 1 900 m³/s).

The diversion of flow results not only in ecological improvements but also in a reduction of the tractive forces in the main river, causing a reduction of sediment transport. The results prove that especially at longer periods of bank-full discharges, which are of great importance for the river bed forming, a remarkable relief for the river bed can be achieved: the critical grain diameter marking the beginning of sediment movement decreases by about 15 to 20 %, therefore, less sediment will be transported and the bed erosion will be reduced.

ACKNOWLEDGEMENT

The study was carried out on behalf of the 'Nationalparkplanung Donau-Auen', Vienna, and financed by the Ministry for Environment, Youth and Family, Vienna, GZ. 01 3131/5-I/1/88.

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SOIL POLLUTION IN FLOODPLAINS OF THE RHINE RIVER IN RHINELAND-PALATINATE

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INTRODUCTION

The Rhine represents a life artery in Western Europe from manifold aspects. In the total course of the Rhine extending over more than 1,000 km five riparian states have an important share in its catchment basin.

It is for more than 150 years that the flow regime of the Upper Rhine has been influenced by man's intervention. In particular the impoundment regulation of the Upper Rhine by dams (from 1955 to 1977) has entailed decisive changes in the flow regime of the Rhine. Naturally existing flood zones have got lost as flood retention spaces. The necessities of flood protection require quick measures for providing flood retention spaces by dike relocation and controlled polders, which should reduce the critical flood situations to the proportion prior to the Upper Rhine regulation (1955).

In this connection, the Federal Land of Rhineland-Palatinate has undertaken the obligation to provide flood retention spaces of altogether 44 million m³ capacity in the next years. In this project consideration will be given both to ecological aspects and actual utilization interests.

Charged by the Land Authorities of Rhineland-Palatinate for Water Management, in 1991 the Institute of Sediment Research at the University of Heidelberg prepared a study, which contains an inventory of persistent harmful substances in soils and plants of the floodplains of the Rhine; this survey is aimed at delimiting possible agricultural utilization hazards, which might result from the realization of flood retention measures [Müller & Yahya, 1991].

POLLUTANTS IN SOILS AND THEIR ASSESSMENT

Soils act as a buffer against different environmental impacts. They filter harmful substances, but they themselves may then become contaminated. If their capacity of binding pollutants is exhausted or the physico-chemical conditions change, there is the possibility of noxious substances getting to the groundwater or to the food chain, implying in this way hazards for man and animals.

Besides a great number of organic contaminants, it is first of all the heavy metals that contribute to soil pollution.

Harmful inorganic and organic substances are released to the Rhine as point-source pollution from industrial and municipal waste water or as diffuse-source pollution from infiltration water, traffic routes, atmosphere and agriculture. In the river water they are dissolved or adsorbed on suspended sediment and transported away over various distances. Pollutants adsorbed on suspended matter are deposited with the fine sedimentary material if there is a decrease in flow velocity. Inundated areas are also subject to sediment deposition, which may restrict, at higher pollutant concentrations, the use of flood zones as grassland and for cultivation of cereals or vegetable gardening.

The above-mentioned study by [Müller & Yahya] presents an estimation concerning the

influence of flood on soil and vegetation pollution in floodplains by heavy metals, halogenated hydrocarbons and polycyclic aromatic hydrocarbons; the antecedent contaminant concentrations are discussed in consideration of actual limit and guide values.

For estimating heavy-metal concentrations in soils the often occurring concentrations according to Kloke [1980] are used as guide values. In addition, the limits of maximum permissible contaminant concentrations as defined in the Sewage Sludge Ordinance of 1982 as well as the limit values given in the draft of Amendment to the Sewage Sludge Ordinance of 1990 (not yet in force) are included in the estimation. This draft proposes a reduction in the hitherto valid limit values for Cd, Cu, Zn and Hg. A further reduction in the limits of maximum permissible heavy-metal concentrations is planned for Cd and Zn in soils with a pH of 5 to 6 and/or in light soils.

In the Federal Republic of Germany the 'Netherlands List' [Anonymous, 1988] is used for estimating soil contaminations by harmful organic substances. According to this, differentiation is made between reference values 'A', test value 'B' and restoration value 'C'. The reference values are not to be understood as normal basic contaminant concentrations, but as guide values for a relatively low pollution degree. If a concentration of 1 mg/kg is reached, stage B is introduced for the sum of polychlorinated biphenyls (PCB) and chlororganic pesticides (COP), which makes closer investigations advisable. From a concentration of 10 mg/kg upwards soil restoration measures are recommended. In order to provide a value of comparison for dioxine and furane, the Federal Office of Health has suggested the use of the so-called toxicity equivalent TE. According to that, soils with dioxine contents up to 5 ng TE/kd can be used for agricultural purposes without reservation. At concentrations between 5 and 40 ng TE/kg a restriction in the use of soils for cultivation is recommended. Soil exchange is proposed for children's playgrounds from 100 ng TE/kg upwards and for settlement areas at concentrations exceeding 1,000 ng TE/kg.

CONTAMINANT CONCENTRATIONS IN FLOODPLAINS OF THE RHINE IN RHINE-LAND-PALATINATE

[Müller & Yahya] have collected a great number of accessible soil analyses so that they have been in a position to present a coherent picture of contaminant concentrations for soils in the flood zones of the Rheno-Palatinate Rhine section along the river course.

The best way of pointing out clearly the situation of soil pollution in the floodplains was to make a comparison between soils inside and outside the flood zone.

HEAVY METALS

For nine larger zones in Rhineland-Palatinate on the whole a great number of analyses of the upper soil have been evaluated. The results have shown that in all soils investigated in the floodplains of the Rhine in Rhineland-Palatinate there are generally slight increases in heavy-metal concentrations in the flood zones as compared with the non-inundated control areas. Exceedances of the limit values defined in the Sewage Sludge Ordinance occurred only in the Boppard region on the Middle Rhine for lead, zinc, cadmium and mercury. This heavy-metal load is supposed to have been caused by the former establishment of smelting works at Braubach. Corresponding to the same trend as for the Rhine sediments, downstream there is an increase in heavy-metal concentrations in soils of the floodplains. This is conditioned by a precipitous extension of the catchment area e.g. downstream from the inflows of larger tributaries to the Rhine. As a result of a decrease in the heavy-metal concentrations in the Rhine water since the 1970s, a relatively low additional contamination of the soils by noxious substances may be reckoned with. In the flood and control

areas the following arithmetical mean values and medians, respectively, have been determined for the heavy-metal concentrations (table 1).

In assessing the heavy-metal situation the median should definitely be considered because this value, in contrast to arithmetical means, is not biased through outliers.

The mean values (arithmetical mean and median) of chromium, copper, nickel and arsenic concentrations are approximately identical in both areas investigated or they are slightly lower in the control areas than in the floodplains. By contrast, the means of lead, zinc and mercury concentrations in the soils of flood zones are considerably higher; this is also due to the fact that the increased zinc and lead concentrations in soils of the Boppard region (former establishment of smelting works) influence the arithmetical mean values to a great extent. The difference between the mercury concentrations may already have been caused by differences in the analysis methods.

Heavy metals	Floodplains		Control areas (seldom flooded or non-flooded)		Limit values of the Sewage Sludge Ordinance (acc. to the Amendment draft)	
	arithmetical mean value	median	arithmetical mean value	median		
Cadmium	0.875	0.650	0.637	0.510	3	(1-1.5)
Mercury	0.511	0.293	0.218	0.126	2	(1)
Nickel	24.3	22.5	20.3	22.3	50	(50)
Copper	35.7	29.0	23.8	19.2	100	(60)
Zinc	529	112	109	72.5	300	(150-200)
Lead	254	49.0	113	40.5	100	(100)
Chromium	37.2	29.5	33.1	27.7	100	(100)
Arsenic	9.1	8.5	9.1	7.9	-	-

Table 1 Mean values of heavy-metal concentrations (mg/kg) in flood and control areas (seldom flooded or non-flooded forelands) in comparison with the limit values defined in the Sewage Sludge Ordinance

ORGANIC POLLUTANTS

For a long time little attention has been paid, save for acute cases of damage, to soil pollution by harmful organic substances. That is the reason why in this respect only few data have been published until now. Owing to their physical properties, toxicity and extensive persistence, some components call for particular interest. It is to this group that e.g. the following substances are reckoned:

- hexachlorobenzene (HCB)
- polychlorinated biphenyls (PCB)
- chloropesticides (DDT, α -, β -, γ -HCH)
- polychlorinated dibenzene-p-dioxine and furane (PCDD/F)

Organic contaminants arrive at the soils of floodplains in the same way as heavy metals, their transport nearly always proceeding in the form of particulates adsorbed on suspended sediments. Within the scope of investigations on heavy-metal concentrations, soils were also tested for their chlorinated hydrocarbon contents, partly at the same sites and sampling points in the Rhine flood zones of Rhineland-Palatinate and in non-inundated areas.

For the sum of PCB, Congenere No. 28, 52, 101, 138, 153 and 180 ('Ballschmitter Congenere') the following mean concentrations were calculated in 1987 and 1988:

1987	Speyer		Ingelheim		Boppard						
	F	T	F	T	F	T					
HCB	Ü	3	4	n.n	n.n	128	157				
	K	2	3	n.n	n.n	n.n	n.n				
DDT	Ü	3	5	54	66	83	103				
	K	34	39	28	34	319	487				
PCB	Ü	2	3	5	7	84	99				
	K	n.n	n.n	n.n	n.n	16	19				

1987	Wörth		Eich		Gaulsheim		Niederwerth		Linz		
	F	T	F	T	F	T	F	T	F	T	
HCB	Ü	12	16	8	11	5	7	5	6	14	16
	K	3	4	n.n	n.n	n.n	n.n	18	23	7	10
DDT	Ü	3	4	14	19	11	16	10	12	29	34
	K	23	30	n.n	n.n	181	207	20	25	11	15
PCB	Ü	10	14	14	20	20	28	14	17	92	94
	K	2	2	2	2	2	2	32	41	24	34

1988											
HCB	Ü	353	488	36	37	4	7	7	8	12	15
	K	2	2	n.n	n.n	n.n	n.n	n.n	n.n	6	8
DDT	Ü	14	19	9	12	10	17	19	23	16	21
	K	28	35	n.n	n.n	132	151	1	1	2	3
PCB	Ü	31	43	18	24	17	30	19	24	47	59
	K	2	2	n.n	n.n	n.n	n.n	2	2	8	11

Ü = flood zones K = control areas
 F = raw mass T = dry mass n.n = non detectable

Table 2 *Arithmetical mean values of concentrations of HCB, DDT and sum of PCB ('Ballschmitter Congenere') in µg/kg for different sites in Rhineland-Palatinate (1987/88)*

In all sites, except the Boppard region, the samples contained less than 100 µg/kg of organochloric pesticides (OCP). At Boppard/Braubach a maximum of 1,407 µg/kg was measured in a non-flooded area.

A remarkable increase in HCB was determined with 488 µg/kg in the flood zone at Wörth in 1988. In the year 1987, however, only 16 µg/kg was measured at the same point. As regards DDT contents, it must be noted that the concentrations partly attain higher values in the control areas than in the floodplains. A similar valuation has proved to apply to PCB. All samples indicated lower concentrations than 100 µg/kg, save for a sample from the flood zone at Boppard/Braubach where a PCB content of 180 µg/kg was detected.

Concerning soil pollution in floodplains of the Rhine by harmful organic substances we generally obtain a non-uniform picture, which is dependent on the specific conditions of the site (releases of sewage sludge, plant protectives, etc. to the soil). For a farther reaching differentiation along the river course no sufficient data were available.

Dioxine and furane are compound classes of two phenyl rings, combined through an oxygen bridge bond. They are generated in special chemical synthesis processes and combustion processes (PCV), particularly in the presence of catalytically active copper, as well as in production processes of the cellulose industry. In order to determine the contamination load by polychlorinated dibenzodioxines and furane in the floodplains of the Rhine, in 1990 and 1991 investigations were carried out by the Land Authorities for Water Management at five sites of the Rheno-Palatinate Rhine section, both in flood zones and seldom-flooded or non-flooded areas respectively. The results of these investigations have shown low toxicity equivalent values (TE) from the southern Land border to Ludwigshafen. All measured values remain under the soil guide value recommended by the Federal Office of Health, given with 5 ng/kg TE. In contrast, the investigations on soils with low-growing fallow land vegetation downstream from the mouth of the Neckar at Ludwigshafen have revealed an exceedance of the guide value in two places at Ibersheim/Hamm with a concentration of 11.4 ng/kg and at Gaulsheim with 16.7 ng/kg. In consideration of these investigation results the Rhine can be supposed to exert an influence on soil pollution by dioxine and furane in fallow areas of the floodplains. In farmland soils considerably lower concentrations could be found (dilution effect due to soil ploughing). Table 3 shows the concentrations determined in five sites in 1990 and 1991, in terms of ng/kg TE.

Site	Low-growing fallow-land vegetation 16.10.90 0 - 10 cm		Farmland 06.03.91 0 - 30 cm	
	Ü	K	Ü	K
Daxlanderau	0.8	1.3	-	-
Neupotz	0.9	0.3	-	-
Ibersheim/Hamm	11.4	1.0	1.1	0.3
Gaulsheim	16.7	0.4	0.7	0.2
Sinzig	4.1	0.5	3.2	0.2

Ü: floodzone K: seldom flooded or non-flooded area

Table 3 Toxicity equivalents of PCDD/F (after BGA, Federal Office of Health) in the areas under investigation, expressed in ng per kg of soil

As regards plants, the transfer of PCDD/F from the soil to vegetation appears to be relatively slight. Investigations in North Rhine-Westphalia have established only low transfer factors between the contaminant concentrations in soils and those in corn and grass. Contaminations through immissions are dominating in the transfer to plants.

CONCLUSIONS

The 'Rhine Action Programme' includes the plan of reducing the discharge of priority substances into the Rhine in an order of magnitude of 50 % by the year 1995 [International Commission for Protection of the Rhine against Pollution, 1989]. For the possible future soil pollution of flood zones of the Rhine the realization of these measures means a decrease - in the same proportion - in the pollutant input to the soils by floods. Considering the present pollution load situation and the improvement to be expected in the pollutant concentrations in the Rhine, even if it may be reckoned with a higher contamination for soils and plants in new flood zones of the Rhine in Rhineland-Palatinate than in seldom-flooded or non-flooded areas, this is likely not to surpass the degree determined in already existing floodplains and to remain under the relevant limit and guide values.

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5. HUNGARY

HYDROBIOLOGICAL SURVEY IN THE GEMENC PROTECTED LANDSCAPE AREA

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INTRODUCTION

The lower section of the Hungarian Danube River has an extended floodplain situated on the right bank between the confluence of the River Sió and the city of Baja. This place, called Gemenc Protected Landscape Area, that has a relatively large forest combined with a side arm system, is one of the last original gallery forests that were usually bound to the big European rivers a few hundred years ago.

At present, neither the wood stock nor the side arm system is in its original state: large scale river training works have been started already in the last century along the whole Hungarian Danube stretch in order to improve the navigability of the river and to reduce the chance of ice-jamming.

In this stretch of the Danube some of the former old branches were in a very late stage of their evolution already (Rezéti-, also called Veránkai-Danube). The regulation of these overdeveloped meanders was evidently urgent together with the stabilization program carried out in the main channel.

However, nowadays disadvantageous side effects of the human activity in this region are recognized. The accelerated siltation of the old, formerly active channels caused a drastic change in the original aquatic habitat pattern. The elements of different communities have also been changed.

A limited number of hydrobiological investigations have been done in the 1960s concerning the southern stretch with the side arm system. The *Rotatoria* and *Crustacea* plankton community was studied by Kol & Varga [1968] and Dudich [1969]. The detailed survey of the *Rotatoria* plankton all along the Hungarian Danube included this section [Kertész 1963, 1967]. Malacological studies of Richnowszky [1963], dealing with different types of water around Baja (including the floodplain), described 34 aquatic mollusc species in this region. Results referring to the recent hydrobiological state are completely lacking.

The emerging need of a complex nature conservation program in the Gemenc Protected Landscape Area, including the restoration of the floodplain ecosystem, required the evaluation of the hydrobiological state of the side arms. The results of the study program are shortly presented in this paper.

MATERIAL AND METHODS

Seasonal chemical (14 variables) and hydrobiological (phyto- and zoo-plankton, macrozoenthon) sampling was carried out during 1991:

- a in two side arms above Baja, in the Rezéti-Danube (RD) (fig. 1); 7 sites
- b the Vén-Danube (VD); 3 sites
- c in the River Danube (D) one site
- d in the connected smaller side and dead arms (only macroinvertebrates were sampled here)

The hydrological conditions at the sampling time were characterized by those water level values that have been measured on the nearest staff gauge in Baja:

16-19 April: 152-180 cm (low water period);

01-04 July: 526-584 cm (flood period);

16-18 Sept.: 133-134 cm (subsequent low water period).

In April, during a low water period, only the lower half section of the Rezéti-Danube and the outlet of the Vén-Danube could be sampled, because the water depth became less than 30 cm along the stretches. In September, when a very strong water level decrease occurred again, even shorter parts of the channels were navigable than in April. In July the sampling period coincided with a very high flood, so that the total length of the two side arms was investigated.

Phytoplankton and filtrated zooplankton samples (through a plankton net with 70 μm mesh size) were collected from the middle part of surface water at each sampled cross section, using Lugol and formaldehyde solution for fixation. Qualitative and quantitative analysis of the plankton samples were carried out with an Opton type Utermöhl-invertoscope using 2 ml volume sedimentation chambers. The population density of planktonic algal taxa was estimated in the form of abundance scores (logarithmic interval scale).

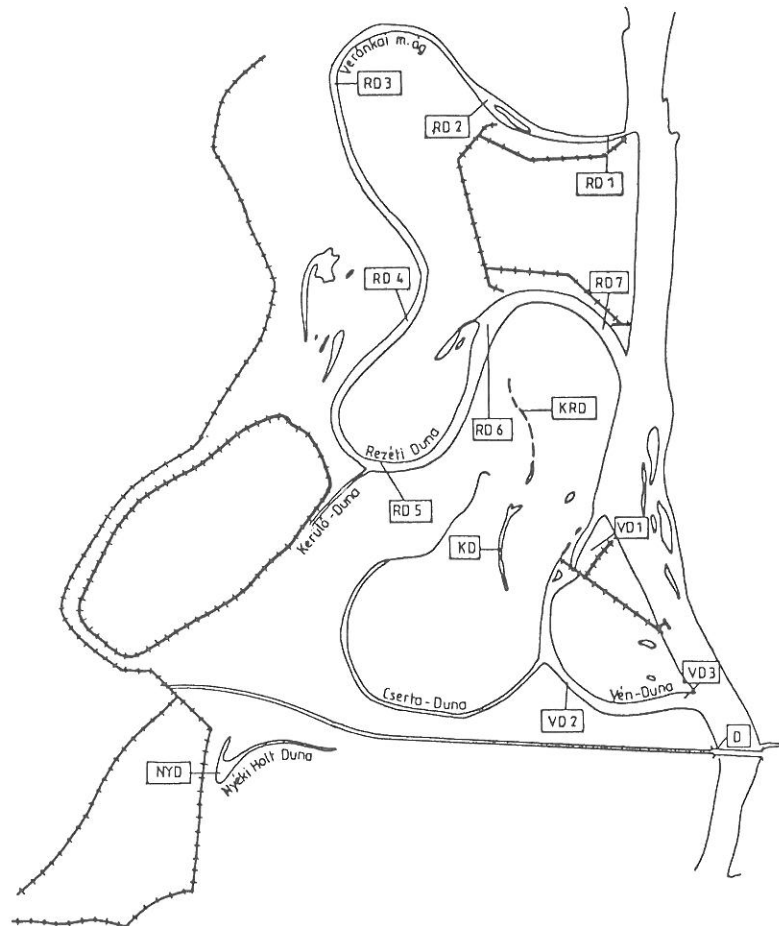


Figure 1 Map of the study area

The macrozoobenthos community was sampled with an Ekman-grab and a hand net (400 mm mesh size). Preliminary cross-section sampling was used for the recognition and the separation of the different habitat types. Three quantitative grasped subsamples were taken at each sampling point having the muddy bottom type habitat in the side arms.

The benthonic communities of some small arms, that have only a very occasional connection with other water branches during high flood periods, were also sampled (see fig. 1: Kis Rezáti-Danube (KRD), Káposztás-Danube (KD), Nyéki Holt-Danube (NYD)). A hand net was applied to collect qualitative samples from the rocky shore line (edge community) near the inlet point of the Rezáti arm, and also in the small water bodies and former active channels.

Multivariate analyses have been used [Podani, 1988] in the study of the spatio-temporal differences on the basis of phytoplankton data and the following environmental variables:

1. pH;
2. conductivity (COND);
3. suspended material (SM);
4. chemical oxygen demand (COD-Mn);
5. chemical oxygen demand (COD-Cr);
6. NH_4 - N;
7. NO_2 - N;
8. NO_3 - N;
9. dissolved organic N (DON);
10. particulate organic N (PON);
11. soluble reactive P (SRP);
12. soluble non-reactive P (SNRP);
13. total particulate P (TPP);
14. algal biomass as chlorophyll-a (CHL-a).

RESULTS

Two basic habitats, the pelagic and the benthic types were identified in the Rezáti- and the Vén-Danube during the preliminary sampling.

The group of chemical variables and the plankton community structure data are good descriptors of the biological water quality in the pelagic habitat for small-scale changes, depending on the seasonal hydrological situation.

Multivariate analysis was carried out with 124 phytoplankton taxa and the chemical variables (fig.2). Important homogeneity over the sites was observed, concerning both types of data, during high flood (July), caused by a considerable discharge through the side arm system. At low water conditions (April and September), unpredictable structural changes in the plankton community (algal blooms etc.) could be observed in the side arms. Their isolation from the main channel and the available nutrient supply is responsible for the eutrophication process, and consequently for water quality problems.

The zooplankton species assemblage can be characterized by *Rotatoria*, *Cladocera* and *Copepoda* species (altogether 88 taxa), most of them being characteristic in eutrophic, slow flowing or stagnant waters. The mass production of Rotifers during spring is a known feature of the Danube and the side arm system. In April the total number of individuals in the lower section of the Rezáti-Danube was 5-10 times higher than in the Danube. The summer flood reduced the

biomass considerably (dilution effect). Nevertheless, 58 species were registered and the Rotifers remained the dominant elements of the zooplankton. Most of the species were not really pelagic, they came probably from the connecting stagnant waters. The permanent discharge from the Danube caused a very similar community structure along the two arms.

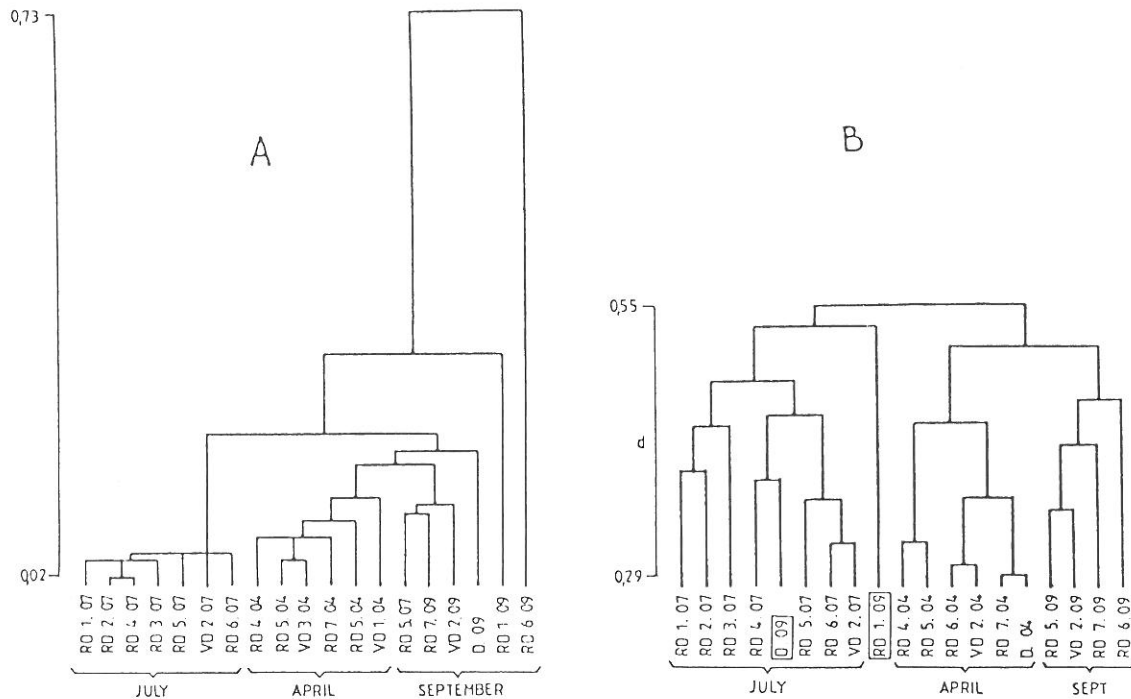


Figure 2 Classification results of (a) chemical and (b) phytoplankton data.

The macrozoobenthon clearly indicated the succession of the river bed (as a result of filling processes). The frequent and considerable change of the water level and the durable dry periods resulted in a stable community only in the deepest, permanently flooded part of the side arms. Due to the highly uniform pattern of the available habitat types, the quantitative sampling method was applicable for the collection of the benthon community in these channels.

The number of individuals of Oligochaets was the highest in the lower sections of both side arms in April, July and September (max. value: 17,000 i/m²), because the downstream stretches have the thickest sediment layer consisting of very fine particles and organic-rich material. This kind of habitat is particularly optimal for worm taxa with highly saprophilic character.

Beside these mud-dwelling worms, only the Chironomids were abundant everywhere in the slow flowing and stagnant water bodies. During the flood period in July, their number became ever higher. At this time of the year the members of the *plumosus* group, feeding on organic detritus, were quite common in many places. Oligochaets were present everywhere in the side arms during the sampling period, especially in the downstream ends of the water courses. Chironomids were dominant only in mid-summer, coinciding with the flood.

The occurrence of other taxa like the larger mussels (*Anodonta anatina*) and snails (*Viviparus acerosus*) was relatively high, but their presence in the grabbed samples only occasional. A high mortality rate was experienced in the downstream end of the Rezéti-Danube (at RD7 point) in September among the mussels. Almost 90 % of the *Anodonta anatina* were dead after the extremely high flood in August: 112 shells of recently died mussels were found in 1 m² with 12 living ones. The reason was most probably the burial effect of the thick layer of the bottom sediment forced to move by the very high discharge rate during almost two weeks.

No stable invertebrate community develops in the temporary waterbodies, due to extremely different hydrological situations (i.e. inundation and subsequent drying up) during the year. The diverse channel system of the area forecasts its importance in nature conservation, but it was not experienced during this study concerning the investigated communities. All of the taxa found in the lenitic (stagnant) stretches are very common in eutrophic waters. The Kis-Rezét and the Nyéki-Danube had a community consisting mostly of *Heteroptera* nymphs (water bugs) and *Ephemeroptera* larvae, indicating the frequent drastic disturbances (i.e. drying out, sudden floods, organic load, oxygen depletion) during the vegetation period.

Low values of dissolved oxygen were measured in the Kis-Rezét arms under the thick *Spirodela polyrhiza* (duck weed) layer during July and September. The occurrence of *Trapa sp.* and *Nuphar luteum* shows the extended filling process both in the Kis-Rezét and the Kposzts-Danube. The Nyéki-Danube was almost completely dry during the summer.

The macroinvertebrate fauna of the River Danube is highly similar to the other Hungarian stretches upstream. The most common taxa are leeches (*Erpobdella* and *Dina sp.*), water snails (*Bithynia tentaculata* and *Lymnaea auricularia*) with mussels (*Dreissena polymorpha* and *Sphaerium comeum*) and Crustaceans, like *Corophium curvispinum* and *Dikerogammarus villosus*. The sampled stony shore line habitats have usually forceful currents that provide rich nutrient supply for the characteristic filter feeder elements of the biotecton: both the zebra mussels and the *Bryozoan* species. Many individuals of a *Hydropsyche* taxa are living here fixing themselves and other taxa (i.e. *Sphaerium comeum* specimen) to the stony surfaces.

CONCLUSIONS

There are different activities and interests along the investigated main and side arms (navigation, flood protection, nature conservation, game hunting, professional fishing, recreation et.). On the basis of the present preliminary ecological study the following conclusions have to be mentioned in order to formulate the needs of the interventions.

The characteristic ecological state of the two side arms is determined by the hydrological circumstances. Abundant inorganic and organic nutrient supply causes eutrophication, especially in the lower sections during the period of small water discharges from the River Danube. Consequently, the secondary production, in terms of zooplankton biomass, is increased as well.

During stagnant water periods, unpredictable changes may occur in the plankton community structure causing water quality problems. Similar deteriorated conditions are known from the side arm system of the Upper Hungarian Danube (Szigetköz), facing similar water discharge problems.

The relatively poor bottom fauna is a good descriptor of the late stage of the filling-up/siltation process. The highly eutrophic taxa, the Oligochaets and the Chironomids (most of them belong to the *plumosus* group) characterize the uniform muddy habitat type along both of the side arms.

As a result of these studies, the following interventions could be mentioned in order to improve the ecological situation along this Danube section:

The river bed has to be renovated in both side arms in order to improve the discharge conditions along the whole length of the channels. The inlet of the Rezéti-Danube is completely blocked because of sedimentation caused by two rock fills, situated in the main arm just above the side channel. Interventions are needed to avoid the siltation occurring already in the main Danube-bed. Large scale dredging and the removal of the rock blockings from the side arms might solve the problem of sediment depositions, especially at the upper half of the Rezéti-Danube.

The increased water transport through the branches might help sedimentation problems in the downstream sections as well. The improved hydrological conditions will probably provide a more diverse pattern of available aquatic habitats for the biota.

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FLOOD BEDS OF KÖRÖS RIVERS

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INTRODUCTION

The most important effects in the forming of the Körös rivers have been flood control and river regulation in the 19th century. Only at the beginning of this century shipping, irrigation and canalization were dealt with. Water quality and ecological functions are emphasized in the middle of the seventies.

Considering that the catchment area is situated in two countries, it would be desirable to establish general water management in the whole area.

KÖRÖS RIVERS

The catchment area of the Körös rivers (figure 1) is 27,537 km², situated on the left bank of Tisza river. 53% of these territories is part of Rumania, 47% is in Hungary. The full length of the rivers is nearly one thousand km, but only 240 km is under the control of the Körös Valley District Water Authority.

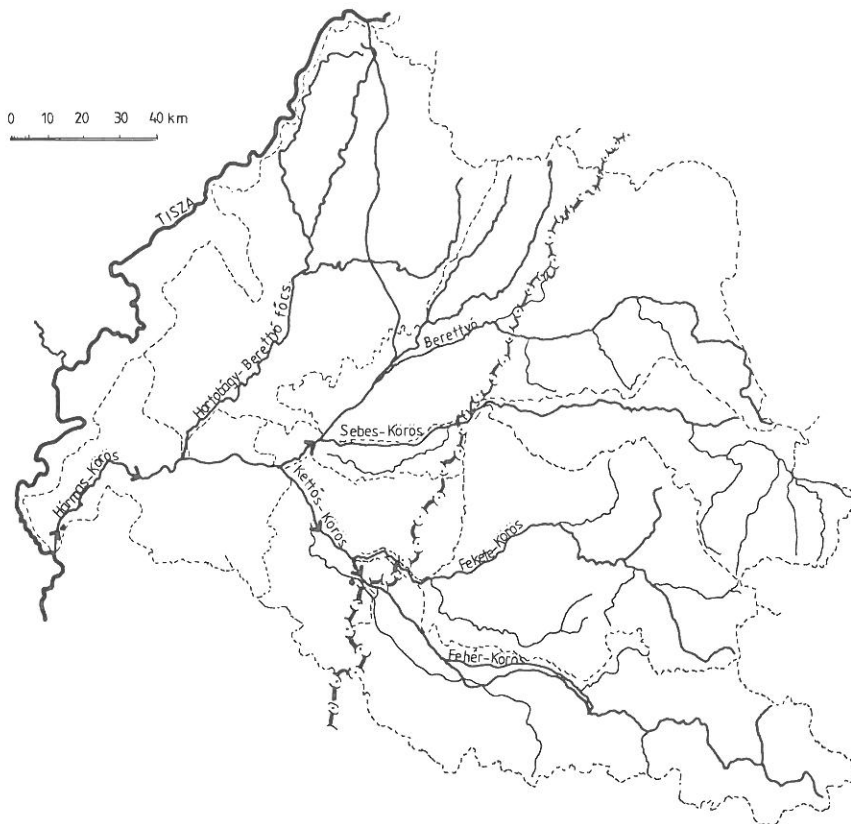


Figure 1 Catchment area of the Körös rivers

Although the Sebes-Körös, Fekete-Körös and Fehér-Körös rivers collect water from mountains like a fan, Hortobágy Berettyó is the main channel of the inland waters. Recipients of these are Kettős-Körös and Hármas-Körös, which has 1021 m³/s as its highest discharge. In the region controlled by the authority (4108 km²) the most important task is *flood control*, because 2821 km² is floodplain, 5-6 meters below flood level. The average yearly precipitation is about 500-540 mm due to the continental climate. That is why 37,100 hectares is *irrigated* from canalized rivers.

The designed *shipping* capacity is 200,000 ton/year. Before the second World War it was 30,000 ton/year, but later, due to special economic development (undeveloped) fully stopped. As for *inland waters*, the Körös rivers are recipients of 1,350 km long canals, with 65 pumping stations, with a capacity of 162 m³/s. *Nature protection* has officially begun in 1979, when the Nature Conservation Area was established for a stretch of 65 km in the flood bed of the Hármas-Körös river, covering an area of 4,500 hectares.

THE PAST

At the end of the Middle Ages an area of 1,440 km² was swamp in Körös Valley. Flood control and river regulation works have begun in the 17th century. More works were carried out between 1808 and 1895, when parallel with the construction of dikes a new bed was made for the Berettyó and partly for the Sebes-Körös and Fehér-Körös rivers. More than hundred curves of rivers were cut off (figure 2) to ensure a shorter passing of floods. The hardest task was to determine design discharges and distances of dikes. The latter caused several problems in the upstream parts of the rivers. Our authority built two needle weirs in 1896 and 1906 to begin canalization. Till 1979, three others were constructed for irrigation and shipping.

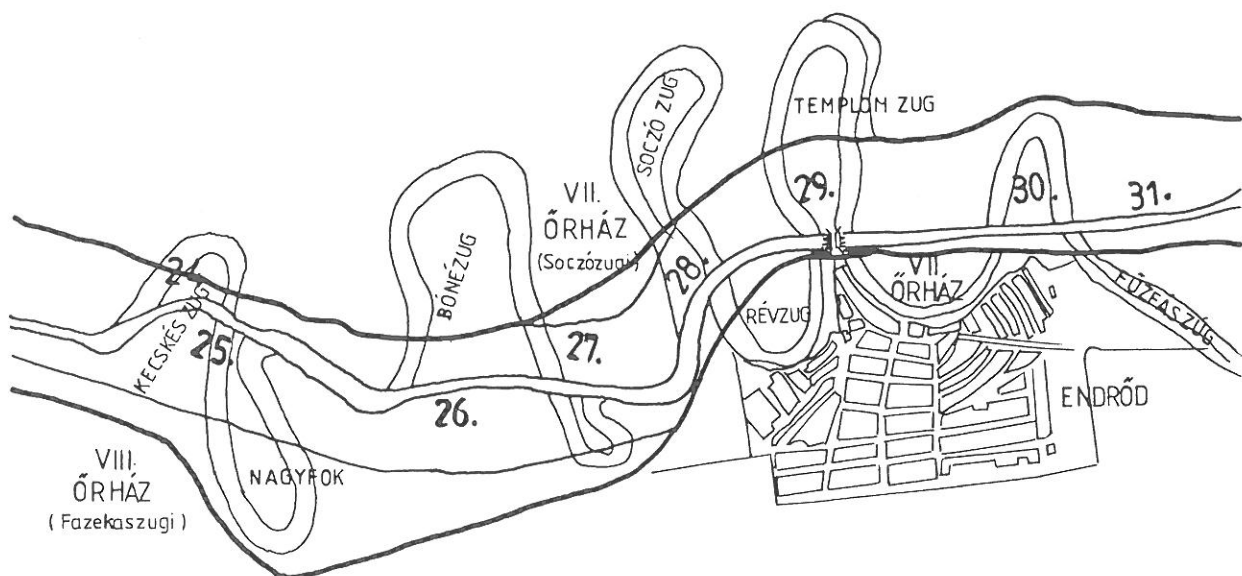


Figure 2 Typical river regulation of the Hármas-Körös river

THE PRESENT

Flood control

The most important task of the flood beds of the Körös rivers is to ensure the passing of floods and ice. That is why they have to be held in a suitable condition. In 1977 we made a plan for the maintenance of flood beds. In this, VITUKI research account No. B.201 and our experiences have been taken into consideration.

The plan contains the following parts of flood beds (figure 3):

- Bank strip: 10 meters at the bank of the river, to ensure control measuring and maintenance of river training structures
- Free strip: upstream, where dikes are too near (80-100 meters) the whole flood bed has to be free, i.e. forests are not permitted; downstream, where the distance of the dikes is 250-550 meters, only a 100-200 meters wide strip must be free. These have been determined by local conditions to improve the passing of ice floods only.
- Middle strip: this part of the flood bed is neutral for the practice of flood control.
- Protecting forest: dikes can perform flood control functions only with protecting forests in broad flood beds. Winds above 10 m/s can make such waves that earth dikes are damaged. The first function is protection against wave action. The second one is to defend the dike against the ice pressure. The third one is to get fasciae for flood fighting and for brushwood structures in river training. Special technical standards have been made for planting (figure 4) and maintenance of these forests. There are 988 hectares of protecting wood in our authority; 80% is willow, 10% is poplar and 10% oak and any other trees.
- A 10 meters protecting strip for the maintenance of dikes.

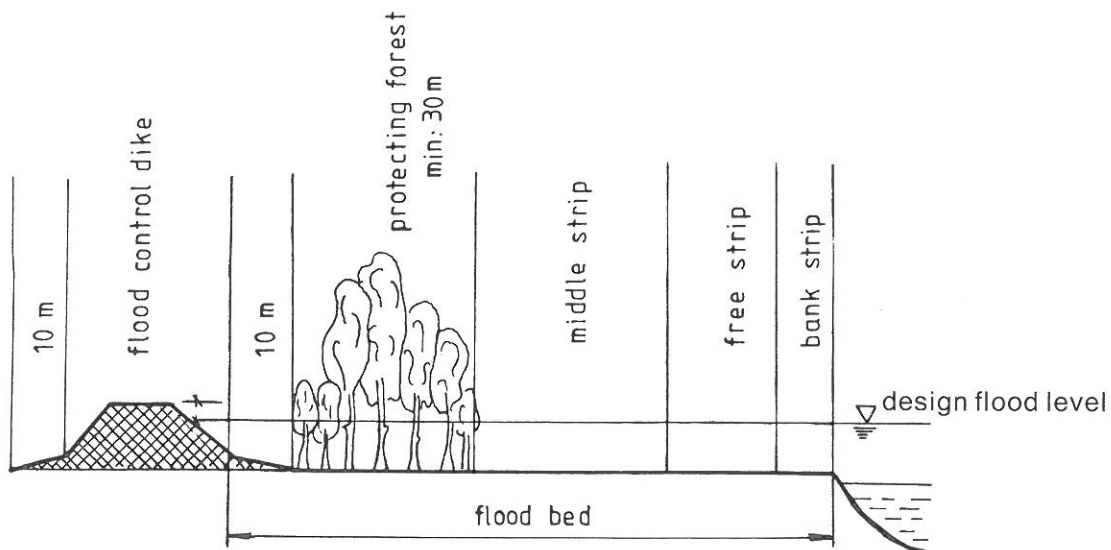


Figure 3 Parts of the flood bed

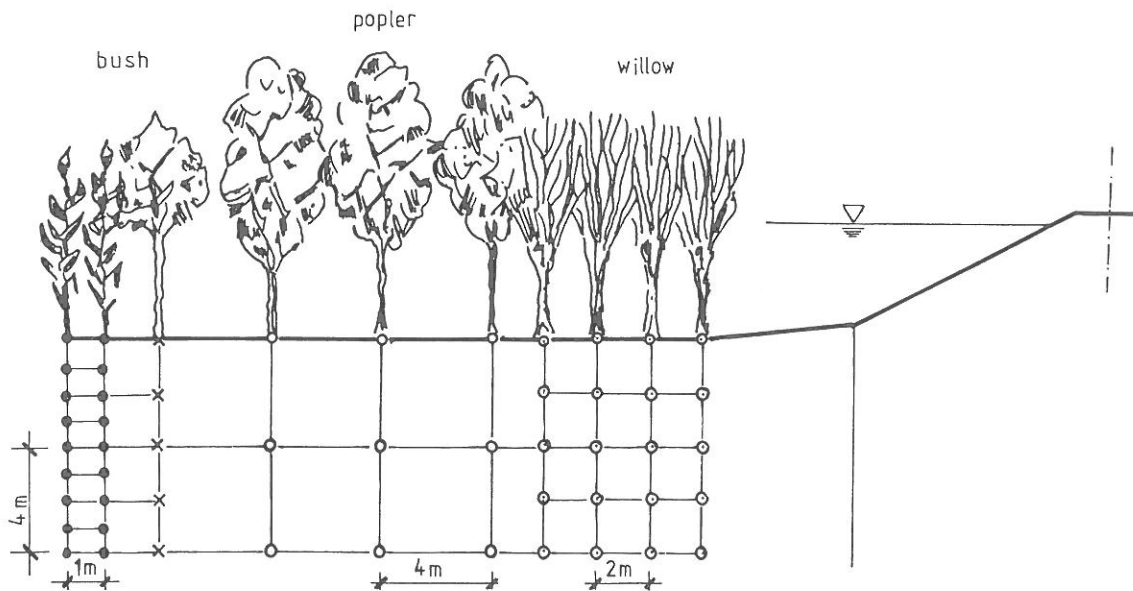


Figure 4 Planting of protecting forest

Nature conservation

With flood control and river training works made mostly in the last century, a secondary floodplain scenery was born, becoming one of the treasures of Hungarian nature conservation. Very important parts of this scenery are the hydraulic structures too. Because of growing agricultural production some vegetations and animals found shelter in the flood bed of rivers. Their favourite site is the old beds of rivers and the borrow pits remaining there from the past. The most important animals are the otter (*Lute*) protected all over Europe, of the birds the little egret (*Egret gazette*), the squalor heron (*Areal rallied*) and longer owl (*Asia flambeaus*).

OPPOSITES

Flood control and river training works helped to save a part of the secondary scenery of the Hungarian Great Plain. Nowadays we have to provide for both - sometimes different - interests. Some of the purposes of hydraulics offend the interests of nature, e.g.:

- A very serious problem is the seepage in the subsurface. A possible solution is a diaphragm wall, or wells on the dry side of dikes, but sometimes the most simple and cheap is to fill borrow pits.
- As was said before, without protecting forests dikes cannot provide flood control functions. For planting or reconstruction of woods and to ensure sufficient growing, borrow pits also have to be filled up.
- The establishment of hydraulic structures and dikes upstream caused higher and higher flood levels downstream. Nowadays only half of the dikes controlled by our authority has a sufficient measure. Strengthening continuously goes on with the sediment of the flood bed. These works also caused damages to the scenery where the material was taken away.

Opposites have to be solved inside our authority, because it is not only an organization for water management, but also a manager of a nature conservation area.

THE OXBOWS ALONG THE DANUBE BETWEEN R.ST. 1515 AND 1465 KM

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INTRODUCTION

Deliberate water management activities have a history of several centuries in Europe, in the course of which the philosophy underlying the objectives underwent repeated changes.

Subsequent industrial and agricultural development have called for stabilized water levels. Mean and low water training of the rivers were accomplished, reservoirs serving a variety of purposes were built and canals, weirs were constructed in the developed areas to control ground-water levels in this period. The projects were intended to serve the purposes of navigation, industrial and agricultural water uses.

Beginning in the mid-sixties of the present century, following the successful accomplishment of the foregoing, in their majority single-purpose projects, the spreading use of fertilizers and pesticides and rapid industrial development have presented growing water quality problems to the water management professionals. Conservation and improvement of the quality of surface- and groundwater have, therefore, become major concerns in water management.

Presently, prompted on the one hand by the varying degrees of success in water pollution control efforts, on the other by the higher priorities attached to ecological resources, water management has become all over the world an increasingly integrated part of overall environmental protection, once it was realized that water is an organic component and even a decisive element of the natural cycles. Consequently, the objectives and impacts of any water management project must now be considered in their interrelations with virtually all other elements of nature. Recognition of these processes which took place in the western parts of Europe 10-15 years ago, but in eastern Europe in recent years only, called for radically new methods, approaches and for engineers inspired by a new philosophy.

The success of flood control efforts in Hungary was demonstrated by the experiences gained over the past century. The flood levees made reliable industrial and agricultural production and created safe living conditions for the population.

Consequent upon the physics of these interferences, the higher flow velocities resulted in the accelerated scouring of the mean-water bed along the trained river reaches and the training projects failed to meet the requirements of navigation. This raised the need of training the mean- and low-water channels as well. Training work in this period concentrated exclusively on the main channel and consisted of the construction of parallel and transverse structures, as well as of implementing additional cuts. These projects have succeeded in creating the uniform navigation channels, but produced additional oxbows in the floodplains which were again treated as valueless water surfaces. The mean and low water training projects have failed to produce consistently definite results, the channel contractions have induced further scouring, especially in the alluvial beds, producing not only obstacles to navigation, but lowering also the groundwater table adversely in the areas flanking the river.

As a final solution to these problems river canalization by the construction of river dams was envisaged which would have met the growing demands of navigation and developed the ancillary power potential.

Following the termination of the major river canalization projects after World War II, adverse experiences were collected along the impoundment and tail-water reaches of the river dams, in particular of the diversion-canal type power stations. The protests of the new and vigorous environmentalist movements have virtually stopped construction work on low-land power projects, leaving at several locations the hitherto continuous training works unfinished.

As a consequence of these evolutions the present generation of engineers has inherited a number of problems awaiting solution which the set of newly arising ecological requirements has raised and the challenge of which must be faced without impairing the results achieved thus far. As an illustrative example of the host of problems, it is proposed to deal here with the state of the abandoned oxbow system situated along the right-hand bank of the lower Hungarian Danube section, where the problems encountered are typical of the possibilities and methods of meeting the changing expectation facing the hydraulic engineer.

HISTORICAL REVIEW OF THE TRAINING EFFORTS

One of the aesthetically most pleasing and perhaps ecologically most valuable parts of the numerous floodplains in Hungary is known as the Gemenc Nature Conservation Area situated on the right-hand bank of the Danube, between River Stations 1515 and 1465 km, from the mouth of the Sio Canal to the embankment of the Baja-Pörböly railway line.

Besides other values, this area is a game reserve of European fame and provides a unique habitat for several species of wild animals.

Prior to the flood-control and reclamation project of the 19th century, the right-hand floodplains of the Danube formed a vast, coherent marshland.

The ambitious river training, flood control and drainage project started then in the interest of creating flood safety was completed by the end of the century (fig. 1). The works included 15 cuts over the Danube section between Fajsz and Mohacs, which shortened the bed by 96 km and created a round 30 km long oxbow system along the 46 km long main channel.

Under this river training and flood control project the mouth of the Sio Canal through which the excess water from Lake Balaton is discharged to the Danube, was relocated some 30 km upstream. Minor changes to the landscape were subsequently caused by the construction of the flood levees and the tailgate and lock on the Sio Canal.

The project has created adequate flood safety to the reclaimed areas and satisfactory navigation conditions in the main channel. In this respect the hydraulic engineering measures were unquestionably successful, since these corresponded to the expectations of those times and contributed to the economic development of the area.

On the other hand, in keeping with the river training principles prevailing then, water supply to the connecting oxbows was limited, or discontinued entirely which caused eventually fundamental changes in the ecological conditions.

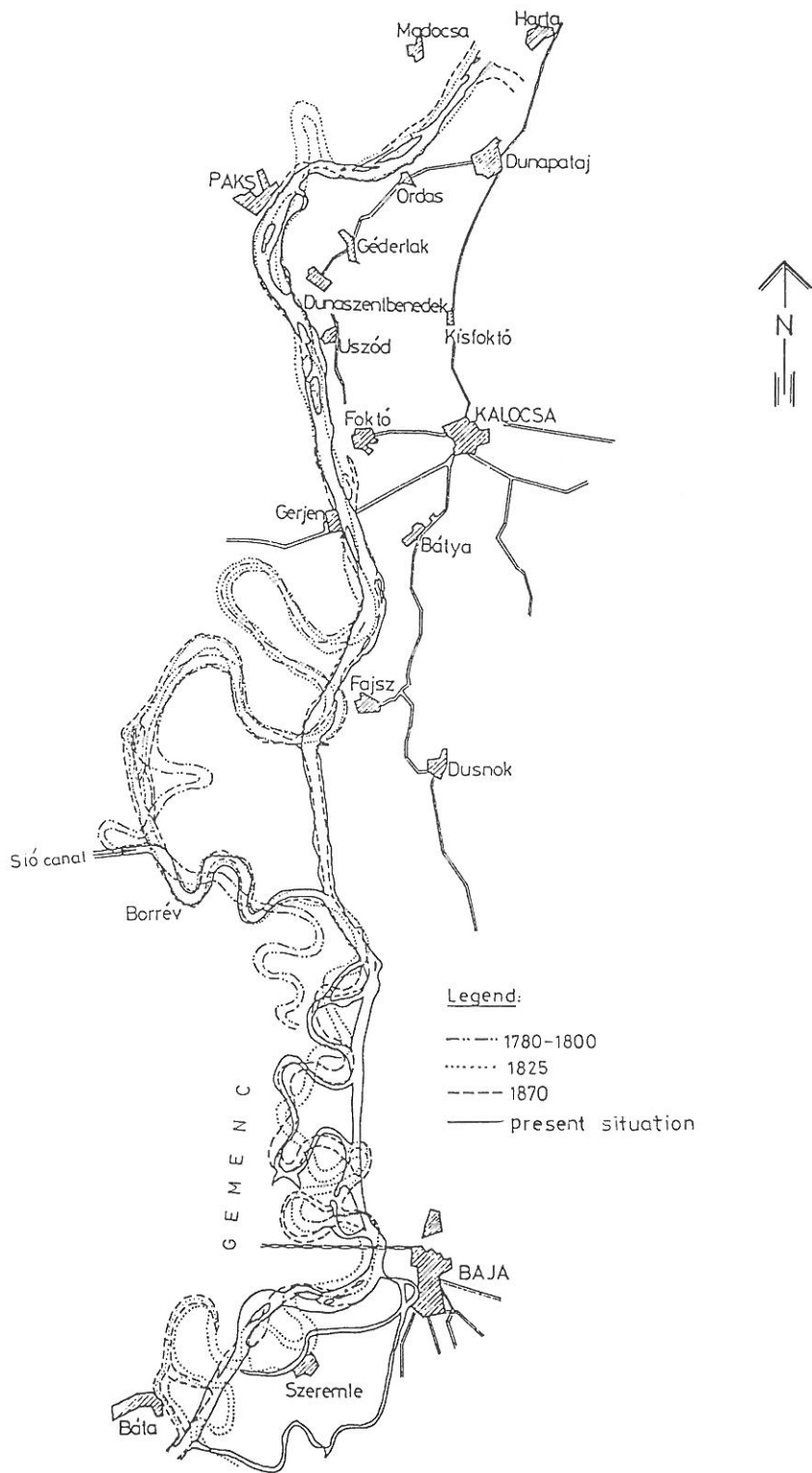


Fig. 1 River training of the XIXth century

THE PRESENT SITUATION OF THE WATER SYSTEM IN THE GEMENC AREA

The oxbows in the Gemenc floodplains are silted up, receive water irregularly, the water surfaces shrink, the connecting areas display signs of drying and ecological changes.

The area considered (fig. 2) is interwoven by 15 ancient stream beds which represent five different water types, viz.

- the laterals of the Danube with flowing water at river stages higher than the mean,
- the periodically dry laterals which carry water at times of minor floods only,
- dry laterals which are filled only on occasions when the entire floodplain is inundated,
- ancient stream beds holding water permanently, i.e., undrained areas with a permanent water cover, and
- extensively silted, severed ancient stream beds in which a temporary water surface remains after floods only.

The forests which cover more than 70 % of the Gemenc area are intensively exploited. The rest consists of natural willows and shrubs. Natural, or close-to-natural hardwoods form fringe forests over a very small, less than 5 % part of the area only.

The area is, however, strongly endangered for the following reasons:

- Forestry management is conducted with growing intensity. The ancient forests are cut, while modern forestry practices leave no chance for the close-to-natural older forests to retain their structural and species diversity.
- The primary aim of river training being to maintain sufficient flow in the main channel, little concern is given to divert water to the laterals, and in the silted-up floodplain there is hardly any communication between the ancient beds. The river plays thus a decreasingly important role in shaping the landscape and in sustaining the natural resources.
- The game population has reached excessive levels causing damages especially to the young shrubs and trees. Longer inundations may enhance the grazing damage.
- Uncontrolled recreation has invaded the area, as a result of which unauthorized lodges were built in the most valuable locations.

DEVELOPMENT OBJECTIVES

Development should be directed, besides restoration objectives, towards meeting the variety of demands for water uses, with due regard to the possibilities and natural conditions.

The primary aim of the measures contemplated is to prevent further deterioration and decay of the Gemenc fringe forests while addressing the complex demands in the development of the entire area.

To the north of the Sio Canal, in the Fadd-Dombori and Tolna area, the demands of the existing water uses, viz. recreation, fish farming and irrigation, should be satisfied while providing the necessary protection to the bank filtered water resources as potential future sources of domestic water supply. The measures envisaged (dredging, sewerage, etc.) are expected to improve the quality of surface waters and to enhance recreation opportunities in the area.



Fig. 2 Plan view of the Gemenc oxbows

To the south, around the town of Baja, on the other side of the main Danube, the Sugovica Danube arm should be developed primarily for recreation purposes which is expected to have beneficial effects on tourism in the region, just as the development on the northern side.

These measures are expected to keep any major human impacts away from the Gemenc nature conservation area.

Strict measures are considered necessary to prevent uncontrolled mass tourism from invading the Gemenc flood plains. Any tourism must be confined to organized and limited forms. Besides prohibiting new building activities, the existing unauthorized buildings and structures will have to be demolished and removed.

Continuous water supply to the Gemenc oxbows is expected to revitalize the presently drying areas, to restore the former ecological balance, to preserve and to sustain the typical wildlife of the area and to reestablish the phreatic marsh vegetation. In this way we hope to save one of the outstanding biotopes of Europe as a wildlife habitat.

HYDRAULIC RESISTANCE OF THE FLOODPLAIN VEGETATION EFFECTS OF DEFORESTATION/REFORESTATION

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INTRODUCTION

The flood carrying capacity of any river is characterized by the dimensions of both the main channel and of the floodplain. However, the surface flow on the terrain is also influenced by the type, distribution of and/or the natural/artificial changes in the vegetation. More practical problems may arise on river sections confined by flood protecting dykes.

Some results of estimating the hydraulic roughness parameters and the effects of partial deforestation of the floodplain are presented.

HYDRAULIC ROUGHNESS OF THE FLOODPLAIN

Hydraulic resistance is a measure of flow conditions and a useful tool in assessing the effects of human interventions in the river system. To compute any kind of the known roughness/smoothness parameters, the data needed are

- i) the geometry, i.e. the cross sections of the channel and the floodplain between the dykes or the perimeters of the valley
- ii) the distribution of a given flood flowing in the main channel and on the terrain and
- iii) the water surface slope under the same conditions.

Such kinds of data sets measured in the field are real rarities. Some examples from the Tisza River in Hungary are discussed below.

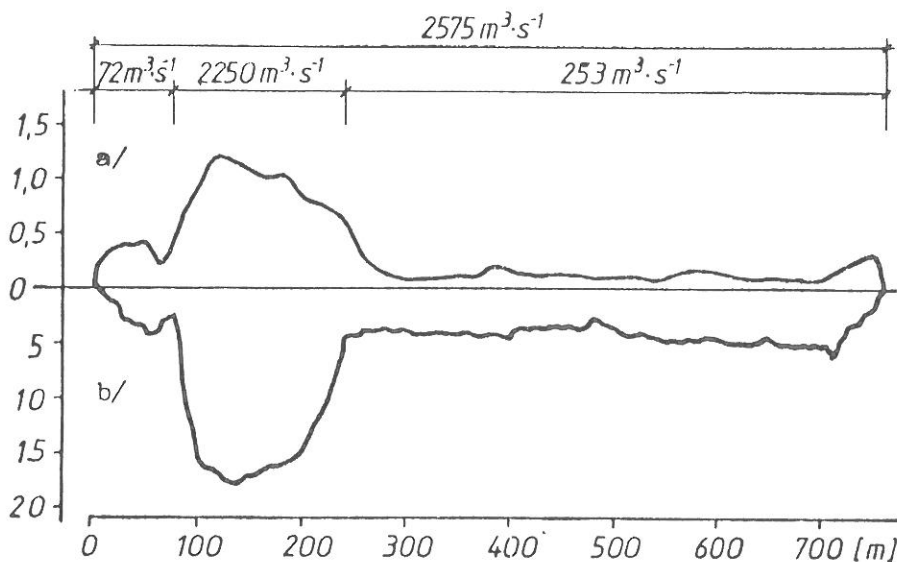


Figure 1 Channel and floodplain of the Tisza River at Mindszent with specific velocities in $m \cdot s^{-1}$ (a), water depths in m (b) and distribution of the flood of $2575 m^3/s$ in June 1970

On the Lower Tisza River at the village of Mindszent during the floods of June 1970 and of July 1974 a number of discharge measurements including the floodplain flow have been performed. The section is confined by flood protecting dykes. The floodplain on the left-hand side of the channel is about 50 m in width, while on the right hand side it is about 550 m. The main channel width is 160 m (figure 1).

The floodplain is forested to about 50 %, the remaining part being mostly under agricultural use and covered also by some bush. The measuring path perpendicular to the channel was cleared of vegetation.

The specific and combined discharges have been calculated by the area-velocity method (figure 1). Unfortunately, the water surface slopes governing the given flows have not been measured. Therefore, average values along a longer section between the neighbouring gauging stations have been used. Thereafter, 'smoothness-values' k of *Strickler-Manning* have been calculated for both the main channel and the combined floodplain. The statistical summary of the results is as follows.

Year	No. of measurements	Flow m^3/s on the floodplain	Hydr. radius m	k $m^{1/3} s^{-1}$	
				Mean	St. Dev.
1970	26	200-300	3-4	7,62	0,77
1974	13	100-200	2-3	9,61	1,70

Contrary to expectations, the mean values are inversely related to both the water depth and the discharge. In other words, flow conditions nearer to the terrain seemed to be smoother than in the higher regions. The only practical explanation could be that the resistance of the tree trunks is smaller than that in the higher zone of the leaves. There is no need to emphasize the hypothetical value of these considerations.

The calculated values of $k = 6-12$ are in good agreement with the estimations used for forested floodplains. It is also a remarkable result, that under the given conditions a reasonably wide floodplain carried only one eighth of the flood (figure 1).

EFFECTS OF PARTIAL DEFORESTATION OF THE FLOODPLAIN

The ice jams of the winter flood in 1956 caused severe damages, levee failures, along the Lower Danube in Hungary. Measures have been prepared to improve the flood carrying capacity of the terrain along the main channel. For this reason, it was proposed to cut the trees/forest from some strips of the floodplain. Investigations have been carried out to assess the possible effects on the flood levels.

The various conditions of the vegetation on the floodplain have been characterized by values of $k = 10-25$. The former means heavily forested conditions and the latter is for clear meadows along the channel.

The calculated changes in the flood levels have been determined by the dimensions both of the river and of the floodplain. The results were highly influenced by the distribution of the flow between the channel and the floodplain.

Some examples of the calculated flood level decreases are shown in figure 2.

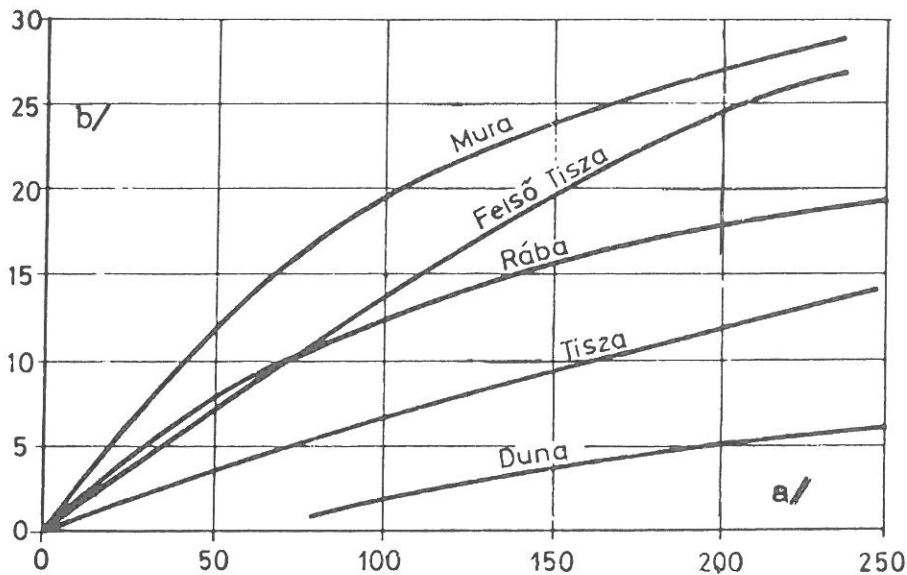


Figure 2 Deforestation of the floodplains in various widths (a) along both banks of Hungarian Rivers and the decrease of the design flood levels in cm (b)

In all the practical cases the effect of partial deforestation remained above the lower limit of 5% confidence interval of the design flood level of 99% probability.

As an inverse method and/or statement it could also be used in cases of reforestation of floodplains. It must be born in mind that the slight level decreases discussed above are results of partial deforestation of some 2 x 100-200 m wide strips on floodplains with significant dimensions. Reforestation in the full width would cause higher flood level increase.

SUMMARY

Based on a number of flood measurements in the field, for a forested floodplain, values of the hydraulic smoothness coefficient k after *Strickler-Manning* have been recalculated. Results verified the generally estimated values of $k = 6-12$.

Calculations proved no significant effects of the partial deforestation of wide floodplains on the decrease of the design flood levels. The method presented can also be used in case of reforestation.

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SZIGETKÖZ

(AN INSULAR WORLD BETWEEN THE BRANCHES OF THE DANUBE)

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INTRODUCTION

The region 'Kisalföld', the plain in Northwestern Hungary, was covered by the Pannonian enclosed sea during the late Tertiary era. By the end of the period the sea, however, had become shallow, choked up. This time the rivers arriving from the Alps and the Carpathians, as the Danube, too, having lost their declivity, continued to fill in the basin sinking relatively fast in the early Quaternary period, with their alluvial, sandy-gravelly deposit. Their courses deviated from those of today; for example, the Danube broken through the Carpathians at Bruck on the Leitha continued its course towards the south 2 million years ago.

Later, because of the continuous alluvium of the basin, the course of the Danube changed and, about 1 million years ago, it intruded into the basin at the 'Dévény' gate, establishing its bed towards the east. The river system of the region began to take shape in this period. Shallows were formed and, after vegetation had settled on them, they were transformed into islands that cut the river bed into branches. The course alterations of river beds were also influenced by collapsed trees, undermined and caved-in banks as well floods. In this way the insular world surrounded northwards by 'the Öreg (old) Danube' and southwards by 'Moson-Danube' had taken shape.

SUBSTANCES

'Szigetköz' is a longish, irregularly shaped area 52 km in length and 6-8 km in width. Its hydrological state is essentially determined by the Danube and its tributaries. It is one of the areas being the most ample in superficial and underground waters. The population settled here has always been fighting against floods. With agriculture becoming more and more intensive overflows could not be allowed any more. Therefore the development of the organic flood-protection embankment line in 'Szigetköz' started, mainly on the recent course, in 1896. This divided 'Szigetköz' into protected and floodplain sides. The insular world endured in the floodplain while the protected side was free from floods. This, however, brought only a partial resolution, as there is in the area sandy gravel with a high water permeability under the overlying layer. Thus the floods have always been followed by inland waters. To drain those, ditches for conducting the inland waters were shortly developed.

As the Danube flows in a suspended bed at this sector, the underground water in the very deep gravel layer is fed also at low water level, therefore the existing outward water level has a determining function in the state of the groundwater. In this space, the outward water level is not only influenced by the existing flow rate but also by the rolled alluvium. Till the 60s only 50-60,000 m³ alluvium of the 350-400,000 m³ rolled here yearly left 'Szigetköz'. This enormous quantity of alluvium having been deposited earlier on the alluvial cone was only able to fill in the floodplain since the construction of the flood-protection embankments. Therefore the standard water levels increased significantly between the years 1901 and 1954. Naturally, not only the main river bed was filled in but also the branches. Between the years 1903 and 1962, the 'Upper Szigetköz' branch system lost over 60% of its bed surface while the increase of the bed surface in the 'Lower-Szigetköz' was only 1.5-2%. This high degree of filling-up indicates that the floodplain has been filled

up considerably not only by rolled alluvium but also by floating matter.

Three main problems resulted from the rise and fill-up of the river bed:

- the question of flood safety related to the standard high-water level;
- the quantitative increase of the seepage water on the protected side because of the water levels becoming higher and higher;
- the number of navigable days being reduced steadily because of the forming of shallows.

Therefore the river regulations for low and mean water levels were started in 1966 basically to improve the shipping conditions. The interventions performed in the course of these operations formed the recent pattern of the branch system in the 'Szigetköz' floodplain. The targets of their operation carried out to establish an organic main river bed were as follows:

- to reduce to a minimum the water loss of the main river bed by means of establishing a uniform bank line and closing the upper ends of the branches;
- to increase the stability of the uniform bank line by closing the branches in series;
- to increase the alluvium moving force by narrowing the mean water river bed with cross dams to enhance the forwarding of the major part of the arriving alluvium.

Shortly after the construction operations had begun, however, a basic change occurred in the quantity of the rolled alluvium. Because of the operation of hydroelectric power plants along the Upper Danube, and the extensive gravel exploitation on the Danube sector downstream of Bratislava, the quantity of alluvium coming to Hungary has been insignificant since the late 60s. Before that, the transportation of rolling alluvium took up much of the energy the Danube derives from the gradient of 30-40 cm/km which is characteristic of this Danube sector extending to 'Snap'. Because rolled alluvium was lacking, the released energy of the Danube is occupied by the demolition of silver-bed ground, which sank 149 cm at stream kilometre 1865 between 1974 and 1990. Though this value lessens towards 'Lower-Szigetköz', recently the entire river bed sector is sinking.

The side overfall weirs made at the time of the mean and low water regulations provided a direct connection to the main bed only at the time of mean and high water in the late 60s. Due to the continuous river bed deepening, this period shortens gradually; the water overflows the weirs only at higher and higher levels, which is more and more rarely. Just then the floodplain takes part in discharging high floods. Then the quantity of floated alluvium is significantly higher than in the period of low and medium water, and as the major part is deposited in the quiet floodplain, this will be filled up continuously. The 'Szigetköz' sector filling up evenly before has altered. While the characteristic low water levels are lowering continuously, the typical mean and high water levels are increasing gradually. It is illustrated well by comparing two sets of high-water figures from the water gauge at stream kilometre 1825.49:

1954	10.500 m ³ /s	692 cm
1991	9.000 m ³ /s	722 cm

These data refer to the intensive alluvial deposition in the floodplain. On the other hand, this water gauge showed only 172 cm 3 months after the flood of 1991. Such a fluctuation - 534 cm - of the maximum-minimum water level has never been typical of the 'Szigetköz'. The organisms living here in biocoenosis accommodated themselves to a considerably lower fluctuation of the water level. They cannot endure it. Altering the river system in this way causes severe problems. In the major part of the year there is no water in the floodplain, due to the decrease of the low water levels, or there is very little and its quality is so poor, because of the missing water movement, that

it is inadequate to preserve the typical biocoenoses.

This is one of the reasons why all the natural biocoenoses come to be forced back. The former fish abundance exists only in fragments; the former indigenous plant species have been forced back into a small territory; the members of the avifauna and other animal fauna can find the conditions necessary for their survival only in smaller and smaller places.

The groundwater levels are decreasing gradually on the protected side. The area had struggled with the problem of soggy till the end of the 60s, but today drought means anxiety. The former ditches for draining the inland water should function as irrigation canals but, due to the river bed sinking, the periods in which water cannot be supplied are becoming longer and longer. Thus the valuable nature conservation areas of the protected side are in danger too. The nature conservation values of 'Szigetköz' have been perishing day after day.

CONCLUSIONS

If the unfavourable developments are impossible to stop, it is to be feared that after a few decades, instead of the wonderful, rough water world, a floodplain covered by vegetation, and on the protected side arid marsh meadows and alder marshes will only be found. A solution of the water supply problems is required as soon as possible to stop this process. For the sake of that, the following tasks have to be carried out urgently:

- Collecting the data related to the nature of 'Szigetköz', their elaboration and evaluation in many respects;
- taking into account the requirements of the desired biosphere, formulating the condition system
- getting to know the condition system, working out a water-supply procedure suitable for the interests of the environment protection and nature conservation, too.

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6. THE NETHERLANDS

CRITERIA FOR ECOLOGICAL REHABILITATION

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INTRODUCTION

In 1990 a working group of governmental and provincial ecologists designed a target landscape with an optimal, sustainable, ecological structure for the region of the large rivers in the Netherlands.

Why?

This region is one of the Netherlands' most complicated areas to plan. Therefore the Fourth Note on Planning in the Netherlands had to be worked out. At the request of the State Planning Office the working group dealt with the 'nature' part. With the help of this work government and provinces selected the most promising floodplains. In some of them government and non-governmental organizations already started ecological rehabilitation.

I will discuss the most important features of that target landscape.

DEFINITIONS

First I will define the concepts 'nature' and 'optimal, sustainable, ecological structure'.

Nature is the whole of abiotic matter, plants and animals and their communities as well as their life conditions with or without the influence of man.

Optimal, sustainable, ecological structure is that nature that can be developed and preserved with the effort of government and non-governmental organizations. That means that in the future nature conservation and river management will limit the expansion of shipping and farming. Excavations will be made in favour of nature and river management.

TARGET LANDSCAPE

Starting with these definitions we designed the following target landscape:

In general and compared with other ecosystems, the river ecosystem is a rough, robust, highly dynamic and productive system populated by opportunists such as terns, gulls, ducks, geese and waders, and die-hards like rats, musk-rats, mice, as well as the bad weeds: thistles, sorrels and twitch. But there are also survival specialists which are adapted to the disastrous world of sudden floods and long-lasting droughts such as snails and amphibian plants. During floods the eggs of birds float away and mammals try to escape or drown. During droughts flocks of dying fish are lying in the drying depressions of the floodplains, while troops of herons are feeding on them. Sudden mosquito plagues show up and liver fluke is threatening.

Unpredictability and instability are the slogans.

Our target landscape has in no way the lovely Arcadian image of pastoral scenery of which

some of us are possibly thinking.

Nevertheless there are places of rest. The high, dry banks made up of sand, rich in chalk, rich in flowering plant species, low in biomass production. Where meadows, thorn shrubs and alluvial hardwood are at home. The river will not flood these banks for more than ten days in the growing season. They are scarce and vulnerable. They serve as a refuge at times of high water, they are the favourite places of horses and cattle and on some of them terns and gulls have their breeding colonies. The functions just mentioned cannot always be combined.

Along the rivers some sand dunes occur. They form another highly qualified ecotope. Though this ecotope is very dynamic, the richness in species is very high as well. We find here mostly short-living plants. It indicates a short-lasting stage in the development of the bank.

In the steep verges of banks sand-martins and kingfishers are breeding.

Each floodplain bounded by a meander has a gradient from upstream and a high botanical diversity, to downstream and a low botanical diversity. This gradient is caused by a gradient from upstream and coarse-grained sand, to downstream and fine-grained sand. The sandy shores are natural. The higher parts are covered partly with willows and poplars.

Inside, the floodplains contain oxbows, wet meadows, clay, sand, and gravel pits and willow-poplar woods. They are important places for meadowbirds, waterfowl, heron and cormorant colonies as well as for storks and birds of prey and for the spawning of fish.

Dead trees will not be removed.

Downstream in the tidal influence of the sea and the influence of Lake IJssel we find reed and willow marshes and wet meadows on peat soil, covered with a thin layer of clay. Here we find peculiar and rare species such as fritillary and ruff.

ECOLOGICAL CRITERIA

The most important mechanisms and conditions for an optimal, sustainable river ecosystem are:

1. Stream characteristics. To keep the natural characteristics, floodplains must not be embanked, but instead they will be enlarged if possible. The summer dikes around rehabilitated floodplains will not be preserved. Preferably, they will be opened downstream, to keep the ecological gradient.

The river must not be shortened. Surface water from the drainage basin comes little by little in the river due to afforestation and water conservation. The seepage water transport from the drainage basin is restored. The use of groundwater is limited. Infiltration of surface water on the riverside seems to be the best alternative. Deep drainage of polders must be diminished in the neighbourhood of floodplains if the latter depend on seepage water. Deep sand and gravel pits can attract too much seepage water from ecologically important areas. At least in floodplains their depth is not useful only to safely store spoil. Anyway they will be made more shallow either by the river itself or by man. Shallow water serves as spawning grounds for fish and amphibians just as inundated meadows and marshes do.

Rivers with flood control dams will be regulated, so that the natural low water in summer and autumn is simulated more or less for foraging waders. A storm surge dam in the Haringvliet provides the tidal influence of the sea on the river and a free transport of sediment to the sea.

The influence of Lake IJssel on the mouth of the Vecht and Zwarte Water will be preserved in favour of fritillary meadows and meadowbirds. When spoil must be removed from the mouth of the river IJssel, it can be used to create marshes there.

Secondary streams can be created preferably in the straight parts of the river, where they naturally occur and where there is no risk of cutting short a meander. Here there are also possibilities for isles.

2. Water quality. In Roman times the water quality was nearly equal to that of the deep groundwater and the amplitude of the water-level was 30 cm! Our target does not go so far, but it illustrates very well the direction in which we think. To start with, we state that the water is clear and clean and fulfils the conditions for salmonides. The phosphate load is the determining factor for the diversity of nature. Therefore it is most urgent that agricultural pollution and pollution by unpurified sewage water must be stopped.

The bottom of the river bed is cleaned following the current plan, in favour of macro-invertebrates and fish. They are food for birds and mammals.

3. The riversides consist of sandy shores and steep bank verges between the groynes. Distances between the groynes will be made as long as possible. Stone will only be used on the river front, when nature-friendly measures are not sufficient. On farmland cattle and horses will not be admitted to the river front. In that way there is room for willows and poplars which will cover the riverside. In nature reserves very extensive grazing will be tolerated down to the river. The government will make an agreement with landowners on leaving strips of land along the river for nature-friendly management of the river front.

4. Introduction of alluvial forest needs bare soil, so the grass vegetation must be removed. Some of the tree species have no seedbank in the neighbourhood and to shorten waiting time we can sow them (oak, ash and elm). Beside tree seed we have to introduce cattle and horses which are adapted to life in the wilderness, beavers, otters, perhaps wild boars, salmon, sturgeon and sheatfish. Introduction will only take place when the quality of the ecosystem is sufficient.

5. Free and safe passage for fish, freshwater lobsters, otters and other animals and plants. This includes in the first place a safe passage over the dams and sluices in the rivers and the tributaries so that fish can reach their spawning-places. In the second place this includes that along the whole length of the river habitats must be present for those species.

The slopes of dikes are very useful as habitat and transport way for the species of the *Arrhenatheretum* and the *Medicagini-avenetum*. The water authorities manage these slopes as nature reserves. They will be encouraged by government and provinces.

6. Size. Nature development on floodplains needs large areas for the following reasons:

- The elements of the river ecosystem have a minimum size for good functioning and development. A large area is needed to combine all the elements to obtain an optimal diversity.

- The river dynamics and the grazing cause local extinction of species and create new living conditions for species. That needs a larger area than conventional nature management needed, but it tends to be safer. The old hayland nature reserves will be kept as such and as a natural seedbank for the developing natural banks. (Never throw away your old shoes, before you have bought new ones.)
- The largest territories of expected top predators and the minimum size of populations determine the minimum size of the floodplain to be developed. Nature reserves outside the floodplains have to be taken in account.
- To develop the whole gradient in the 'meander floodplain' it is necessary to develop the whole floodplain.
- Nature needs to be undisturbed as far as disturbance is not natural. Rest is also required for walking, cycling, picnicking and limited fishing and hunting in rehabilitated floodplains. We need large areas to get that rest.

7. Relations with other ecosystems next door or remote must be investigated carefully. Let me remind you only of the relations which geese have with the arctic, sand-martins with Africa and breeding meadowbirds with the neighbouring peat meadows of Holland and Utrecht. Earlier I mentioned the link of seepage water with other parts of the river basin. Population pressure brought us cormorants and marsh harriers from the Oostvaardersplassen.

SELECTION

To select the most promising floodplains for starting ecological rehabilitation we used the following criteria:

1. The occurrence of actual or potential nature values (ecosystem elements, botanical values and zoological values); the more the better.
2. The position of the floodplain with regard to the climatological gradient and with regard to the different stream characteristics of the river.
3. The specific relations with other ecosystems.
4. The size of the floodplain, or the size of the combination of floodplains.
5. The height and relief with regard to the high water level.

FINALLY

I will finish with two statements:

1. The success of ecological rehabilitation of river floodplains depends largely upon the quality of the whole drainage basin.
2. The time for ecological forecasting studies is over. Now it is time to learn by trial and error and to monitor the ecological rehabilitation of river floodplains.

ECOLOGICAL REHABILITATION OF THE RIVER IJssel

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INTRODUCTION

The River IJssel is one of the three branches of the River Rhine in the Netherlands. From Westervoort it streams in a northerly direction along medieval towns such as Zutphen, Deventer, Zwolle and Kampen and after 110 km it flows into Lake Ketelmeer (figure 1).

Near Westervoort the River IJssel has a width of 75 m and a flow velocity of 0.5 - 1.1 m/s, changing to 170 m and 0.3 - 0.7 m/s near Kampen. The slope of the IJssel is 8.5 m.

The IJssel has no weirs, so fish can migrate without obstructions between the River Rhine and Lake Ketelmeer.

The river is of great importance for shipping, which has caused strong erosion of the river banks. To stop erosion the banks were armoured with rocks in the period 1960-1980 and consequently c. 90% has lost its natural character.

The River IJssel has extensive floodplains (c. 10,000 ha) of which c. 80% is in agricultural use; 90 % of this as grassland, the rest as arable land with predominantly maize.

The floodplains are almost yearly flooded, mainly in the period December - February. Very low water levels became rare after the construction of the Rhine-weir near Driel in 1970.

In the floodplains c. 30 sand and clay pits were created this century.

ECOLOGICAL IMPORTANCE

The higher parts of the floodplains and the dikes are of great importance for plants of Alpine origin such as *Agrimonia eupatorium*, *Ononis spinosa* and *Salvia pratensis*. Along the lower IJssel there are locally vegetations with *Fritillaria meleagris*.

Upstream from Zwolle water vegetations in the river are rare but downstream from Zwolle water vegetations have returned during the last two decades with species such as

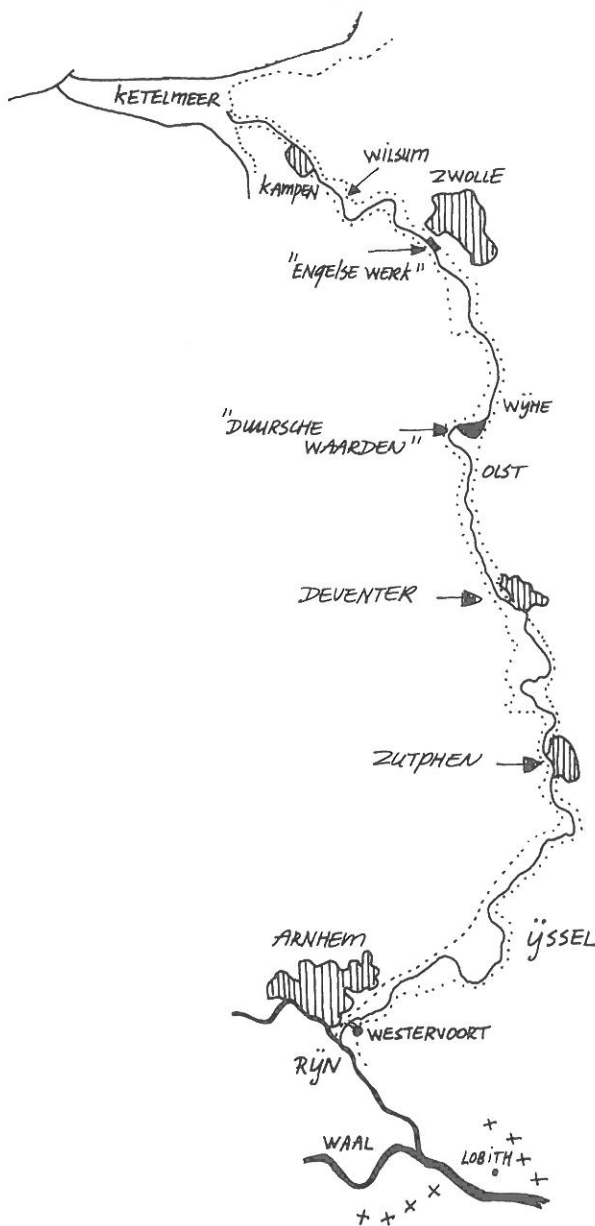


Figure 1 The River IJssel

Potamogeton pectinatus, *Potamogeton nodosus* and *Nuphar lutea*. Downstream from Wilsum there are still natural vegetations on the banks of *Phragmites australis*.

The faunistic importance is mainly ornithological. About 100 species breed in the floodplains. The most important species are Cormorant, Bittern, Grey Heron, Garganey, Shoveler, Marsh Harrier, Corncrake, Ruff, Black-tailed Godwit, Black Tern, Little Owl, Bluethroat, Yellow Wagtail, Bearded Tit and Penduline Tit.

The river and its floodplains are a wetland of international importance for migrating and wintering water birds, especially when the floodplains are flooded or during severe winters.

Every year 50,000-130,000 water birds winter on the river and its floodplains. The most numerous species are: Mute Swan, Bewick's Swan, Whooper Swan, Bean Goose, White-fronted Goose, Wigeon, Teal, Mallard, Shoveler, Pochard, Tufted Duck, Merganser, Coot, Lapwing, Ruff, Snipe and Curlew.

ECOLOGICAL REHABILITATION

A study of the Province of Overijssel in 1987 made clear that the ecological importance of the River IJssel and its floodplains and dikes is threatened, mainly by:

- agricultural intensification
- stability works on the dikes
- armouring of the natural river-banks with rocks.

In 1989 the province of Overijssel published an action programme (IJsselvisie) to rehabilitate the ecological importance of the banks, floodplains and dikes. The province of Gelderland did the same concerning the southern part of the river.

The main ecological goals of these action programmes are:

- agricultural extensification of the floodplains
- ecological management of the river dikes
- ecological restoration of the river banks
- ecological restoration in the floodplains

PROJECTS

Agricultural extensification

On 2900 ha of floodplains (29%) it is possible for farmers to make an agreement (Relatie-nota) with the Netherlands government to extensify the agricultural management or to sell their grounds to a nature conservation organization. The farmers receive financial compensation for the agricultural extensification.

The extensification is a success, because in c. 10 years some 1400 ha became extensified. Therefore the possibilities for extensification will be enlarged in 1993 up to 50% of the floodplains.

Ecological management of the river dikes

At the moment only 25 % of the dikes along the northern part of the River IJssel is managed ecologically. This percentage can grow to almost 60% if a large number of farmers make an agreement to extensify the agricultural management and if the river boards pay more attention to the subject.

Ecological restoration of the river banks

Rijkswaterstaat is making a long-term programme for the ecological restoration of the river banks and recently has realized a few pilot-projects near Wilsum to protect reed beds.

Ecological restoration in the floodplains

In 1989 the first project, 'Duurse Waarden', was realized and a second project, 'Engelse Werk', is executed at the moment. Enlargement of the 'Duurse Waarden' project is in preparation. The main objective in these projects is increasing the role of the hydrodynamic, morphodynamic or ecological processes of the river in the floodplains.

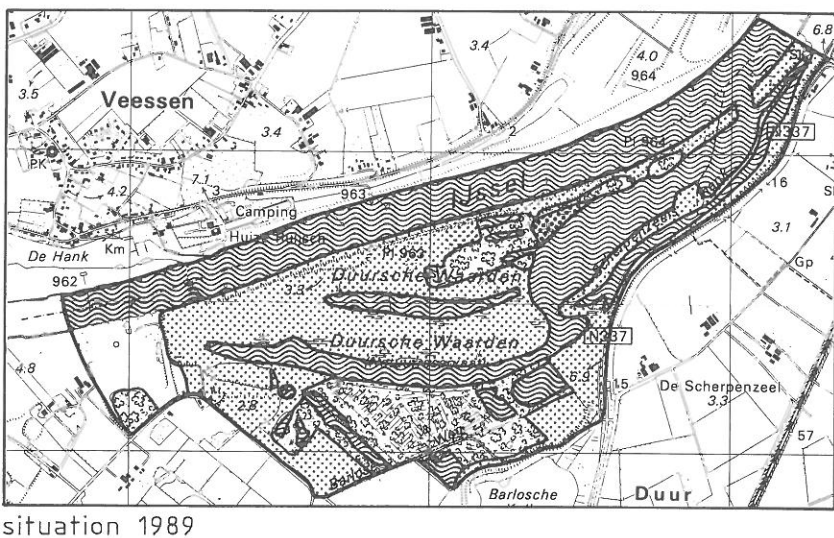
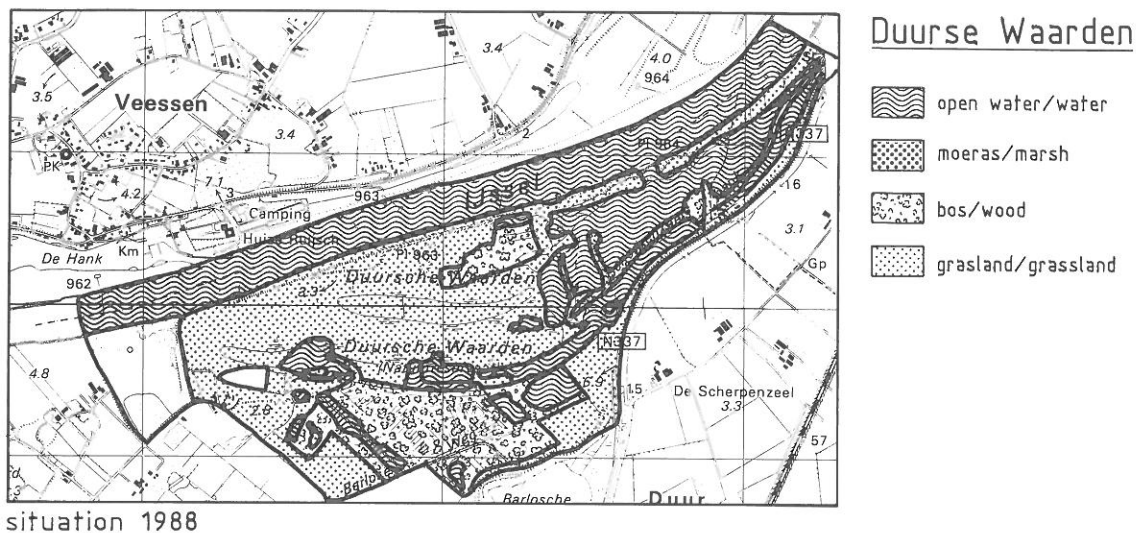


Figure 2 Nature restoration project 'Duurse Waarden'

Nature restoration project 'Duurse Waarden' (figure 2)

In 1989 a plan was executed to enlarge the ecological significance of the northern part (110 ha) of this floodplain, which was already a nature reserve. The project was initiated by the Ministry of Agriculture, Nature Management and Fisheries and is the first example of large-scale ecological restoration along Netherlands rivers.

The following activities took place:

- at the downstream end a entry was made in the summer dike between the river and the nature reserve to increase hydrodynamic, morphodynamic and ecological processes.
- shallow water was dredged and circumstances were created for the spontaneous settlement of marsh and wood (20 ha in all).
- the density of grazing cattle (all year round) was extended to 0.5 animal/ha. Highland cattle and Icelandic ponies were introduced.

The following vegetations are expected to expand: water vegetations (*Potamogeton* and *Nuphar*), marsh vegetations (*Carex* and *Phragmites*), grassland vegetation (*Cynosurus*) and woods (*Salix*).

The following breeding birds are expected to settle or increase: Cormorant, Night Heron, Greylag Goose and Penduline Tit.

A programme has started to monitor the ecological and morphological changes. The first results of macrofauna are available which show a negative trend because of the increased influence of the water of the River IJssel (which has the same poor quality as the Rhine) in this nature reserve.

The ornithological trend is more positive with the increase of breeding numbers of Cormorant and the resting numbers of waders. The reduced density of grazing cattle also shows a positive trend. The structure of vegetation became more varied and locally shrubs and trees have settled in the grasslands. Probably marsh will not be able to develop because of the settlement of huge numbers of willows.

Nature restoration project 'Engelse Werk' (figure 3)

The floodplain 'Engelse Werk' is situated on the right bank of the River IJssel near Zwolle. In 1991 a plan was developed to transform this agriculturally used floodplain (30 ha) into a nature reserve. The project was initiated by the province of Overijssel. The execution of this plan is projected in the autumn of 1992.

At the moment the following activities are taking place:

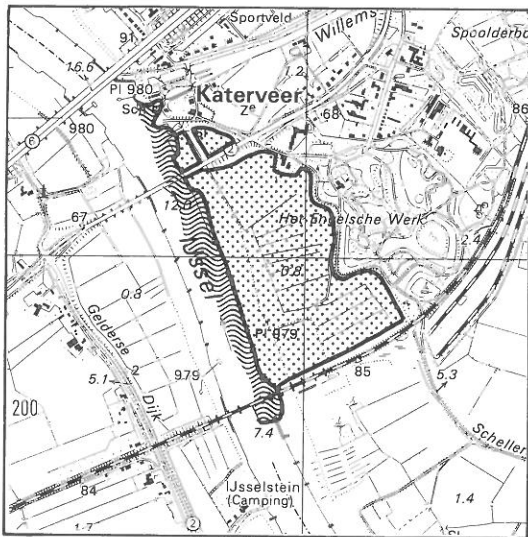
- shallow water is dug (8 ha)
- circumstances are created for the spontaneous settlement of a small *Phragmites* marsh and a small *Salix* wood.
- draining will be stopped
- mowing of grasslands will stop and extensive grazing with Dutch cattle and horses will start (not in winter).

At the moment the botanical significance is limited to the dikes. As a result of the above-mentioned activities the following vegetations are expected to expand: *Potamogeton* and *Nuphar* vegetations, *Phragmites* marsh, *Calthion* grasslands and *Salix* woods. About 50 species of birds are expected to settle with as most interesting species: Grey Heron, Greylag Goose, Garganey and Penduline Tit.

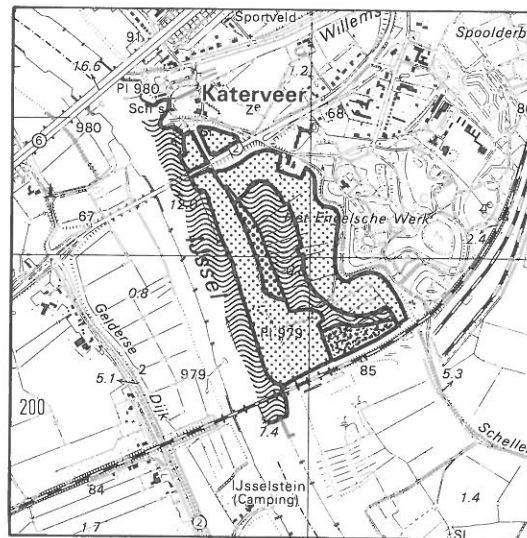
The most important goals of the project are:

- improving the significance for migrating and wintering water birds and waders.
- improving the conditions for breeding birds.

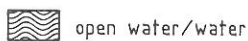
Engelse Werk



situation 1992



situation 1993



open water/water



moeras/marsh



bos/wood



grasland/grassland

Figure 3 Nature restoration project 'Engelse Werk'

To attain these goals, inundations are necessary in winter and spring but undesirable in the breeding season (May-August). Therefore the low dike between the river and this floodplain will be spared at a height of 90 cm + NAP to prevent floods in the breeding season. To enlarge swampy conditions in December-April draining will be stopped. The results of this project will be monitored.

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SIDE CHANNELS ALONG NETHERLANDS RIVERS

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Lowland rivers in the Netherlands were often shallow, the location of the river bed could change periodically and vegetation and animal types were developing in places which are results of hydrological and geomorphological phenomena. Many side channels and islands appeared and disappeared.

Man has changed the river landscape for the benefit of safety against flooding, shipping, agriculture or other economical functions. The river changed into one regulated low water bed for shipping with a constant width and beside this channel floodplains, mostly dry and then used for cattle, brickyards and sand and gravel works. Nowadays the omission of the various morphological differences, side channels for instance, has caused a rather poor river ecosystem.

The development of side channels along our rivers is one of the measures necessary to reintroduce organisms which lived here a long time ago.

By definition the water in a side channel flows, also at low water level circumstances. If the water velocity is moderate, one may expect water vegetation in the channel. Shipping waves, however, may have a negative influence on water vegetation, also in side channels. Vegetation may be present also on the border of the side channel: on the slopes and in the surroundings where the frequency of flooding is so small that vegetation is not harmed by it (floodplain forest).

In the wet side channel area we expect organisms like types of macrofauna and fish. A side channel gives the opportunity to create ecological habitats which are specific to the river ecosystem but are not tolerated in the main stream itself, i.e. 'snag habitat' (wood, in and around the water), stable and shallow sandy or muddy banks, 'moving sand habitat', clay deposits, water vegetation. The following table shows types of species which may be expected.

<u>vegetation species</u>		<u>(macro)fauna</u>
water vegetation	border vegetation	<i>symposiocladius lignicola</i>
<i>Potamogeton pectinatus</i>	<i>Lythrum salicaria</i>	<i>nevermannia maculata</i>
<i>Lemna minor</i>	<i>Phalaris arundinacea</i>	<i>lipiniella arenicola</i>
	<i>Myosotis palustris</i>	<i>detritus</i>
	<i>Polygonum amphibium</i>	<i>ephoron virgo</i>
	<i>Rorippa amphibia</i>	<i>palingenia longicauda</i>
	<i>Veronica catenata</i>	<i>pothamnatus luteus</i>
	<i>Carex acuta</i>	<i>stenochironomus</i>

Table 1 Expected species in and around a side channel

There are a few river functions which are so important that the development of side channels may not harm them, such as the safety against flooding and shipping. This leads to two requirements concerning side channels: firstly they may not causes a decrease in the shipping depth during

low water periods and secondly a side channel with its surroundings may not lead to an increase of the high water level criterion (HWC).

From an ecological view there are also a number of requirements. First of all a side channel should always, or nearly always, have a water flow or at least retain water. This is because of the possibility for organisms which can move to stay in the water if they need to. The flow velocity should be moderate because of the water vegetation. The slope of side channels should be very gently, especially for border vegetation. A sandy or gravel bed is preferable to silt.

Morphological problems can occur as follows. When part of the water flow of the main bed streams through the side channel with a smaller concentration of the sand or silt flow, in comparison to the main flow, sedimentation may occur. This causes a decrease in the main flow depth and is therefore unfavourable for shipping.

Another problem occurs when the water velocity in the side channel is too low. A sedimentation of sand takes place in the entrance of the side channel and it will be cut off from the main stream at the end. Therefore it is very important to realize the right sand concentration in the side channel.

Figure 1 gives an indication of the development of the discharge in the side channel during the time, caused by the change of the bottom level by erosion or sedimentation.

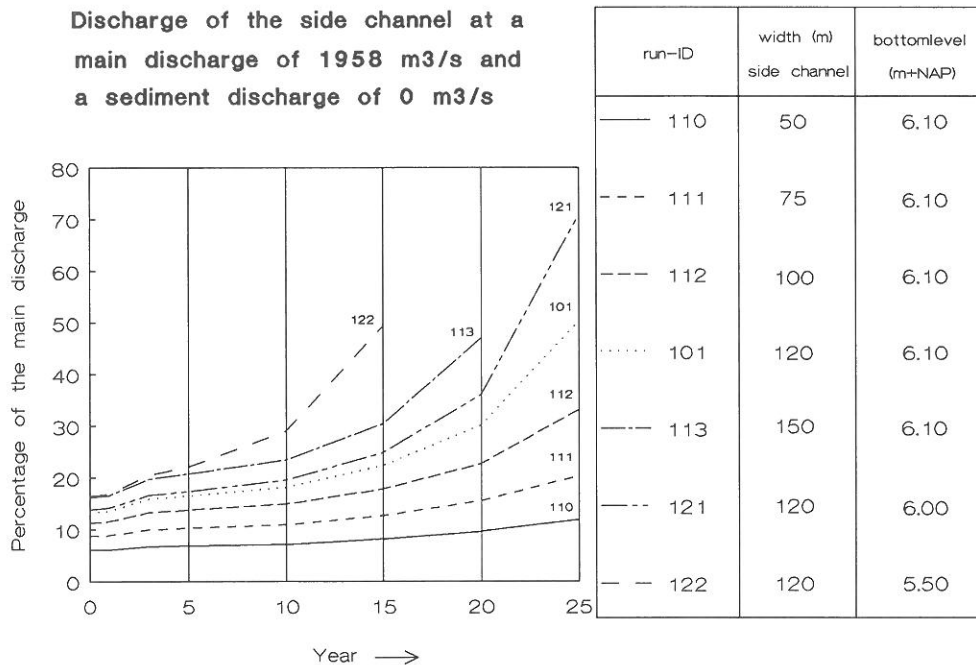
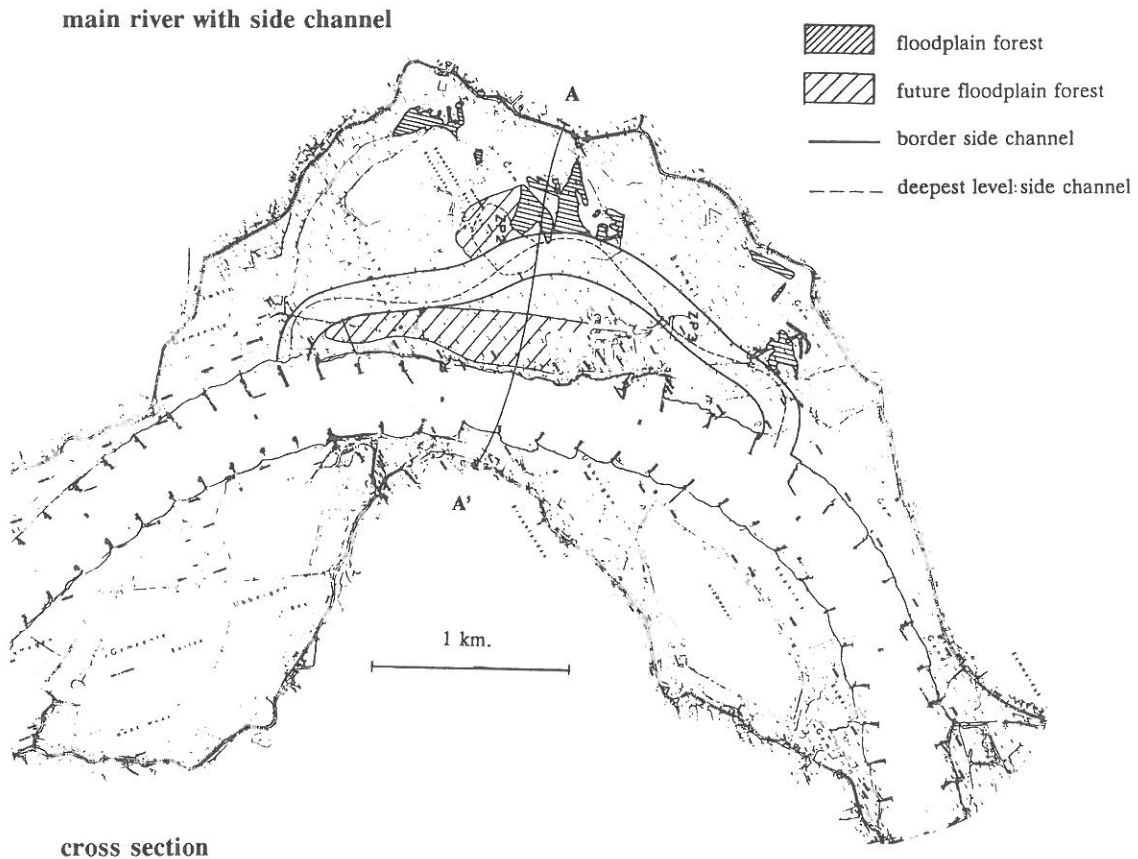


Fig. 1 Change of discharge through the side channel in time in relation to width and bottom level

Research has led to the conclusion that in regard to the requirements as mentioned above, it is impossible to realize a side channel without special facilities for lowering the discharge. Besides it seems also necessary to prevent sand sedimentation in the side channel, for instance by making a sand deposit at the entrance.



cross section

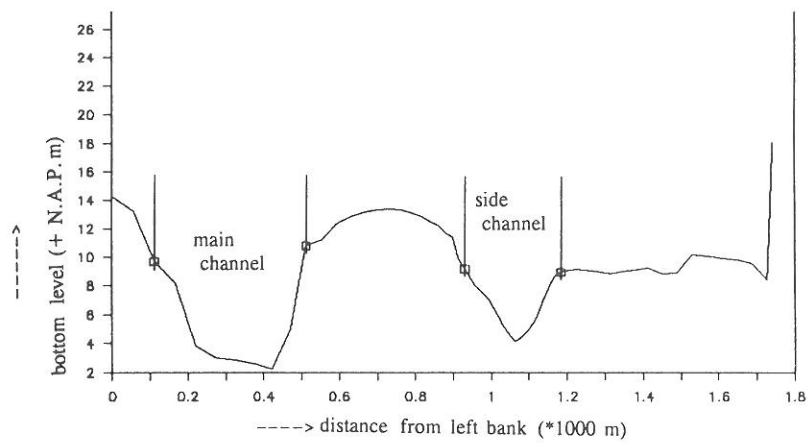


Fig. 2 Global dimensions of a side channel for Netherlands river systems

So, to develop a side channel in Netherlands circumstances, one has to make a sort of entrance construction which regulates the water and sand discharge. The global dimensions of a side channel in Netherlands circumstances are shown in figure 2.

The stability of the side channel can be quite a problem in floodplains in the Netherlands. The side channel may not attack the back side of the groynes along the main bed and on the other side the main dike along the river, by meandering.

Therefore one should make fixed points along the channel. Of course one can realize this by small stone groynes, but there are also other possibilities like rather stable vegetation, a wooden construction or the use of gravel.

In the River Rhine in the Netherlands there is at present no side channel. There are, however, a few ecological restoration plans in preparation which include a side channel. The river control board has decided to realize just one side channel to get experience with the consequences. If they are positive, more side channels will be projected.

In 1993 the draft of the side channel in the River Waal near Sint Andries may be completed. If this plan is realized, an ecological, morphological and hydrological monitoring program must be started. The results of that program are important for following drafts and finally for part of the ecological river restoration.

FISH PASSES IN THE NETHERLANDS RIVERS

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FISH PASSES IN THE NETHERLANDS RIVERS

Within the framework of the International Ecological Rehabilitation of the Rhine, a program in which the Rhine riparian states cooperate, a number of aims was formulated.

One of these aims is to create a river environment that allows a re-establishment of a natural population of salmon and sea trout in the Rhine system. Because of the many morphological and hydrological changes of the Rhine during the last century, one cannot expect that large numbers of anadromous fish will return to the Rhine systems. Regulation, a bad water quality and on the Neder-Rijn canalization are the reasons for the absence of salmonides.

Our aim is to get a population which can re-establish itself in the Rhine. Apart from water quality a lot of measures have to be taken to allow the anadromous fish species to migrate up and down the Rhine system.

The river systems in the Netherlands: the Rivers Rhine and Meuse, have many weirs and barriers that prevent the migration of fish species. In 1989 the Ministry of Transport, Public Works and Water Management and the Ministry of Agriculture & Fisheries decided to cooperate in taking measures and making fish passes so that anadromous fish species are able to reach their spawning and nursery areas at upstream sites in the rivers. An ambitious plan that has to be completed by the end of the 90's.

So far five weirs in the Overijsselse Vecht have been provided with fish passes and in 1993 the Overijsselse Vecht will no longer be a barrier for migrating fish.

In the River Meuse there are 7 weirs. Two of them are provided with a fish pass. This year a start has been made with another 2 fish passes. The other weirs are subsequently modified.

Back to the River Rhine: at this moment plans are worked out to improve the migration of anadromous fish in the Rhine branch the Neder-Rijn. The weir at Hagestein has a high priority and will be followed by those at Amerongen and Driel.

Up to now the fish passes which have been built, all have an identical concept: basins placed in a row with a small difference in height between two adjacent basins. The fish is supposed to swim and jump from one basin to the other, till it reaches the upstream side of the weir complex (fig. 1).

It is known that in small streams and rivers this type of fish pass functions properly, but so far we have no experience with larger rivers like the Neder-Rijn and Meuse. We do not know whether the sea trout or the salmon which appears each year in front of the weir, is able to find the narrow entrance to the fish pass in relation to the large width of the weir.

Therefore research has been and is still carried out in order to increase the possibilities of

migrating fish to pass a weir complex. At the weir of Hagestein in the Neder-Rijn an attempt was made to lead the fish away from the weir itself into the ship lock. The ship lock has larger dimensions and therefore it could be a more attractive migration route, than the relatively small fish pass of the basin-type (figure 2).

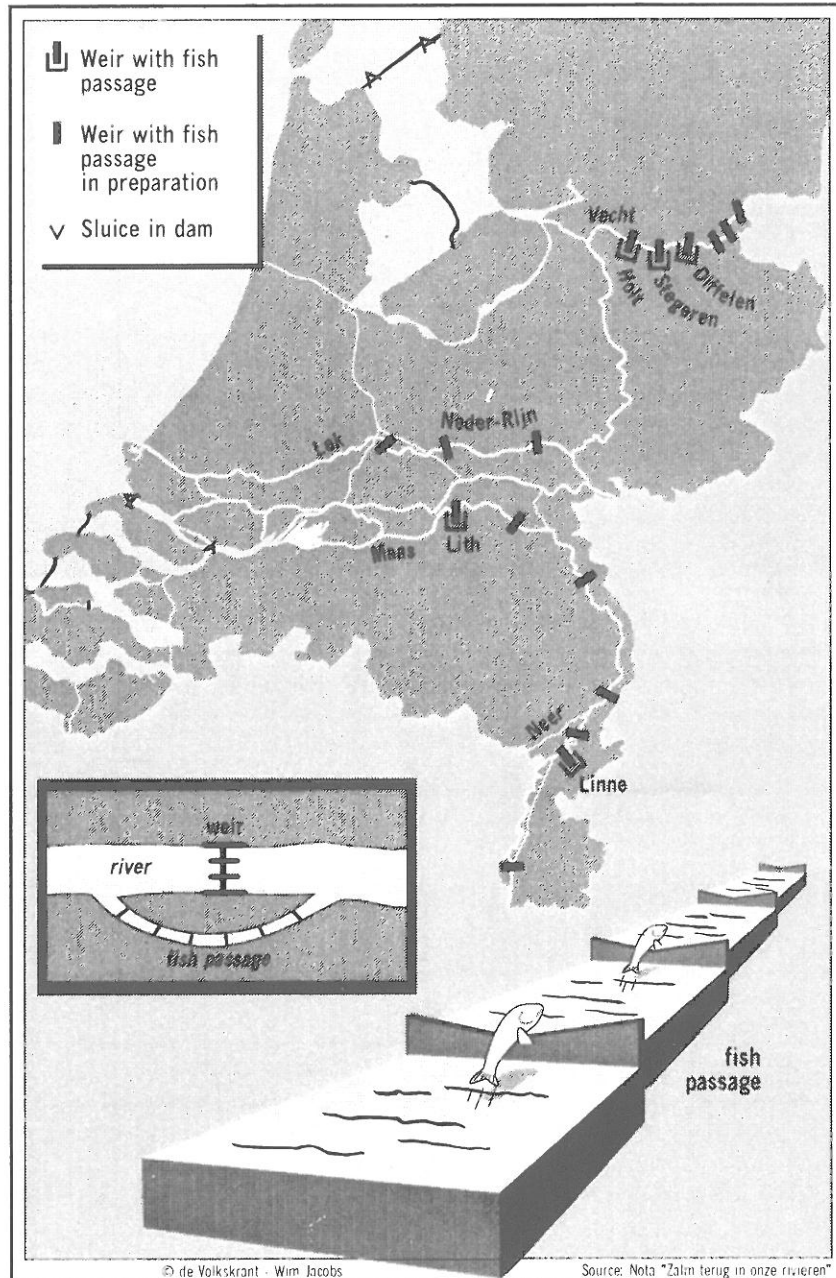


Fig. 1 Fish passes in the Netherlands

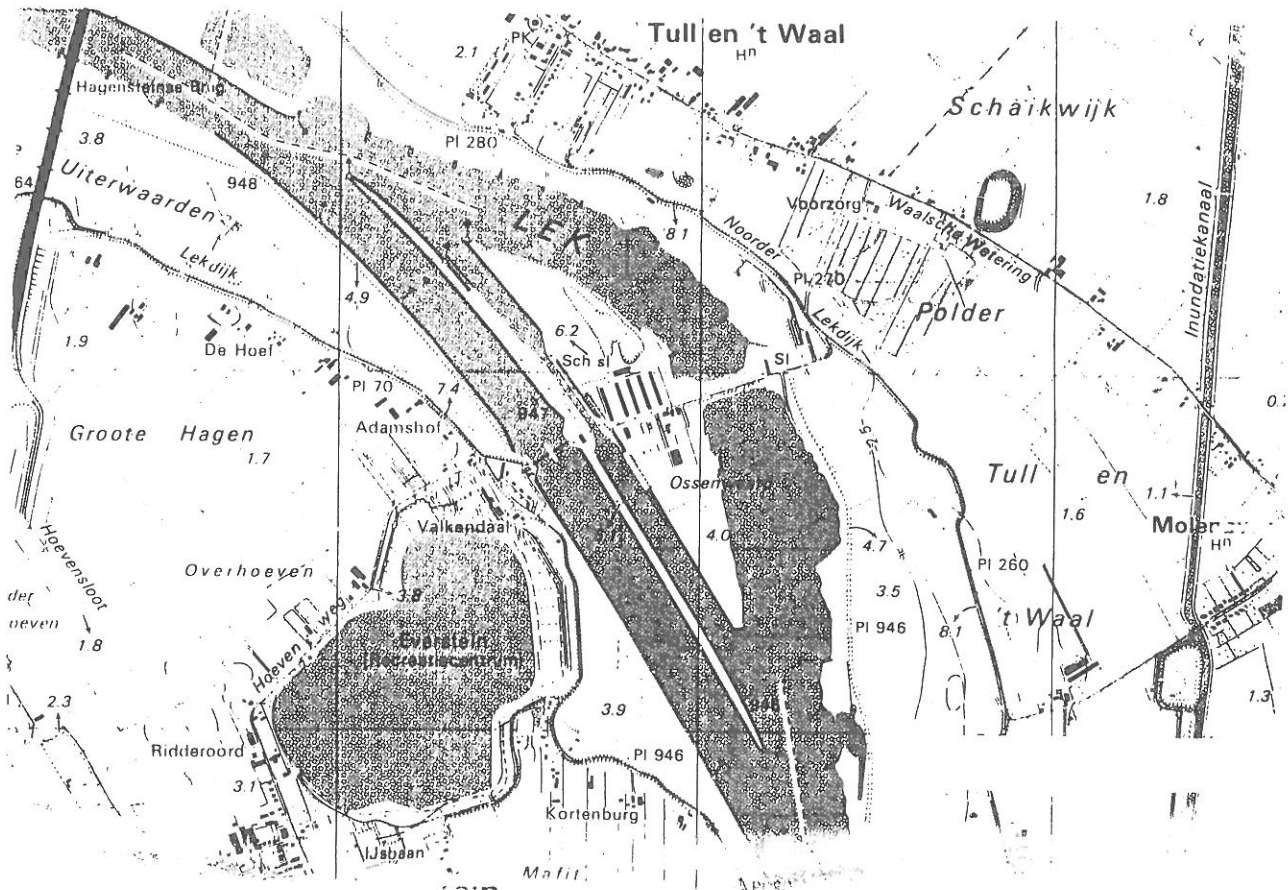


Fig. 2 Weir complex at Hagestein

In an experiment carried out this year, a large net was stretched across the river in front of the weir. The net was made of nylon ropes which were tightened between a cable at the bottom and another cable at the water surface. The velocity of the water coming from the weir site causes a vibration of the nylon ropes. The vibrations alarm approaching fish and they are supposed to swim along this vibrating fence in the direction of the ship lock. In earlier days this technique was also used to catch salmon, and nowadays it is practised locally in the Eastern Scheldt to catch anchovy (figure 3).

Because sea trout migrates against the direction of the water stream, a lure stream was created in the canal in front of the ship lock in order to stimulate the fish to swim in that direction.

In order to evaluate the number of sea trout that migrates via the ship lock, we try to follow the paths of the salmonides. So, a number of so-called 'salmon traps' were placed to catch salmonides, where they were marked and thrown back into the river.

Five salmon traps in total were placed, three downstream of the weir and two upstream of the weir complex (figure 4). Salmonides which were caught were labelled with a so-called Carlin tag, an internationally approved label. Most of the labelled animals were replaced at the same location where they were caught. Several times during the experiment the chamber of the ship lock was completely fished with a large fishing net stretched between two small boats to determine the total number of fish and fish species present in the lock chamber.

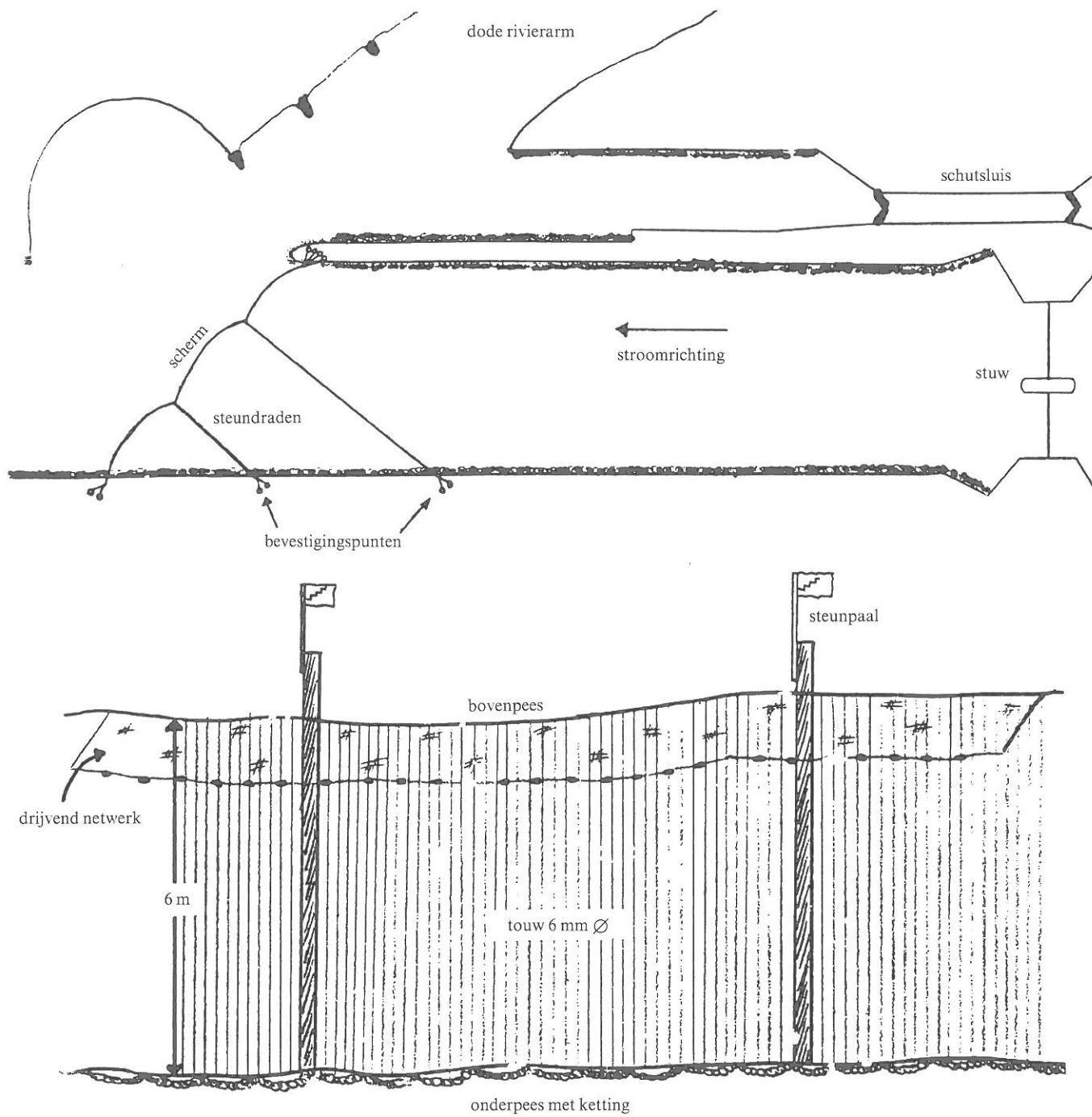


Fig. 3 Situation of net across the river

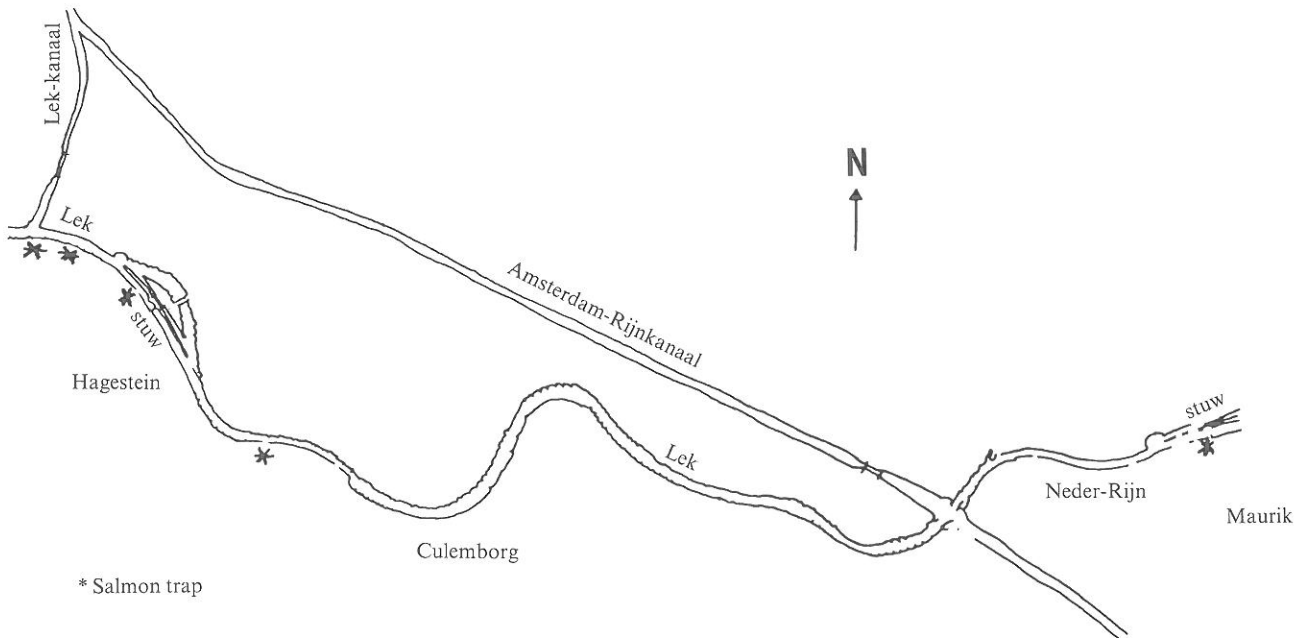


Fig. 4 Schematic map of the research area with the location of the salmon traps

The results of the experiment:

- A total of 127 sea trouts were caught between May and September 1992 and were thrown back.
- 125 sea trouts were caught downstream of the weir. Only two individuals were caught upstream.
- Four labelled sea trouts were re-caught in the fish traps placed downstream of the weir.
- The sea trout remains only a few weeks in front of the weir and subsequently swims to other locations.

Conclusions so far:

- A net as a fish-leading system does not operate at this type of locations, mainly because the accumulation of water plants and other floating objects in the net causes a lot of problems.
- The use of the ship lock as a fish pass for sea trout was not effective.

FLOODPLAIN RESTORATION: A CHALLENGE FOR RIVER ENGINEERING

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INTRODUCTION

In the Netherlands part of the Rhine system several functions make use of the river environment. The desire to rehabilitate the floodplains demands evaluation of lay-out and administration of the existing river system. This paper aims to present the efforts to integrate the grown ecological interest into Netherlands (upper-)river administration and accompanying problems.

HISTORICAL RIVER DEVELOPMENT

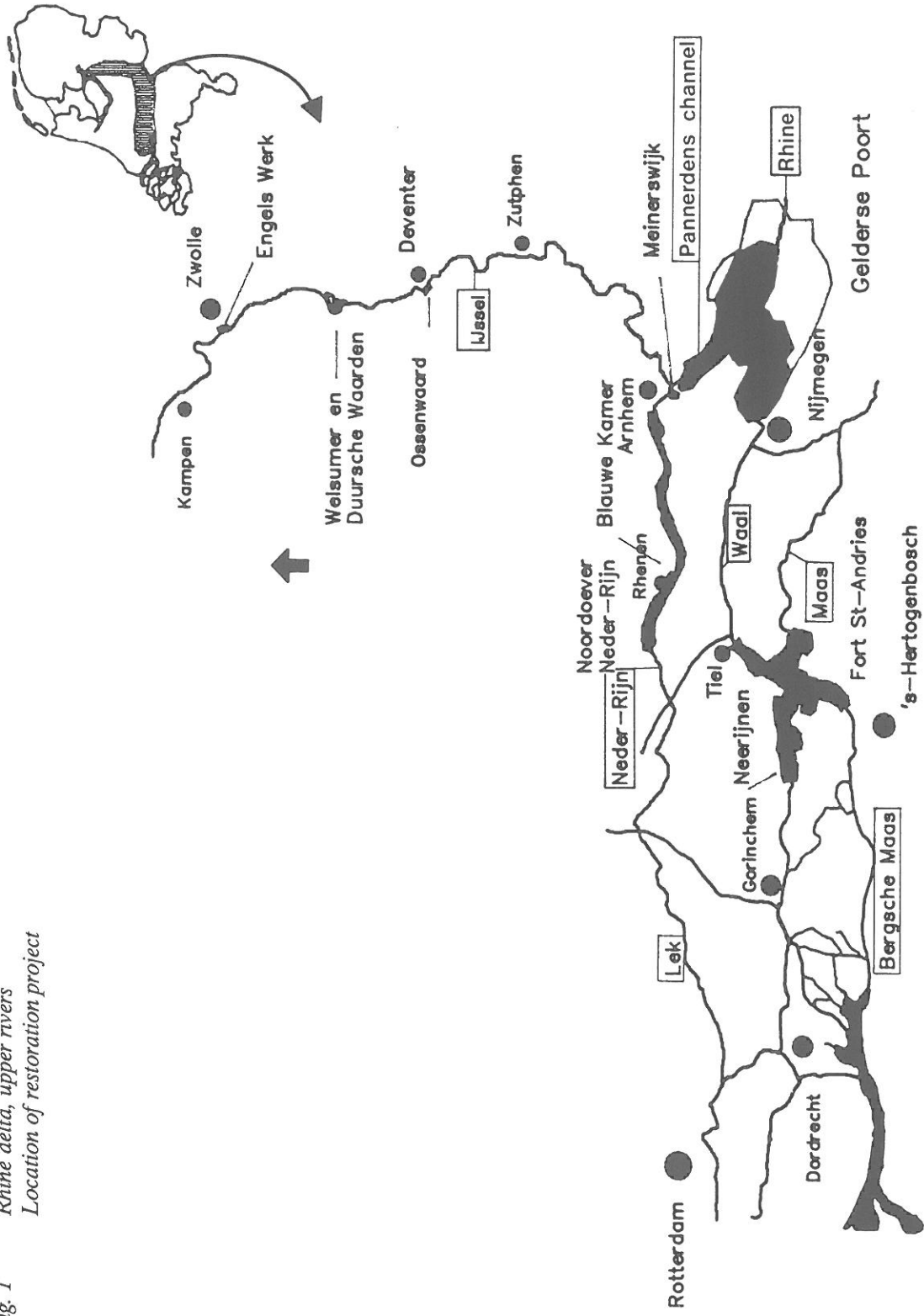
The delta of the River Rhine is found in the Netherlands (fig. 1). At Pannerden, 5 kilometres downstream of the border with Germany a bifurcation divides the water of the Upper Rhine into roughly one third into the Pannerdens Channel and two thirds into the River Waal. The bifurcation at Westervoort divides the discharge through this northern branch again. One third goes to the River IJssel (thus one ninth of the Upper Rhine discharge) and two thirds flow into the Lower Rhine (thus two ninths of the Upper Rhine discharge).

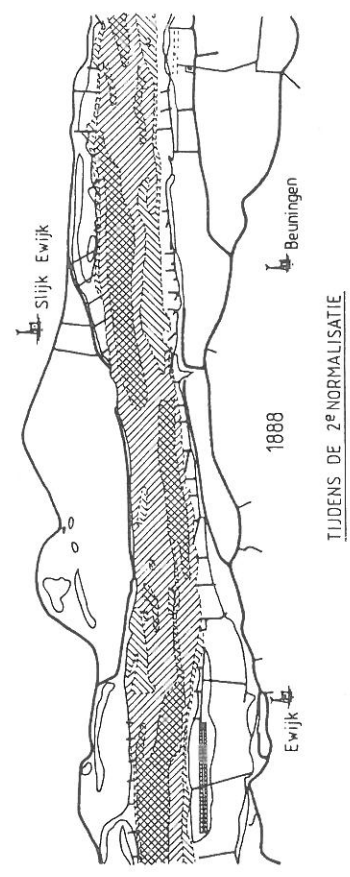
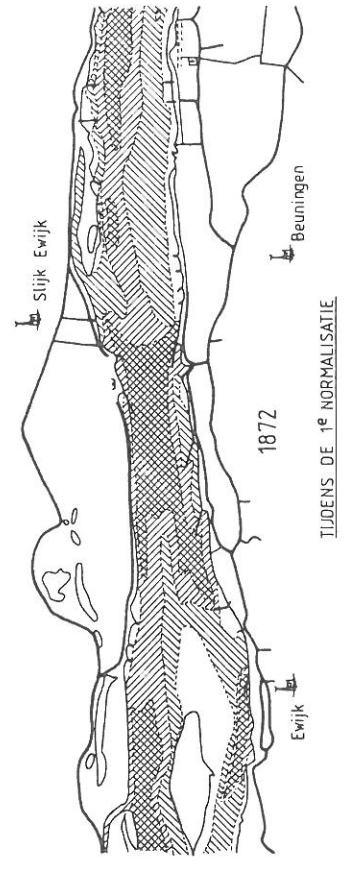
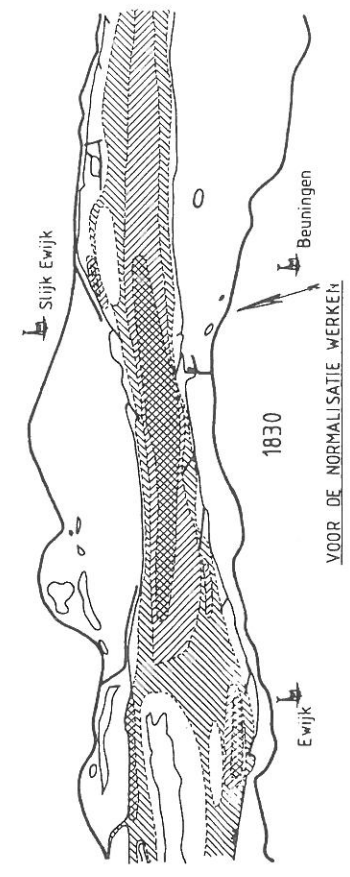
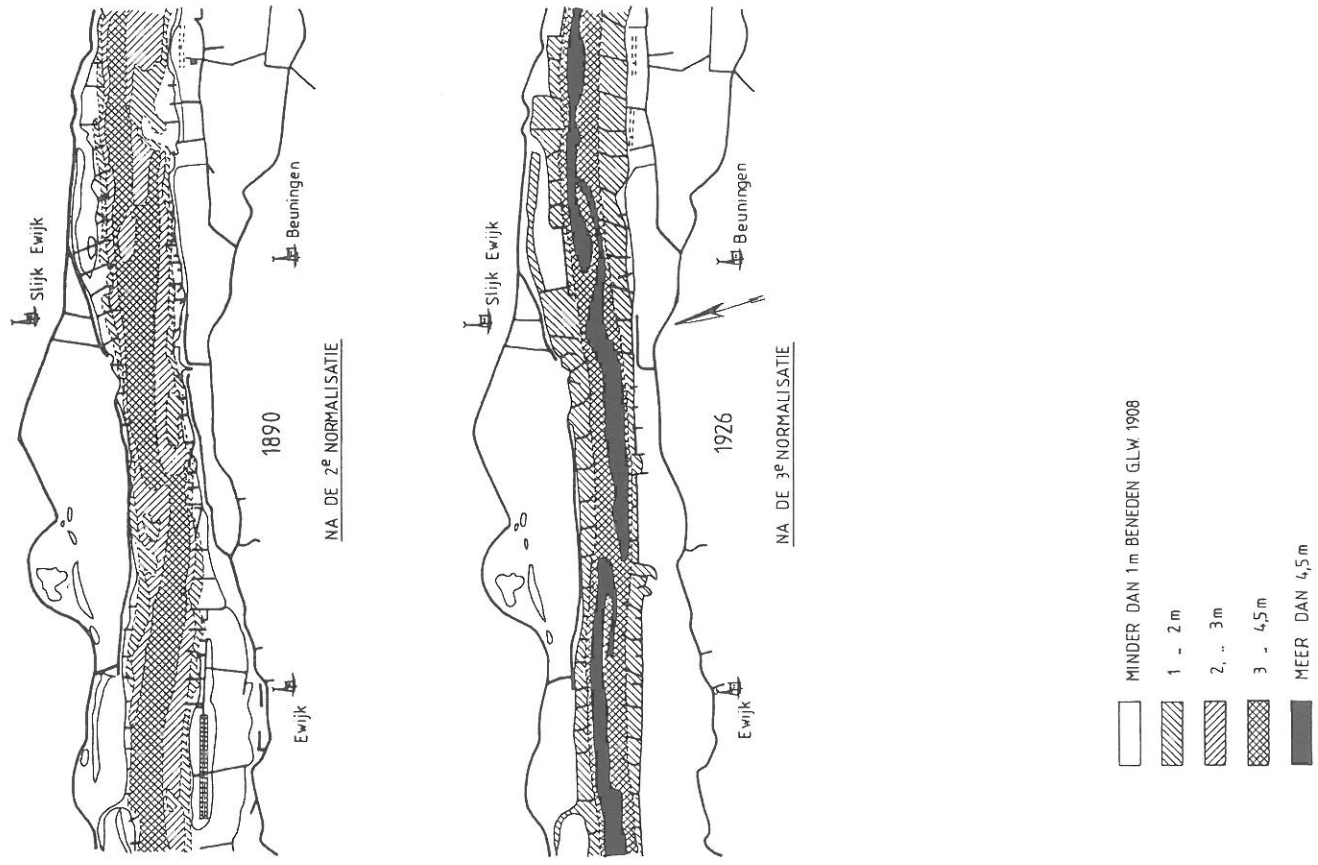
The rhythm of these distributions may lead to the conclusion that the system maintains a 'natural' equilibrium. However, the contrary is the case: it took our ancestors much effort to keep the northern Rhine branches open. Before the year 1600 the River Waal discharged more than 90% of all Rhine water to the North Sea. During the famous Eighty Years' War with Spain, the Spanish soldiers could cross the River IJssel on foot, because the river was silted up. This military fact, together with commercial arguments, raised by the Hansa towns of Zutphen and Zwolle, led to the desire to more or less control the distribution of discharges at the bifurcation points. The States of Holland established therefore the first Rijkswaterstaat office, with as primary task to administer the Netherlands Rhine branches. Rijkswaterstaat started to regulate the river by cutting off bends, building groynes and spur-dikes. Especially the efforts to give the bifurcations a good lay-out were fruitful in achieving a relatively stable distribution of discharges.

However, the problem of frequent flooding of the river's adjacent lands still had not been solved. In the last century the regulation works have been carried out with the aim of defining a unique minor bed, with a more or less constant width. In this way the forming of banks and erosion pits was kept to a minimum. Thus, together with sufficiently high flow velocities the forming of ice-dams was prevented. Closing of lateral channels increased the degree of safety against flooding even more. In the Netherlands the system of minor and major bed turned out to be very favourable, not only for safety against flooding but also for the interests of navigation and agriculture.

Especially the improved conditions for navigation led to the second and third phase in river regulation (fig. 2). Nowadays the so-called normal width (between groynes) is constant over long reaches of all Rhine branches. The improved conditions for agriculture led to the use of the floodplain as farmland, with grass as major vegetation. Natural growth became almost entirely banned from the floodplains.

Fig. 1 Rhine delta, upper rivers
Location of restoration project





- MINDER DAN 1m BENEDEN GLW 1908
- ▨ 1 - 2 m
- ▧ 2, ... 3 m
- ▩ 3 - 4,5 m
- MEER DAN 4,5 m

Fig. 2 Phases in river regulation

RIVER ADMINISTRATION

From the above-mentioned the following functions of the river may be deduced:
 Primary function: Safe discharge of water, sediment and ice. This is assured by our system of minor and major bed with the elements: summer dike, winter dike and groynes.
 Added secondary functions are: navigation, agriculture, recreation, ecology. Especially the importance of the latter functions has grown in recent years.

The above-mentioned interests pose different and often conflicting demands upon our river system. The table below summarizes these demands, as they can be formulated for the ideal situation in which the demands of the particular interest can be fully met.

<u>Interest</u>	<u>Geography</u>	<u>Defences</u>	<u>Hydrology</u>
SAFETY AGAINST FLOODING	summer dikes winter dikes groynes	'armoured' constructions rock	Guarding max. design water levels and discharge distributions
NAVIGATION	summer dikes deep minor bed	'armoured' constructions rock	Up to 4,0 m water depth: total discharge through minor bed
AGRICULTURE	summer dikes polder dikes grass, no natural vegetation	'armoured' constructions	no flooding
ECOLOGY	summer dikes with entries, lateral channels natural vegetation	'soft' defences no rock	dynamic flooding

From this table it is understandable that the "traditional" interests SAFETY AGAINST FLOODING, NAVIGATION and AGRICULTURE could get along quite well. These interests do not pose large policy problems to river administration, apart from optimization questions (e.g. the Lower Rhine canalization).

However, the ECOLOGY interest is a different matter, which at first sight appears hard to integrate into river administration. Together with growing attention paid to ecological rehabilitation of floodplains, river engineering principles are scrutinized by specialists in other fields, e.g. ecologists, who also want to "use" the river environment. Questions have to be answered to what extent the existing river system may be altered to give ecology a chance, without giving away precious merits of the present system.

It must be emphasized that one should stay aware of the sometimes disastrous events experienced in the past. Though much knowledge has been gained in specific river engineering fields, hydraulics and morphology, the exact behaviour of the river can only roughly be approached. Especially local changes are very hard to predict. This is one of the reasons why river engineers may appear reluctant to 'give away' security that has been built into the present river system.

RESTORATION PROJECTS

The elements in ecological restoration projects can be summarized as follows:

- Removal of rock defences along certain reaches, to enable migration of natural elements from and to the minor bed.
- Increase flooding frequencies of parts of the floodplain.
- Variation in the level of the floodplains, so that flora of varied nature can develop. This variation in levels also leads to a variety in locations with different flooding frequencies.
- Floodplain forests. Especially these elements cause resistance to flow, resulting in higher water levels.
- Oxbow lakes, having channels with one opening to the minor bed and channels with a downstream and upstream opening to the minor bed (lateral channels). These elements may compensate resistance caused by forests.
- Development of river dunes.

The problem of integrating the above demands into river administration can best be illustrated by examples of floodplain restoration projects (see also fig. 1). The projects Millinger Waard and Fort St. Andries will be discussed. The Millinger Waard is a polder within the Gelderse Poort area, situated immediately downstream of the bifurcation Pannerdense Kop. The Fort St.-Andries project area is situated in the Middle Waal. This project aims to establish a major lateral channel in the floodplain.

The Millinger Waard project

Fig. 3 shows a river map of the project area, with projected changes in vegetation and geography. Design dike heights are based upon computations of water levels along the river that go with a design discharge which occurs once every 1250 years. A rigid boundary condition for any work to be executed in the minor bed or in the floodplain is the demand not to raise the design water levels anywhere in the river system. Thus, the discharge distribution in the design situation may not be altered. Two-dimensional flow models are used to compute actual and future flow fields. The flow field is determined by hydraulic parameters: topography, geometry, slopes, discharges, hydraulic roughness. Every element in the floodplain represents a certain resistance to flow (or roughness). The most important hydraulic problem appears to be defining the actual roughness and estimating roughnesses of future vegetation. If planned works do change design flow fields, other works have to be devised with the aim of neutralizing the negative effects. These latter works are called "compensating works".

Fig. 4 shows various computations of the flow field during this design situation. Fig. 4a shows the basic situation, without works. Fig. 4b shows the flow field when the original plans are executed without any compensating work, to reduce the water levels. A 5 cm increase of the water levels and a 1 % increase of the design discharge through the Pannerdens Channel are the results. This reduces the safety against flooding which is not acceptable. Fig. 4c shows the plan with compensating works. In this case part of a high terrain has been lowered and a large well alongside has been created.

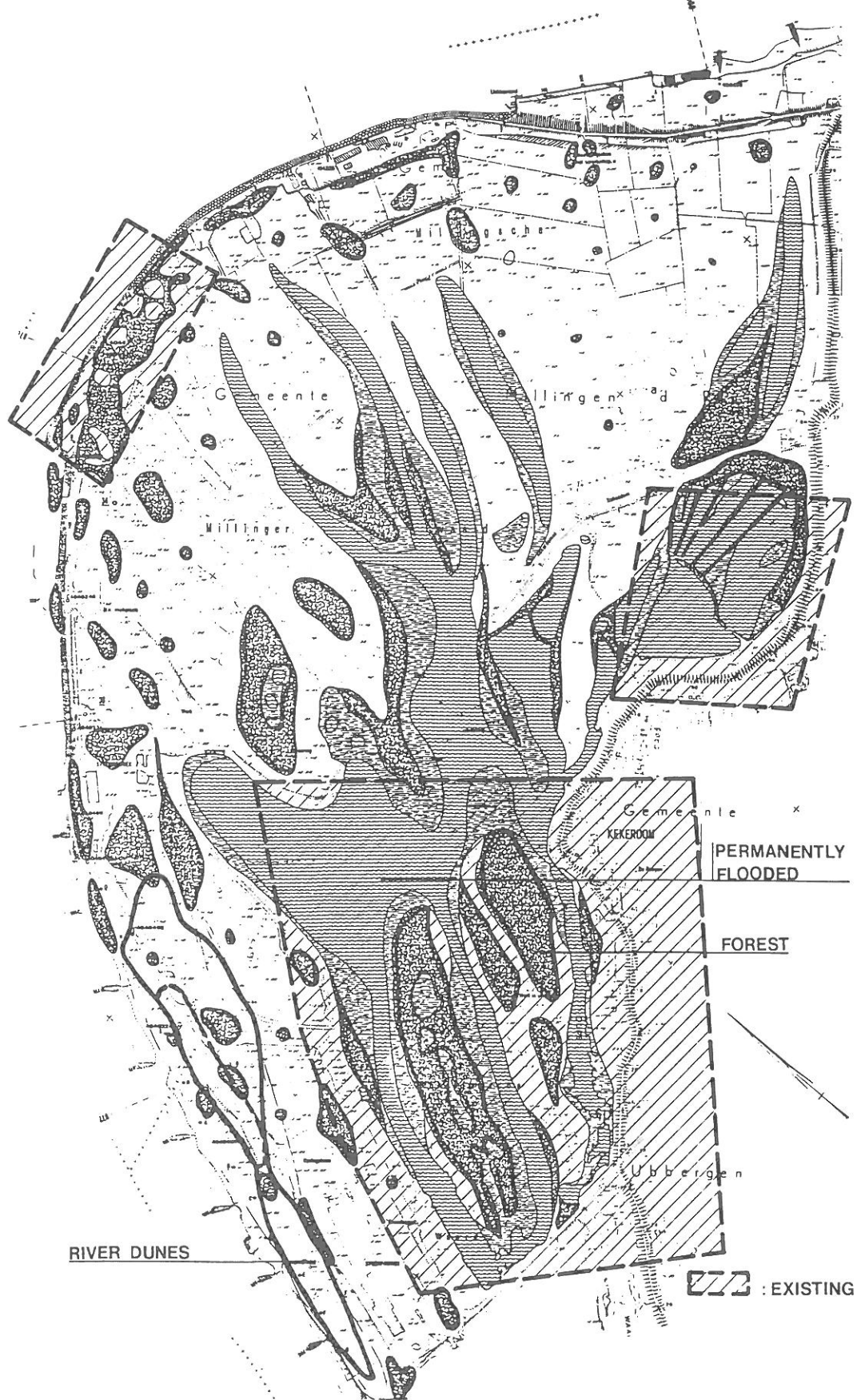


Fig. 3 Millinger Waard project

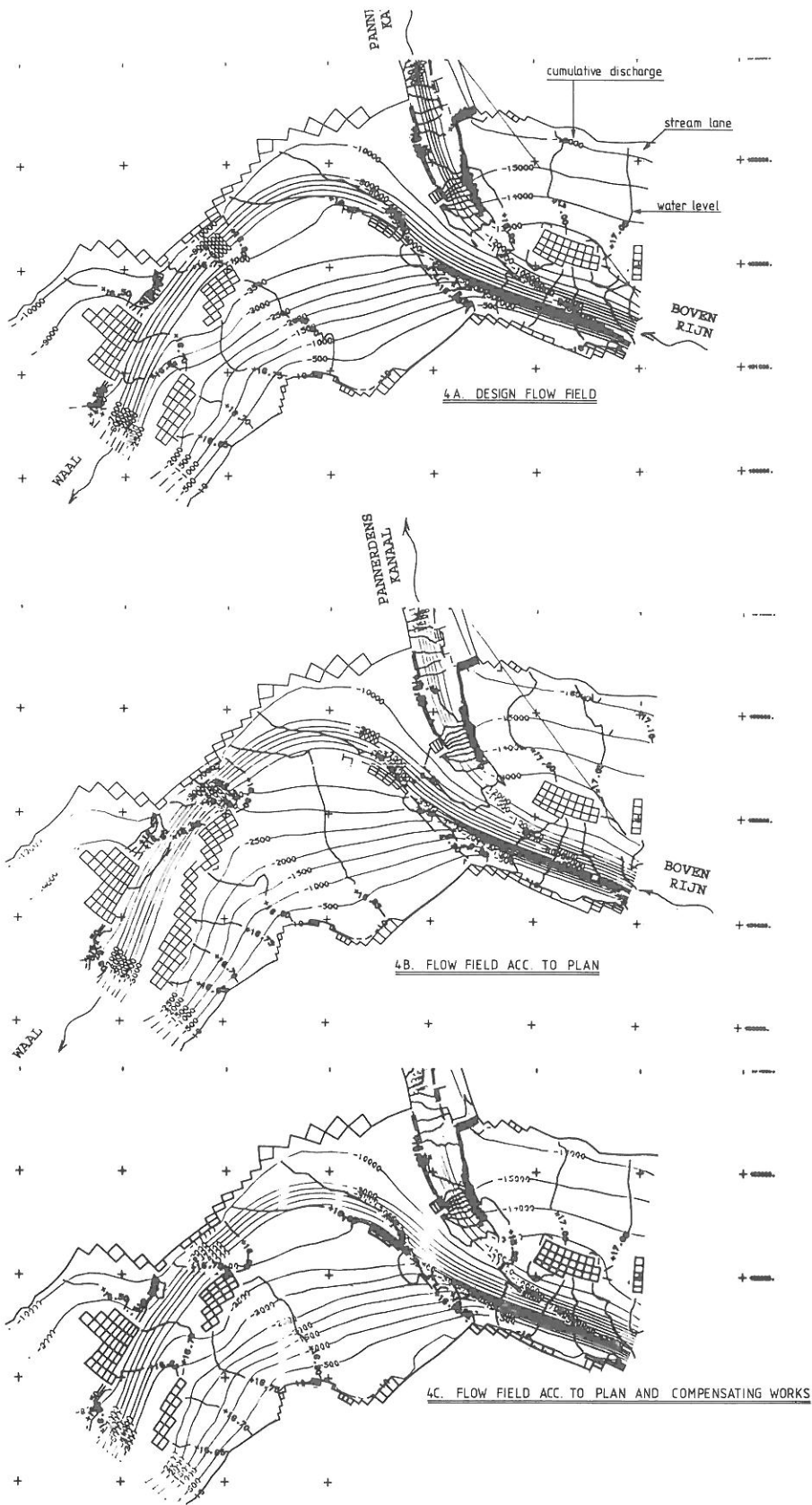


Fig. 4 Millinger Waard flow fields

The Fort St. Andries project

Fig. 5 presents a very rough sketch of this project. From a river engineering point of view the lateral channel is very interesting. Because of uncertainties regarding morphological behaviour and thus potential hydraulic dangers, such features have been banned from the Millinger Waard project, situated immediately downstream of a bifurcation. Through the Fort St. Andries pilot project it is tried to gain experience on the character of lateral channels.

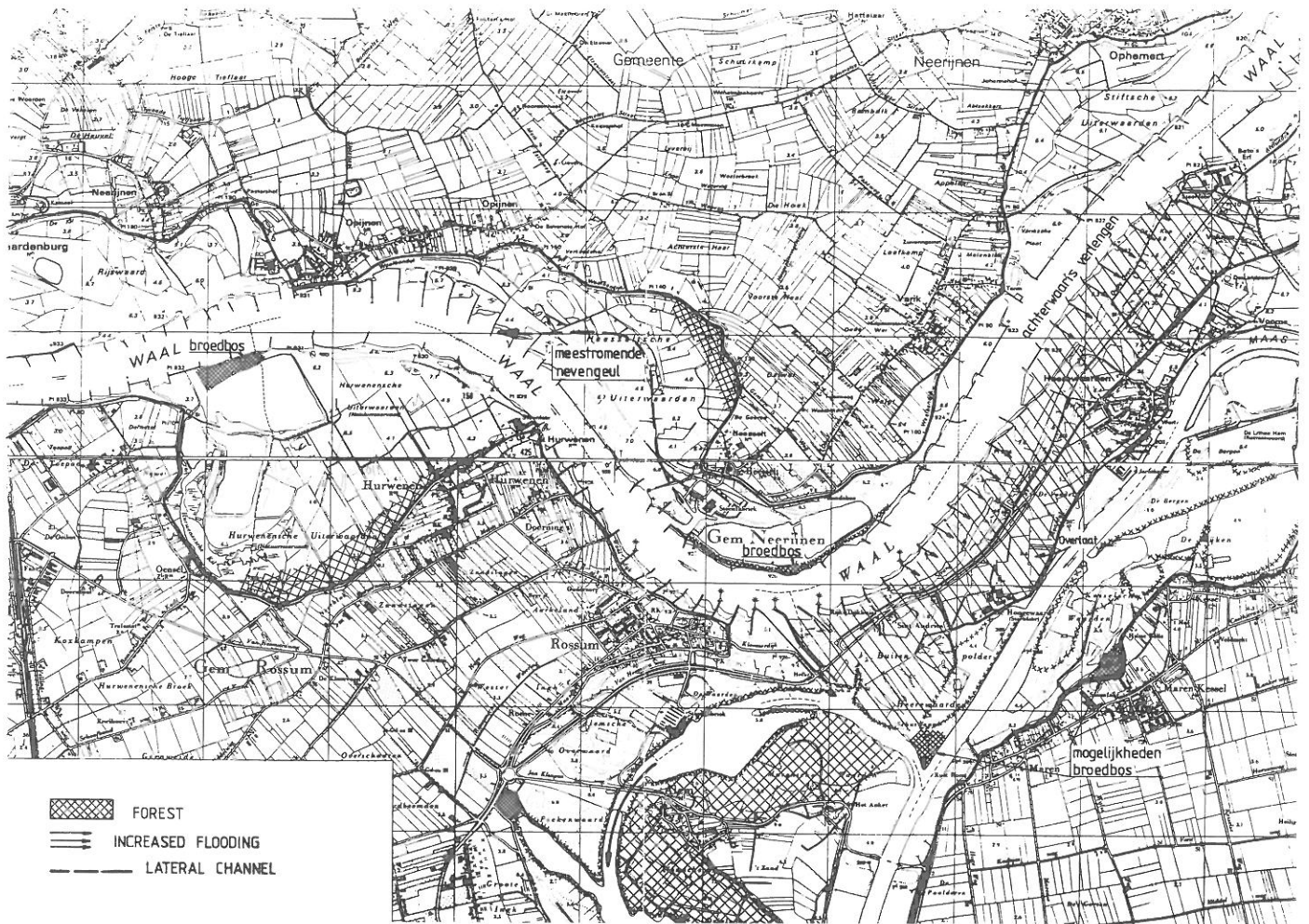


Fig. 5 Fort St. Andries project

Major ecological demands on a lateral channel are:

- quasi-permanent flow
- always wet: depth more than 0.5 m
- small flow velocities, less than 0.5 m/s
- gently sloping banks (1:30)
- preferably meandering with deep and shallow reaches.

Major boundary conditions arising from river administration:

- stability of dikes, banks and groynes must be assured
- location of lateral channel should be controllable
- no reduction of safety of navigation
- no reduction of economic importance of the river for navigation, so no reduction of the LAD (Least Available Depth).

With the above conditions the design of a lateral channel can start. The hydraulic design of the lateral channel determines the morphological impact on the minor bed. Aggradation of the minor bed may turn out significant for the LAD between the important port of Rotterdam and the Ruhr area, the major destination for Rhine navigation. Depending on the local situation and general river administration policies, measures are required to counter-attack potential aggradation of the minor bed. Measures can be: raising the summer dike, narrowing the minor bed, reduction of discharge through the lateral channel. These hydraulic and morphologic analyses have to be carried out before the ecological lay-out can be further elaborated.

The full impact of lateral channels is still not understood satisfactorily. Research has to be started in the following fields related to lateral channels:

- sediment transport
- stability and meandering potentials
- effects of major floods.

Investigations in the field and development of 2-dimensional mathematical morphological models, for forecasting morphological changes in the floodplains, may provide more knowledge of the behaviour of the river system equipped with lateral channels.

SUMMARY AND CONCLUSIONS

The lay-out of the Dutch Rhine-system has historically been determined by the primary function SAFETY AGAINST FLOODING and the functions AGRICULTURE and NAVIGATION. The originally abundantly present function ECOLOGY has suffered from the attention given to the other functions. This can be explained considering the different demands that are posed upon the system. Today the ecological function must be restored as much as possible, taking into account other interests. The local situation and the weighing of interests shall define the basic dimensions (length, depth, thalweg) of the lateral channel. This requires a good insight in ecological and morphological developments, which define future hydraulic situations. Pilot projects in the Netherlands are set up to gain relevant experience.

WORLD WILDLIFE FUND REANIMATES DELTA OF RHINE

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IN 1991 THE WORLD WILDLIFE FUND (WWF) HAS STARTED SEVERAL PROJECTS FOR REHABILITATION OF FLOODPLAINS IN THE TOP OF THE RHINE DELTA.

The river Rhine reaches the German-Netherlands border in a region called the Guelderland Fork, 'Gelderse Poort'. This is the place where the Rhine divides into Waal and Nederrijn, and a few kilometres downstream it divides into Nederrijn and Ijssel. The name Gelderse Poort is associated with the geological situation in which the Rhine has broken through the ice-pushed ridges of Montferland and Nijmegen-Kleve.

In this area the WWF has started up 20 projects, in order to accelerate the ecological rehabilitation of the Rhine ecosystem in Germany and the Netherlands. From Emmerich and Kleve to Arnhem and Nijmegen river engineers and ecologists, citizens and politicians are invited or already involved to observe the first live results of active restoration of nature on river banks. The WWF stimulates a large expansion of wetland reserves in the Rhine floodplain between 50 and 100 square kilometres in the Gelderse Poort area.

Starting up with the 'Blauwe Kamer' project

A similar but smaller pilot project which was partly supported by the WWF is the 'Blauwe Kamer Riverbank reserve'. It is initiated and realized by a Netherlands private nature conservation organization 'Utrechts Landschap', between 1989 and 1992. The Blauwe Kamer is a floodplain along the Nederrijn between Rhenen and Wageningen. In this reserve conditions were created for natural regeneration of wetlands, which are directly influenced by the river water. In July 1992 the summer dike was cut, which used to prevent inundation during slight high waters. Natural grazing with cattle and wild horses is introduced to differentiate the structure of the vegetation. Regeneration of alluvial forests is an important aim in the grazing regime.

The rehabilitation of 'de Plaat', an islet in the Waal river

In the Waal river there was a willow remainder of an islet, situated 10 km downstream of Nijmegen at Ewijk. In 1988, the whole islet was levelled for sand exploitation and because of the growing hydraulic resistance in the winter bed of the Waal. The whole area was destroyed. However, the Ark foundation was going to investigate the development of nature from that moment. But first they had to make an agreement with the local farmer, to stop the agricultural use.

The outcome proved to be spectacular: many plants which formerly could settle on the islands, sandbanks or river banks in the floodplain, had suddenly returned. More than 250 plants were found in the first season. Now, after three years, parts are covered with softwood forest with Willow and Black Poplar.

Initiatives for the revival of river systems

In 1986 'Plan Ooievaar' presented a new vision on the future of the Netherlands rivers area. The most pregnant idea was to liberate nature from agricultural traditions and other influences. A large-scale separation of agriculture and nature was suggested, specially in the floodplains because of the ideal circumstances for regeneration of natural processes which still occur. The first is the flooding of the river with its hydrological and morphological phenomena. The second is the process of natural grazing, from Grey Goose to Elk, because of the luxuriant vegetation in the river valleys.

An important role can be played by the mining of minerals, gravel, sand and clay. If optimal methods are used, large-scale regeneration of nature in the floodplains is possible. This is already practised in the Gelderse Poort.

The WWF has initiated projects in the Millingerwaard (Waal) and Meinerswijk (Nederrijn) where natural grazing with Konik horses and Galloway cows takes place. People can walk around in the reserves without restrictions. This is to improve the public awareness of the importance of rehabilitation of original nature in floodplains. Too many people in Northwest Europe have grown up with the idea that nature is far away and that nature is closed up behind fences, only accessible to hunters, fishermen and biologists. Nature is not as fragile and dependent on human interference as it seems, which must be proved in practice.

Specially the role of grazing animals in these projects is pointed out. The enormous biomass production attracts herbivores, from algae eating water insects and fish to Grey Goose, Beaver, Row Deer, Cow and wild Horse. Regeneration of nature without following this second principal natural process means less efficiency in the regeneration of the ecosystem. The transmission of biomass production into protein is the basis for a great number of organisms. In the ecological rehabilitation of floodplains all room must be used for this, from the bottom of the river to the winter dike.

The WWF will start round trips on the river, to involve people in this nearby West European nature. Observation houses will be built at strategic positions in nature reserves. River floodplain has been bought for grazing projects, and horses and cows are already living there. Studies are carried out on re-introduction of Row Deer, Beaver and Elk, even of the European Sea Eagle and last but not least the Sturgeon.

POLICY ANALYSIS FOR THE REHABILITATION OF THE GEMENC FLOODPLAIN, HUNGARY

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INTRODUCTION

The Gemenc Landscape Protection Area is a Danube floodplain area of outstanding natural beauty and important natural resources, but with seriously conflicting interests. In the Gemenc Floodplain (figure 1), which is for the largest part forested still remnants of the former natural river fringe hardwood forests are present. Gemenc is one of the 36 Landscape Protection Areas of Hungary with a large game stock of Deer and Wild Boar. It offers unique habitat for species as White-tailed Eagle, Black Stork and Saker Falcon.

Since the last century river training works have aimed at flood protection, better navigability and prevention of ice jams. Lower stream velocity in the abandoned side arms and cut-off bends have led to siltation and temporary eutrophication of the side arms. Higher stream velocity in the main channel has led to its deepening and dessiccation of the whole area. Besides, the forestry and hunting practices in the Gemenc area have imposed pressure on the natural floodplain ecosystems and associated water management. Also recreation and commercial fisheries play a role in the area. These developments resulted in a situation which from a nature conservation point of view is far from optimal.

These problems have led to the question how to create proper conditions for regeneration and restoration of the natural ecosystems of the Gemenc floodplain area in such a way that the remaining functions of the area are not affected unduly. Because of the complexity of this question, and the different interests involved, it was decided to start the restoration of the Gemenc Floodplain with a Policy Analysis. This study was started in April 1992 and is now being executed as a joint endeavour of Netherlands and Hungarian institutes, i.e. RIZA (Institute for Inland Water Management and Waste Water Treatment), DELFT HYDRAULICS in the Netherlands and VITUKI (Research Centre for Water Resources Development) in Hungary. The advantages of this cooperation are twofold: for the Hungarian counterpart the policy analysis methodology is a relatively new phenomenon and for the Netherlands Government the experience gained in the Gemenc project can be of great importance for its new approach to river management in the Netherlands. RIZA and VITUKI already cooperated in the field of water management since 1985; the last two years on integrated river management.

STUDY APPROACH

There are at least 6 different interests involved in the Gemenc area: i.e. river management, nature conservation, forestry, hunting, fisheries and recreation. Each of these interests is represented by an official or unofficial kind of organization, e.g. the Regional Water Authorities, the various Ministries, municipalities and societies. The different administrative units, the large numbers of parties involved and the differences in interests result in a complex and difficult decision making process. A policy analysis study can help to structure this process. The advantages

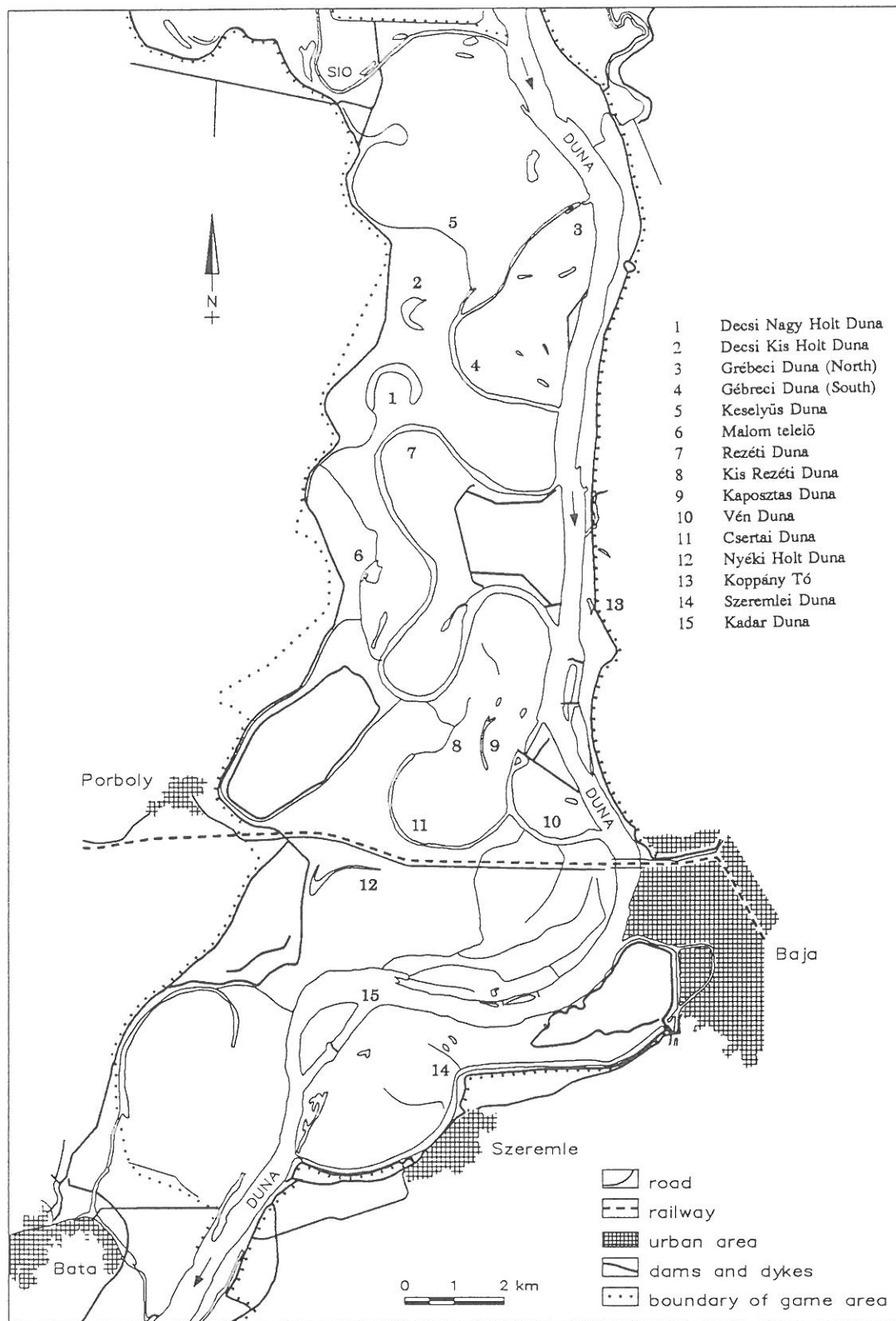


Figure 1 Map of the Gemenc floodplain (adapted from Rademakers, 1990).

of this policy analysis approach are: an objective description of the problem situation and possible solutions, insight into the most effective and efficient measures and an unbiased description of their side effects. This information should enable the competent authorities to make a well-based decision on the future of the Gemenc area. The study itself does not decide: the purpose of policy analysis is to support policy decisions, not to replace the decision makers.

The project approach is characterized by an *identification phase*, a *development phase*, a *selection phase* and a *presentation phase*. In the Identification phase the problems are identified and an initial analysis is made of the cause-effect relationships for the decision situation. In the Development phase solutions are developed to solve the identified problems. The Selection phase comprises analysis and evaluation of possible solutions, followed by selection of a single or several acceptable solutions.

A decision process is not a simple sequence of steps. Inherent in a decision process are factors causing the decision-makers to return to earlier phases of the decision process. Similarly, the policy analysis is characterized by the occurrence of cyclic processes: *comprehension cycles* to improve the understanding of the problem, and *feedback cycles*, when solutions fail to meet minimal standards and new solutions need to be designed or found.

In figure 2 a schematic presentation of the policy analysis is given. The three elementary phases are distinguished and the interaction with the decision maker, which is essential throughout the process is indicated by a bar at the bottom of the scheme. The identification phase is generally referred to as the inception phase of the policy analysis study. In this phase distinction is made between the initial analysis, leading to a problem definition, and the set-up of the approach. The output of this phase is the *Inception Report*.

The development phase comprises two blocks of project activities: data collection and modelling; and a preliminary analysis of measures and strategies. The interaction between the two blocks is cyclic, to emphasize that the analysis has to be tuned to the development of management strategies. The interaction with the decision maker is structured, discussions will be based on the publication of *interim reports*.

In the selection phase a limited number of *strategies* will be selected for detailed analysis. Strategies are a combination of promising measures, which together are supposed to be able to fulfil one or more planning objectives. A strategy for the improvement of the water quality in the backwaters of the floodplain could for instance comprise a combination of dredging, the removal of barriers, the connection of several oxbows with each other and a reduction of waste loads.

Strategies will of course only be defined after consultation with the parties involved. The effects of the different strategies will be assessed under various scenario and system assumptions. This will result in a matrix of strategies versus environmental and other side effects. For example, a strategy could be analysed in the supposed absence of any increase in recreation, commercial forestry or fisheries in the area. On the basis of this matrix the competent authorities can decide on the development desired and consequently on the measures to be taken.

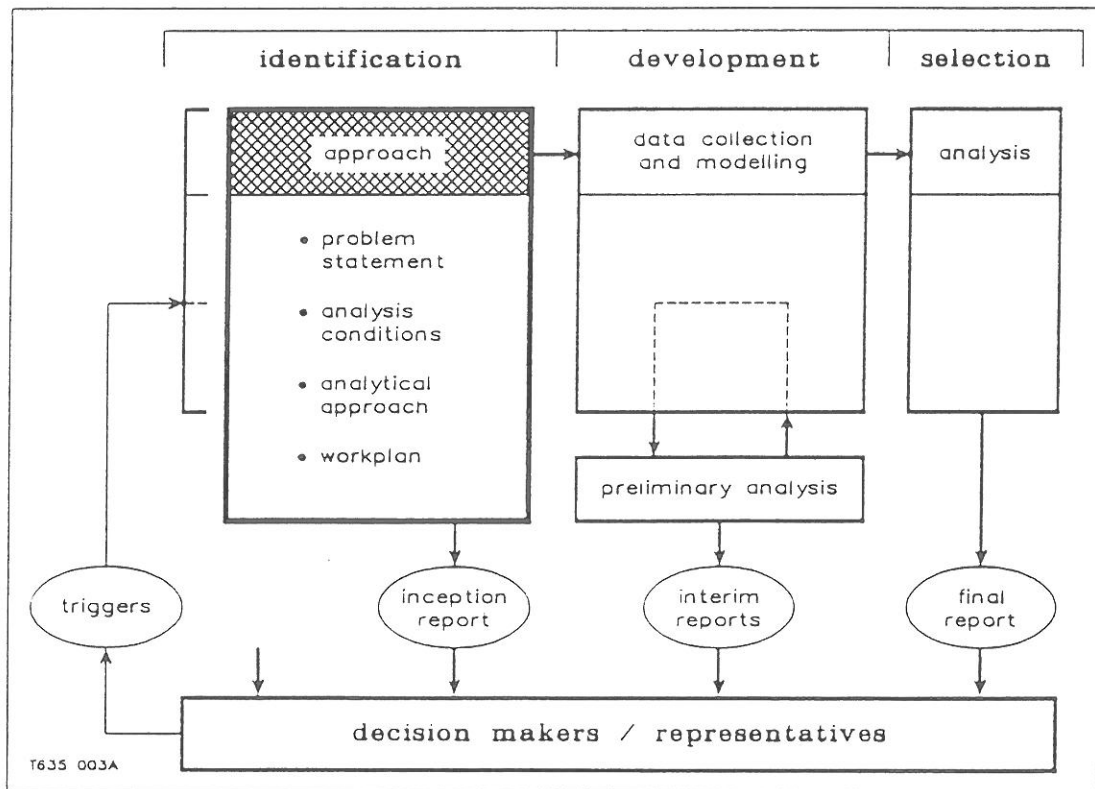


Figure 2 Schematic presentation of the steps in a policy analysis

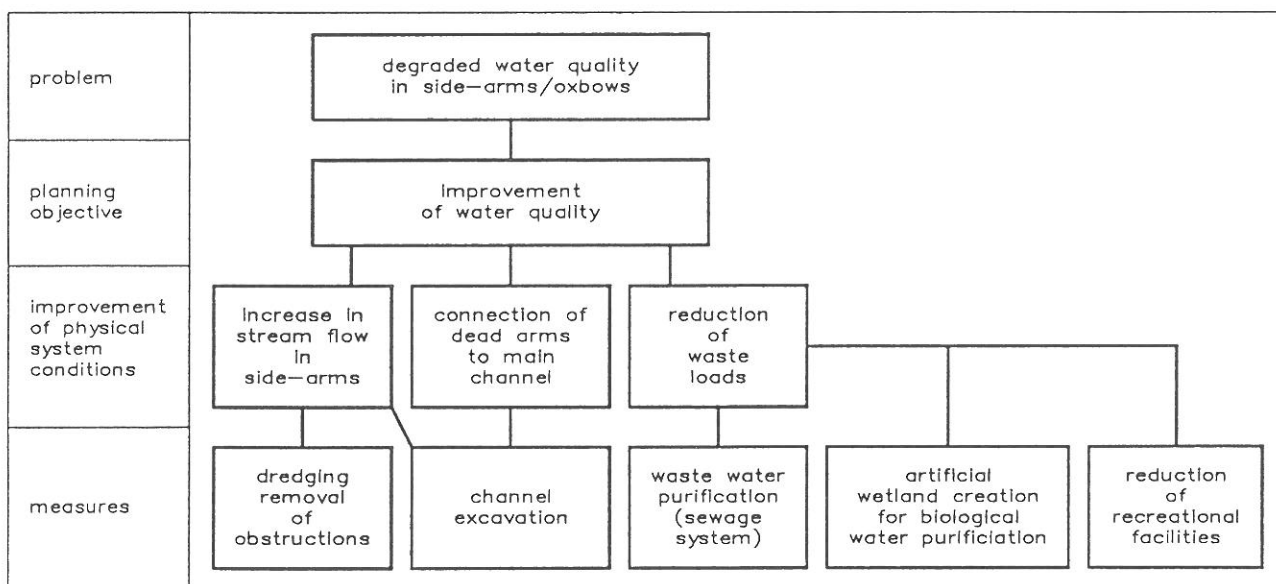


Figure 3 Example of a planning objective and related measures

PROBLEM ANALYSIS

The problems in the Gemenc floodplain can be grouped according to the components of the hydrological system, i.e.: the main channel, the side-arms/oxbow system and the floodplain proper. Besides there is a number of related problems, which do not directly relate to the hydrological system. In table 1 the main problems which have been identified so far are presented.

MAIN CHANNEL	<ul style="list-style-type: none">- river bed degradation (increased stream velocities due to river training)- lateral channels (near islands) obstructed- potentially polluted sediments
BACKWATER SYSTEM	<ul style="list-style-type: none">- degraded water quality- siltation- habitat loss for fish
FLOODPLAIN PROPER	<ul style="list-style-type: none">- groundwater lowering / dessication of forest- obstruction of floods by bunds, dykes and railway
RELATED PROBLEMS	<ul style="list-style-type: none">- uncontrolled recreational activities- forestry activities- excessive game stock

Table 1 Gemenc floodplain problem analysis

River bed degradation:

In the interest of flood control flood levees were built and meanders were cut off along large stretches of the Danube, thus shortening the main channel of the river. The higher flow velocities resulted in the accelerated scouring of the river bed along the trained river reaches. Due to this effect the training projects failed to meet the requirements of navigation. This raised the need of training the main- and low-water channels as well. These training works concentrated exclusively on the main channel and consisted of the construction of parallel and transverse structures and of implementing additional cuts. This resulted in the creation of uniform navigation channels, but induced further scouring as well, especially in the alluvial bed, producing not only obstacles to navigation, but also the lowering of the groundwater table in areas flanking the river [Hajós, 1992].

Long term time series of the lowest annual water levels at all the gauging stations between Dunaföldvár and Mohács indicate a decreasing trend of about 1.5-2.0 cm/y. This indication of riverbed degradation has been induced by former river training works, as described in the previous paragraph, and in the last decades by gravel mining activities [VITUKI, 1991].

In the interest of international navigation, channel conditions must fulfil the requirements, formulated as the 'proposals' of the International Danube Commission. The dimensions of the shipping route are related to the levels of the navigational low-flow (NLFL), where $Q = 1040 \text{ m}^3/\text{s}$ at Baja [VITUKI, 1991].

Obstruction of lateral channels in the main channel:

In the Gemenc stretch of the Danube, a number of small islands are present, of which Kádár Island is the major one. The free river flow in the lateral channels (such as Kádár Duna) along

these islands is hampered by dam structures.

Degraded water quality of side arms and oxbows:

In the Gemenc area 15 ancient stream beds interweave, which represent five different water types [Hajós, 1992; Rademakers, 1990]. Water quality measurements in two of the side arms of the Gemenc area, the Rezáti and Vén Duna, show that nutrient concentrations (N and P) are quite high, (above 1 and 0.1 mg/l, for total N and P, respectively). These concentrations evidently lead to eutrophication and the excessive growth of algae in periods of low flow [VITUKI, 1991].

Siltation of side arms and oxbows:

During the past decades many of the side arms, including the large Rezáti and Vén Duna, have started to silt up. The inflow of water became more and more restricted, esp. in dry seasons. Concurrently river engineering works were executed, including the cutting off of a number of meanders. Factors involved in the siltation process include: the river training works, the lowering of the river bed, occasional filling and natural processes.

In general, the consequence of the siltation is a reduced water flow, leading to water quality problems and even periodically drying out of some side-arms.

Groundwater lowering/dessication of forest:

Due to the river bed lowering also the groundwater tables are supposed to become lower. There is some confusion, however, whether or not this has resulted in adverse effects on the forest vegetation. Richnovsky [1989] reported the disappearance of several aquatic plant species and the appearance of drought-resistant species (viz. *Lamium purpureum*, *Solidago virgaurea* and *Asclepias syriaca*) which might indicate dessication problems. Although at some places the forests seem to suffer from dessication, this might be attributable to the fact that tree species (viz. poplars) are being planted on higher (and drier) grounds where they would not occur under natural circumstances. Unfortunately, time series of groundwater levels are largely lacking.

Obstruction of floods:

The construction of flood control dikes, roads and the railway hampers the free flow of water during inundation. Some parts of the floodplain thus became isolated and at other parts the flooding frequency has decreased.

Uncontrolled recreational activities:

Most of the recreational areas are situated on the left bank and are the result of uncontrolled building of weekend cottages. From an ecological point of view the problems related to these areas are mostly local (disturbance, rubbish dumping, wastewater discharge, visual hindrance). Further expansion of these resorts has been stopped by the competent authorities, but a satisfactory improvement of the situation has not yet been reached.

Forestry activities:

From an ecological point of view, forestry activities with purely productive objectives have quite a number of negative impacts. Most evidently, the replacement of natural forest cover with monocultures of poplars and other fast-growing trees, causes a major decrease of the ecological value. Furthermore, the forestry activities like cutting and transportation cause a disturbance. The infrastructure needed for the transport (roads and dams) hampers the flow of inundation water. And finally the fences around newly planted plots form an artificial barrier for animals.

Excessive game stock:

Long ago the Gemenc forest belonged to the continuous forest system of the Hungary Danube valley. The migration of animals was not hampered and human activities were restricted to limited hunting and fishing. The construction of the flood control dikes and the placement of fences on the border of the agricultural land isolated the Gemenc forest from the surrounding area. At the same time the deer stock was purposefully increased for hunting purposes. This resulted in a situation in which the deer stock exceeds the natural carrying capacity manifold. The effect of the high wildlife density is clearly visible from the lack of natural forest rejuvenation at many places.

STRATEGY DESIGN

'Restoration' implies the reconstruction of a past situation: i.e. before major river training works have altered the water flow drastically. Hence, as a starting point for the formulation of planning objectives, an accurate description of this past situation in ecological terms is needed. The description of this so-called *reference situation* is usually based on a combination of historical research and comparison with other - less disturbed - floodplain sites, such as undisturbed parts of Tisza.

The reference situation refers to idealistic ecological conditions. However, many things have changed since then, which makes the complete return of the Gemenc area from say 100 years ago unrealistic. Therefore we should aim at developing a feasible set of planning objectives: the *restoration plan*.

Main objectives of the restoration plan include:

- improving the ecological equilibrium of the ecosystem;
- improving the water quality in the floodplain water bodies;
- reversing the dessication of the floodplain forests;
- restoration of the natural alluvial processes and original riverine habitats.

Development of the restoration plan will be based on an analysis of the reference situation and on a description of the current problems. Up till now a number of ideas have been proposed to intervene in the current hydrological and landuse situation. These ideas include for instance connecting oxbows to each other and to the main channel, dredging of side arms and adaptation of the forestry activities in the area. As the policy analysis study focuses on the water management of the area, measures which are beyond the competence of the water manager (such as forestry measures) will be taken into account in the form of scenario and system assumptions.

Taking the problem analysis as a starting point, solutions are generated as a step-by-step procedure. First for each problem a planning objective is formulated. For example, the problem of 'river bed degradation' leads to 'stabilization of the river bed' as a planning objective. This planning objective is translated in terms of improvements in the physical system conditions. In other words: how should the system be improved in order to reach the planning objective? For the stabilization of the riverbed two different approaches can be used. The river bed itself can be fixed (effect-oriented) or the flow velocity of the river can be reduced (cause-oriented). Of course a combination is also possible. Finally the measures are identified which lead to the actual improvement of the physical system conditions and satisfies the planning objective. In figure 3 an example is given which illustrates the relation between a defined problem, a planning objective and possible measures.

IMPACT ANALYSIS

The primary analysis of the impacts of the different measures leads to a first selection. Evidently, measures which do not work properly, that are technically or economically unrealistic or have major effects on other important functions should be disregarded in an early stage. This analysis will consist of the following components:

- a) screening of measures on their effectiveness (do they work?)
- b) screening of measures on their efficiency (related to costs)
- c) initial screening of impacts on other system components and related functions

The remaining measures will be analyzed more thoroughly and in relation with each other. In contrast to the primary analysis, during which the measures are screened individually, the final analysis takes into account different sets of measures, together forming a strategy for the restoration (i.e. a restoration plan). Also spatial and temporal aspects are taken into account: a strategy consists of a clearly defined set of measures, including their location and phasing.

The impact analysis will make use of different tools, i.e. a one-dimensional hydrological and morphological model of the river and its side arms, a Geographical Information System (GIS), a water quality model for the side arms and a vegetation model for the floodplain. The results of the impact analysis will be presented in a score card. This is a matrix with the various alternative strategies on one axis, and the different interests and functions of the area on the other axis. The matrix cells are filled with relative scores which are derived from the impact assessment.

The study provides for ample interactions with the parties involved. At several stages during the project, presentations for and discussions with local parties and Government officials will take place.

CONCLUSIONS

At the moment of writing of this paper, the Inception Phase of the study had just been concluded. The preliminary results of the Development Phase are expected to be available mid-September, 1992, which means that proposed measures, their effectiveness and impacts can be communicated and discussed during the Workshop in Arnhem. Also a presentation of the used tools, viz. GIS and modelling techniques is envisaged.

SUMMARY

The paper describes the set-up of a policy analysis study for the Rehabilitation of the Gemenc Floodplain along the Danube in Hungary. The main objective of the study is how to create proper conditions for regeneration and restoration of the natural ecosystems of the Gemenc floodplain area in such a way that the remaining functions of the area are not affected unduely. The study makes use of a variety of tools and methods, such as one-dimensional hydrological and morphological modelling, water quality modelling, GIS and score cards. At several stages during the project, presentations for and discussions with local parties and Government officials will take place.

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THE RELATIONSHIP BETWEEN VEGETATION AND HYDROLOGY/GEOMORPHOLOGY IN THE GEMENC FLOODPLAIN FOREST

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INTRODUCTION

The River Rhine in the Netherlands and the Hungarian lower Danube are comparable rivers [Schoor, 1991]. This in spite of their difference in the moment of the year when their high waters occur; the Hungarian lower Danube has more often summer floods.

In the summer of 1990, a Netherlands-Hungarian field survey was carried out in the Gemenc floodplain forest along the Danube in South Hungary. Rademakers [1990] has reported on it. The vegetation in the studied part of the Gemenc woods is mostly natural and not influenced by forest management. There is a lot of game in the forest; the last decades more than is natural.

During that field survey, the vegetation of the floodplain forest was described for 150 stands in nine cross sections and on a small island. 21 vegetation types are presented in a classification based on structure and species. In every stand, a ground boring has been done to describe the soil. The altitude of the cross sections was levelled and corrected for river slope and geographical situation, so the relative altitude to the gauge of Baja, which is situated in the studied area, is known for all the stands. These data, combined with daily water levels of the Danube, are used to investigate the relationship between vegetation and hydrology/geomorphology in the Gemenc floodplain forest.

METHOD

The most important ecological feature of a floodplain forest is the fact that it is periodically flooded. Altitude and geographical situation determine, together with the water levels, the inundation frequency, which is a factor often used in floodplain ecology (e.g. [de Graaff et al., 1990, Duel, 1991, Knaapen & Rademakers, 1990]). But the river determines more than flooding frequency alone. The whole geomorphology of point bars, natural levees, side channels and channel fill-ups is caused by processes of erosion and sedimentation of the river. In the Gemenc area, the geomorphology is mostly undisturbed and there are a lot of former channels, filled up or not, which have a very high impact on ecology. The filled-up former channels are lower and more clayey than their surrounding natural levees or point bars. Due to bad drainage, and relatively long inundation, the filled-up channels are mostly very wet places. When you compare a filled-up channel and a natural levee with the same altitude (and the same flooding frequency), the filled-up channel remains moist for a longer period. So, for the understanding of ecological processes as succession in the Gemenc area, it is necessary to look not only at the flooding frequency, but also at the floodplain geomorphology.

Forest management and the influence of (too) much game is not involved in the investigations.

First, the relationship between vegetation type and 1) relative altitude, 2) geomorphology, and 3) soil is statistically tested. Due to the fact that most vegetation types are based on only 4 to 7 stands, it was impossible to use parametric statistical methods. Statistical techniques, which are used to investigate the relationship between vegetation type and relative altitude, are Kruskal-Wallis analysis of Variance and the Mann-Whitney test. From these tests follows a statistically

significant zonation of the floodplain vegetation. The relationship between vegetation type and geomorphology and soil is investigated by the Chi-square test. From these tests follows which vegetation types are related to a certain geomorphological element or soil type.

To compare the zonation of the vegetation with other research, and to use the results of this study in the Netherlands, it is necessary to relate the relative altitude of the zones in Gemenc to an independent hydrological value like inundation frequency. Due to the lowering of the water level of the Hungarian Danube and the Netherlands Rhine [Keve, 1992, van der Beek, 1990], it is incorrect to use a 90-years mean inundation frequency curve. The period 1960-1989 is long enough to exclude short-term hydrological fluctuations and not so long that it will be greatly influenced by the trend of the lowering of the water levels [Schoor et al., in prep.]. Therefore, presented flooding frequencies of the vegetation zones are related to that period.

As there is always a statistical spreading in the appearance of a vegetation type on a certain altitude, the 68% interval of the mean altitude of the stands in a zone is presented as borders of that zone. This is more or less equal to the 50% interval of the maximum and minimum altitude of the stands in that zone. Due to skewness, this interval is calculated by percentiles, and not by adding the standard deviation to and deducting it from the mean.

RESULTS - ZONATION

In the Gemenc floodplain forest, there is a statistical zonation in the appearance of the 21 vegetation types. Six zones can be distinguished. Within these zones, three to five vegetation types are represented. The four highest zones partly overlap each other in altitude (and flooding frequency). Table 1 gives an overview of the six zones with the accompanying vegetation types. The altitude of the zones, their (rounded) corresponding flooding frequency, the numbers of stands per vegetation type (n), the correlation with geomorphological elements and soil types and their minimum estimated age is also presented in table 1.

The zonation correlates with earlier investigations in the appearance of tree species in the Gemenc area [Toth, 1958].

Hardwood floodplain forest with ash (*Fraxinus*), oak (*Quercus*) and poplar (*Populus Alba*) and mixed hardwood bushes is situated in zone 1, which is flooded 8-20 d/y. Softwood floodplain forest with mainly willows (*Salix Alba*) is situated in zones 3 and 4 (flooding frequency 25-95 d/y). Rough herbage and reedland are also represented in these zones. The forests with black poplar (*Populus Nigra*) and willows are situated in zone 2, between hardwood and softwood floodplain forest and they are flooded 12-35 d/y. Willow bushes, *Carex Riparia* growth and pioneer vegetation on sand soils are represented in zone 5 (flooding frequency 95-195 d/y), while pioneer vegetation on mudflats, water vegetation and bare sand are situated in zone 6 (flooding frequency >195 d/y).

15 of the 21 vegetation types are correlated with a certain geomorphological element like point bars/natural levees on the one side and filled-up former channels on the other side. The vegetation types which are not correlated with a single geomorphological feature, are mostly correlated with a certain soil type. Geomorphologically, zone 1 is only situated on high point bars and natural levees, which are mainly composed of silt and sand. In the other lower zones, point bars, natural levees and filled-up former channels are all represented. Other distinguished features than geomorphology and soil can be age and succession stage of the vegetation, forest management and game.

zone	altitude m. Baja (68 %)	flooding 1960-1989 (d/y)	vegetation type	n	geomorphology	soil	age (y)
1	6.40-7.30	8-20	1 <i>Fraxinus Quercus</i> forest	6	point bar/natural levee	silt	35
			2b <i>Quercus Populus</i> forest with lower tree layer	6	point bar/natural levee	sand	50
			2c <i>Populus</i> forest with lower tree layer	4	point bar/natural levee	silt/sand	50
			4 Mixed hardwood bushes	5	point bar/natural levee	silt	5
			2a <i>Quercus Populus</i> forest with bush layer	4	point bar/natural levee	sand	50
2	5.75-6.95	12-35	9a grassland	2	all	all	5
			3a <i>Populus Salix</i> forest with lower tree layer	7	all	sand	40
			3b <i>Populus Salix</i> forest without lower tree or bush layer	6	all	clay	35
3	5.10-6.15	25-65	7c Rough herbage with <i>Rubus</i> and <i>Urtica</i> growth	5	all	clay	5
			5a <i>Salix</i> forest with lower tree and bush layer	6	all	clay/silt	25
			7b Mixed rough herbage	9	channel fill-up	silt	10
4	4.70-5.50	50-95	7a Reedland (<i>Phragmites</i>)	7	channel fill-up	clay/silt	10
			5b <i>Salix</i> forest without lower tree or bush layer	17	channel fill-up	clay/silt	25
			5c <i>Salix</i> forest with <i>Salix trianda</i> bushes	7	all	clay	10
5	3.50-4.60	95-195	6a High <i>Salix</i> bushes	7	point bar/natural levee	all	5
			6b Low <i>Salix</i> bushes	5	point bar/natural levee	sand	2
			8a <i>Carex riparia</i> growth	4	channel fill-up	clay/silt	10
			8b Pioneer vegetation on sand soils	25	point bar/natural levee	sand	1
6	< 3.50	> 195	8c Pioneer vegetation on mudflats	6	channel fill-up	clay/silt	1
			0 No vegetation	7	point bar/natural levee	sand	0
			9a Water vegetation	2	channel	-	5

Table 1 Zonation of the vegetation along the lower-Danube in Hungary

RESULTS - SUCCESSION

The outcomes of the statistical tests, which are presented in table 1, are interpreted to a general view on succession in the Gemenc floodplain forest. The following points have been taken into account:

- A channel fill-up can never change into a natural levee or point bar or reversely. Only lateral erosion of the banks can replace a channel and build up new point bars and natural levees.
- In the floodplain sedimentation is taking place. Due to this sedimentation, on the sandy point bars and silty natural levees, a clay cover can develop. The former channels will be filled up more and more with clay. So a sand soil can change during succession in a clay or silt soil, but a clay soil will never change into a sand soil.
- During the succession, the floodplain is becoming higher, which means that succession takes place from zone 6 to zone 1. As the zones are partly overlapping, this must not be read as a rule but as a trend.
- To get a forest with a certain tree species, that tree species has to be represented in the bushes or lower tree layer of an earlier succession stage. When there are no young trees or bushes, a forest cannot regenerate but only degrade to a rough herbage.

In table 2, these general rules are combined into a succession scheme, which gives insight into the development of the Gemenc floodplain forest and the process of succession in relation to different geomorphological elements and soil types.

a) succession on filled-up former channels

In a clayey or silty channel fill-up, first pioneer vegetation on mudflats develop, followed by *Carex riparia* growth and later on reedland. From a reedland a mixed rough herbage may develop.

On a sandy channel fill-up (which means that the clay cover is less than 80 cm) pioneer vegetation on sand soil develops first. It will be followed by low *Salix* bushes which develops in ca. 5 years to high *Salix* bush. What is then going to happen depends on the kind of species that are represented in the bush.

First possibility: few black poplar. When the former channel is filled up more and more and a clay or silt soil develops, the willow bushes will develop into a willow forest in ca. 10 years. If there was a large amount of *Salix Trianda*, which is a bush form of willow, *Salix* forest with *Salix Trianda* bushes will appear. If there is few or no *Salix Trianda*, a *Salix* bush without lower a tree or bush layer will develop from the high *Salix* bush. With further sedimentation, on the higher places the *Salix* forest with *Salix Trianda* bushes can develop into a *Salix* forest with a lower tree and bush layer (with hardwood species). It is also possible that a *Salix* forest without lower tree or bush layer develops. The three types of willow forests on channel fill-ups are not able to regenerate and when the willows die of age, the forest degenerates into a rough herbage with *Rubus* and *Urtica* growth. This rough herbage can develop into a mixed rough herbage full of species and some hardwood bushes. Maybe it is possible that from that mixed rough herbage on a silty soil, a mixed hardwood bush develops, although it is not correlated to channel fill-ups. By cutting the mixed rough herbage, it is possible that a grassland develops.

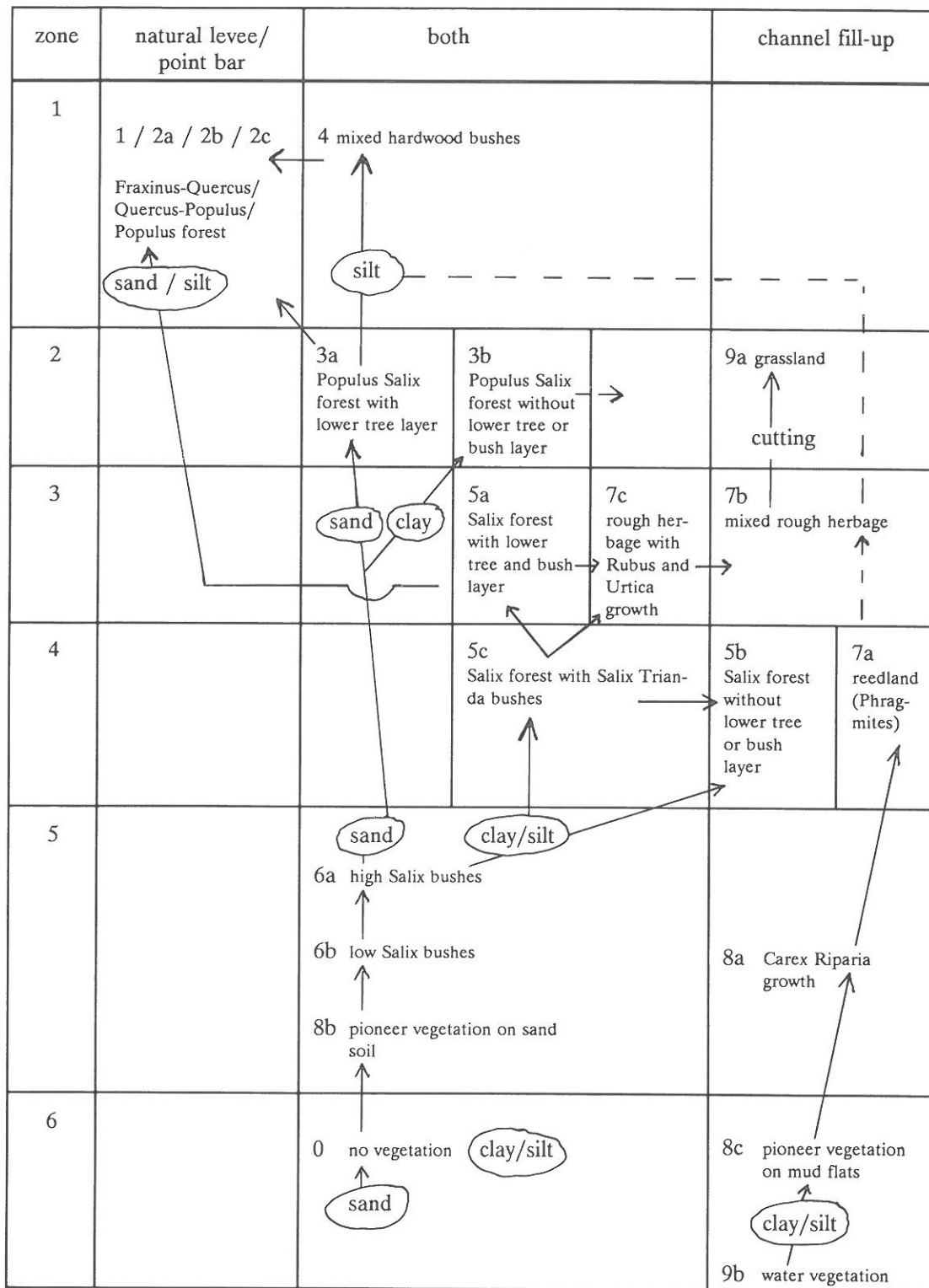


Table 2 Succession in the Gemenc floodplain forest

Second possibility: much black poplar. When the soil remains sandy, the high *Salix* bush will develop into a *Populus Salix* forest with a lower tree layer. When the soil becomes clayey, a *Populus Salix* forest without lower tree or bush layer will develop. There is one thing that has to be mentioned: it is possible that a step in the succession is missing, because it goes from zone 5 to zone 2. In zones 3 and 4 no vegetation types have been found with a certain amount of black poplar. The *Populus Salix* forests are at least 35 years old. The vegetation classification does not include a vegetation type with young black poplars. In the *Salix* bush, the amount of black poplars is also low. There is a possibility that there exists a vegetation type which belongs to zone 3 and 4 out of the cross sections of the field survey. Another possibility is that this vegetation type has been mostly cut clear and white poplars (*Populus Alba*) are planted instead.

b) succession on point bars and natural levees

On the sandy point bar, the succession begins the same as on the sandy former channel. But an important difference is the possibility to get a hardwood floodplain forest, which can only develop on high silty and sandy natural levees and point bars. To get that hardwood floodplain forest, there are three possibilities. Firstly, there is a possibility for a *Salix* forest with lower tree and bush layer on a silty soil to develop into a hardwood floodplain forest. Secondly, from the *Populus Salix* forest with lower tree layer develops a hardwood floodplain forest. And the third possibility is that from the forests mentioned as first and second, a mixed hardwood bush develops, which regenerates to a hardwood floodplain forest.

The differences between the 4 vegetation types which represent the hardwood floodplain forest are complicated. Probably they are related to soil characteristics, which are more detailed than the classification used. It is also possible that the ash (*Fraxinus*) is planted and that the white poplar forest is a secondary forest, which has developed after clear-cut. Because of the many uncertainties in this matter, the four vegetation types are put together as hardwood floodplain forest.

CONCLUSIONS

It is possible to come to a zonation of vegetation types and to a hypothesis of succession in a floodplain forest by means of statistical investigations. Not only zonation due to inundation tolerance, but also geomorphology and soil play an important role in succession in the Gemenc floodplain forest. It teaches us what parameters are important in the succession from pioneer vegetation to hardwood floodplain forest. This can be very valuable in the ecological rehabilitation of floodplain forests. The calculated inundation tolerance of the vegetation types in the 6 zones can also be used in floodplain restoration plans along the River Rhine in the Netherlands.

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ECOLOGICAL RECOVERY OF THE RIVER MEUSE IN THE NETHERLANDS

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Ecological recovery of greater or smaller rivers, be it at a national or an international scale, is of great importance in present water policy making in the Netherlands. Plans have been prepared, or are already under execution to restore rivers (locally) into their original appearance up to a certain extent. Also for the River Meuse, and particularly the - free flowing, unimpounded and non-navigable - reach: the Border Meuse (Grensmaas) between Borgharen and Maasbracht, similar plans are being developed at the moment. In this case, a unique opportunity is at hand for the joint development of ecological and natural resources on the one hand, and other water management aspects like sand and gravel mining, recreation and requirements for lessening flood problems on the other. Sand and gravel mining are strongly connected with legal obligations of the Province of Limburg, so as to meet the national needs for these substances in the future. Inundations by high floods regularly cause problems for villages along the Border Meuse.

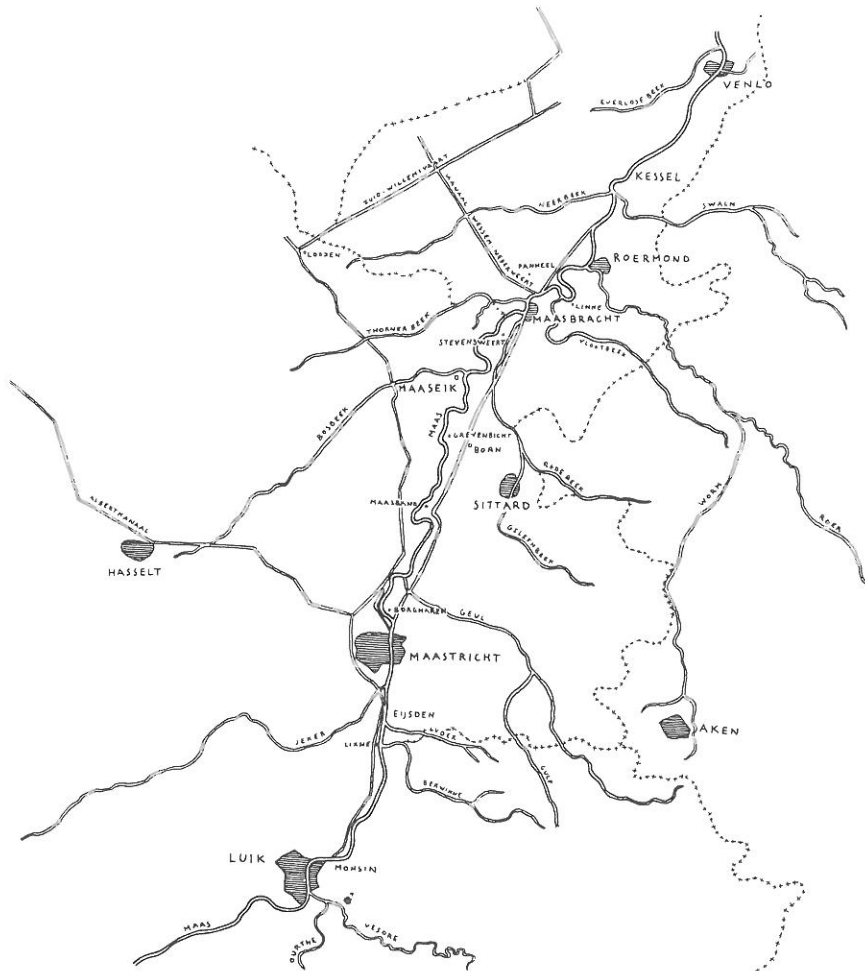


Figure 1 The River Meuse between Luik and Venlo [Helmer et al., 1991].



The River Meuse at Grevenbicht in 1849 (fig. 2) and in 1905 (fig. 3) [Helmer et al., 1991].

The Border Meuse is a river in its middle reaches, which has lost its typical characteristics in the course of time. Where in the past this river reach characteristically consisted in a system of gullies, sand and gravel banks with softly sloping floodplains (fig. 2), the consequences of on-going normalization, sand and gravel winning, and upstream water extraction have become visible more and more. Finally the river emerged as we know it at present: a river consisting in a deeply incised main channel, which only inundates its floodplain at very high floods, and which hardly carries any water in the dry season anymore (fig. 3). As a consequence the original flora and fauna have disappeared for the main part, though the deteriorating water quality of the river has played a role in that too. A first requirement for the restoration of the Border Meuse into a more natural gravel river would be to give more room to typical processes that characterize such a river, such as (free) inundation at lower discharges, and erosion and sedimentation (braiding). Strategies for realizing this are:

- Extending channel width by a factor of 2-3, by which the flow velocity diminishes, which particularly will cause more sedimentation of sand and gravel at floods (fig. 4).
- Local excavation of the floodplains in such a way as to create gently sloping plains, by which an even greater surface comes into the direct sphere of influence of the river (fig. 4).
- Dumping the (unsorted) excavated material back into the main channel, through which river morphological processes will be reactivated.

The expected result of these strategies will be that, in the long term, a wide spectrum of biotopes (channels, banks, and gravel, sand and clayey bottom reaches) will develop, which will provide ideal settlement conditions for a rich and varying flora and fauna. From the results of a preliminary study on the possibilities of ecological development in direct connection with sand and gravel winning, which has been carried out for the Province of Limburg by Bureau Strooming in collaboration with RIZA, it followed that:

- Channel widening and channel bed lowering would be effective strategies to restore the Border Meuse to a more original appearance.
- This would be possible under the (future) requirements of gravel and sand winning, in such a way that it would even be possible at a positive cost-benefit ratio.
- Execution of the plan would also be beneficial to lessening flood problems along the Border Meuse (fig. 5).
- Dumping of sand and gravel back into the main channel, by which the river bottom rises, seems to be an adequate measure to prevent (extra) drying out in the inland areas along the river.
- The prospects for development of swamp wood areas along the river and for pioneer vegetations and related fauna can be called good, when the proposed measures are carried out.
- A full recovery of the ecosystem in and along the Border Meuse, however, is not to be expected in the short term. For that, concentrations of heavy metals, PCB and PAH in the river water are still too high. Particularly fish and mussel-eating birds are expected to be at risk.
- Before starting up full execution of the recovery plan, it is recommended first to obtain experience with the practical effects of measures like channel widening, floodplain lowering and river bed raising on a small scale.

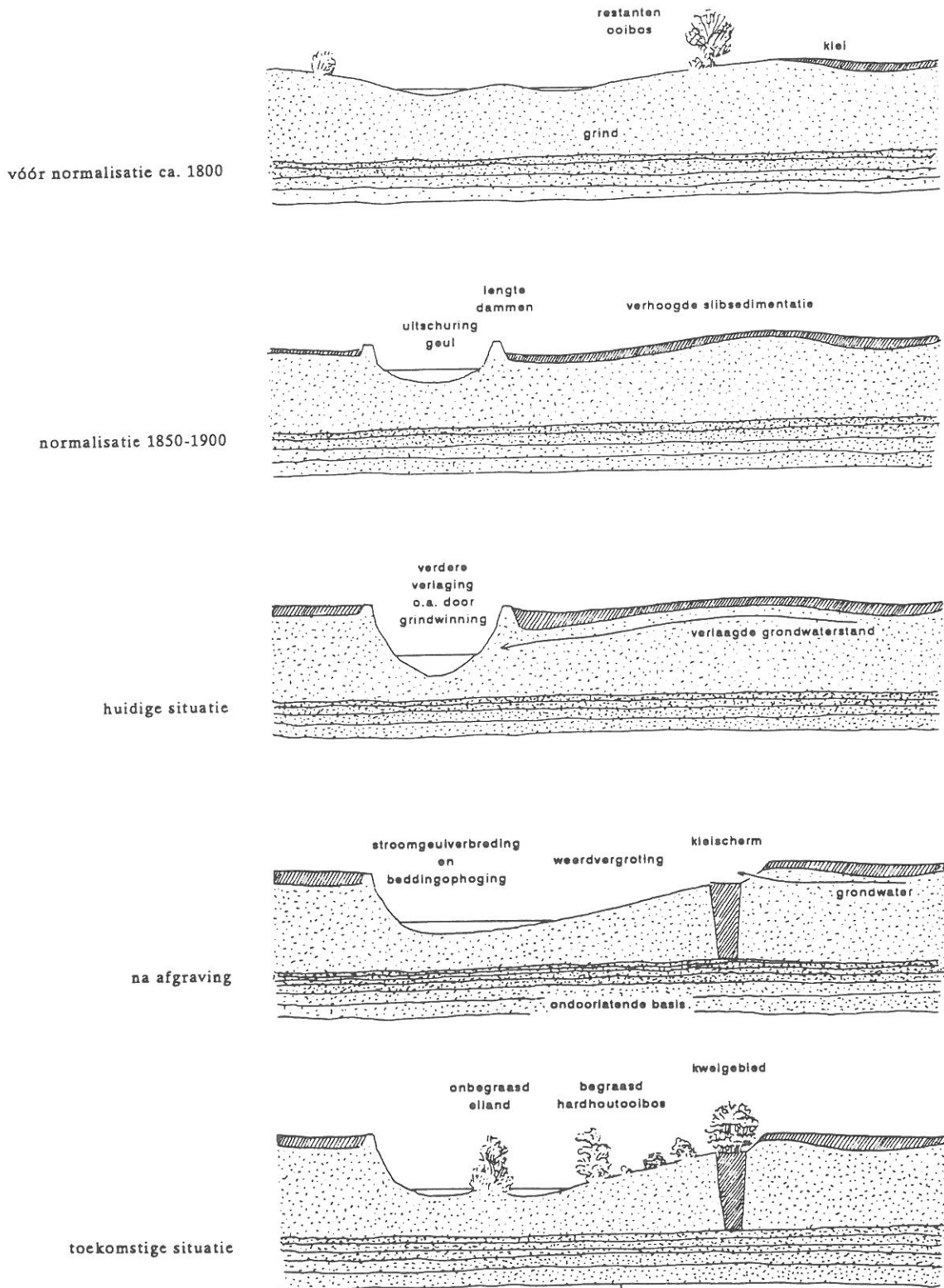


Figure 4 Nature development in the valley of the Border Meuse [Helmer et al., 1991].

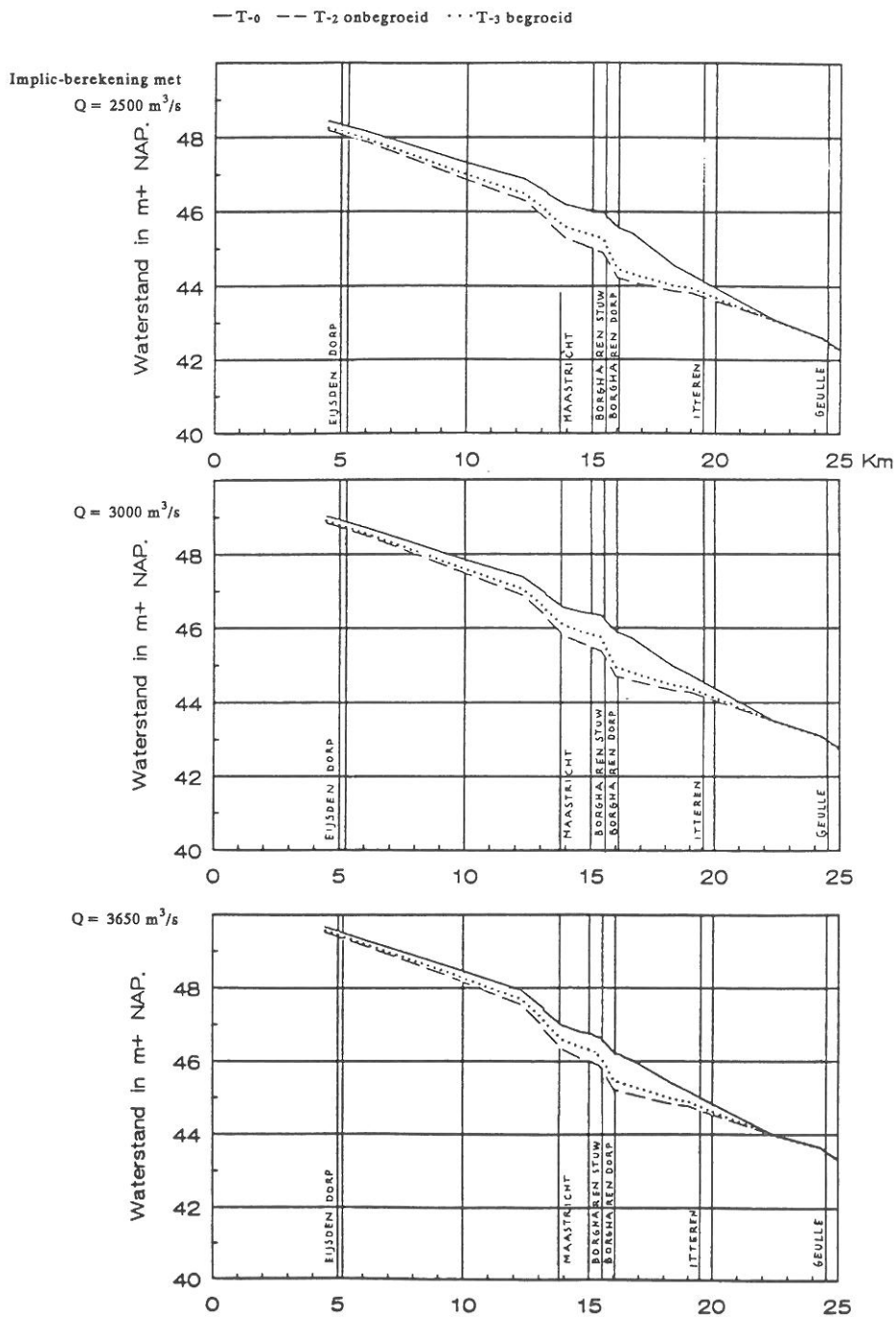


Figure 5 Water levels in the Border Meuse between Borgharen and Itteren at different discharges and in different stages of plant development (T-0, T-2 and T-3) [Helmer et al., 1991].

For the last item the necessary decisions will be made in the short term. When they turn out to be positive, the elaboration of a detailed plan - taking into account all positive, as well as negative effects - will be initiated. In view of the magnitude and the drastic character of the project, a close collaboration between governmental authorities and services at all administrative levels, as well as with other groups of interest will be necessary.

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HYDRAULIC ROUGHNESS OF FLOODPLAIN FOREST

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INTRODUCTION

For the two-dimensional simulation of hydrodynamics in complex river areas in the Netherlands, Rijkswaterstaat uses the WAQUA model system. This system will be one of the instruments for designing and checking the rehabilitation plans of floodplains.

The vegetation of the floodplains provides a very important part of the resistance of the total surface water flow. Little is known about the roughness coefficients of the floodplain, especially in the case of floodplain forest. The roughness coefficients used in practice mainly have been determined from laboratory experiments. Field data are scarce and the postulated relations and vegetation characteristics have a (maybe natural) considerable spreading. With an evaluation of field data an attempt is made for a better understanding of the flow phenomena in floodplain forests.

VEGETATION CLASSIFICATION

The vegetation could be classified into three categories dependent on the ratio between the water depth and the height of the vegetation;

- a: water depth \gg vegetation height
- b: water depth $>$ vegetation height
- c: water depth $<$ vegetation height

Vegetation in category a: could be handled in accordance with bottom roughness. Tables with calibrated roughness coefficients for different vegetation types are available [Chow, 1959].

Few studies have been done on determining roughness coefficients for vegetation in category b:. The interaction between the vegetated region and the non-vegetated region (momentum exchange) has to be described. The faster free surface flow drags the flow in the region in the vegetated layer [Nakagawa, 1992, Tsujimoto, 1990].

In category c: the roughness coefficients can be determined by the geometrical properties of the vegetation and the drag coefficient of a vegetation element. The main problem is how to calculate the geometrical properties of the vegetation and the drag coefficient of a vegetation element. This paper restricts to this problem in the case of heavily wooded floodplains.

ROUGHNESS FORMULATION

In the two-dimensional hydrodynamic simulation system WAQUA the resistance is computed by the CHEZY formula:

$$u = C \sqrt{R i} \quad (1)$$

The force due to frictional resistance on the bottom is:

$$F_b = A_{xy} \rho g \frac{u^2}{C^2} \quad (2)$$

The drag force acting on a vegetation element can be described by the formula:

$$F_v = \frac{1}{2} \rho u^2 C_d h_w d \quad (3)$$

To describe the drag force with the same formula as the resistance force equalization of (2) and (3) gives the C(hezy) value for vegetation:

$$C_v^2 = \frac{2 A_{xy} g}{C_d h_w \sum d} \quad (4)$$

The characteristics of the flow are expressed in the drag coefficient C_d and the geometrical properties of the vegetation in $A_{xy} / \sum d$.

In the literature C_d varies between 1 and 2.0 [Bretschneider, 1985, Klaassen, 1974, Van Urk, 1983]. On the basis of field experiments [Van Urk, 1983] the value 1.65 is used in WAQUA. Although C_d depends on the turbulence intensity and the position of neighbouring elements a constant value of 1.65 seems to be a good approximation.

The largest spreading has to be expected in the vegetation characteristic A_{xy} / \sum . The value varies between infinite (no vegetation) and 20 (very dense bushes).

VEGETATION CHARACTERISTICS

In literature regularly the term vegetation density is used. It is defined as the reciprocal value of the vegetation factor in formula 4:

$$\text{vegetation density} = \frac{\sum d}{A_{xy}}$$

Another occurring vegetation characteristic is the basal area defined as:

$$\text{basal area} = \frac{\sum \frac{1}{4} \pi d^2}{A_{xy}}$$

Cirkel [1991] supposed that the basal area is roughly constant for the different types of floodplain forest. In this case a unique relation could be described between for example the number of trees (branches, twigs) and the vegetation density. In fig. 1 the relation between the number of trees (branches) and the vegetation density, in case of softwood forrest, is plotted for several small floodplain forests. The data are taken from a vegetation inventory by DLO-IBN (Institute for forest and nature research). The drawn line gives the calculated relation for a basal area of $40 \cdot 10^{-4}$. The idea that the basal area is roughly a constant is hung on this. In case of hardwood the spreading is larger, the basal area is roughly equal to $25 \cdot 10^{-4}$ (figure 2).

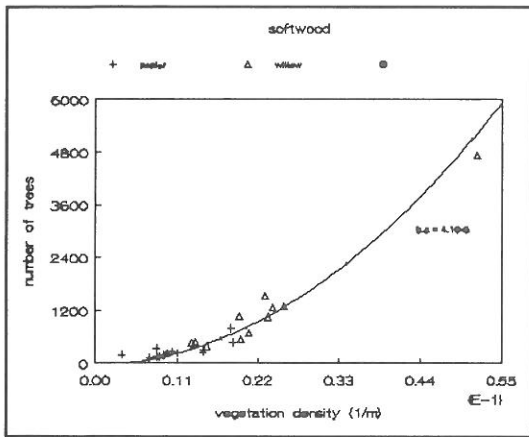


Figure 1 Relation vegetation density/number of trees (softwood)

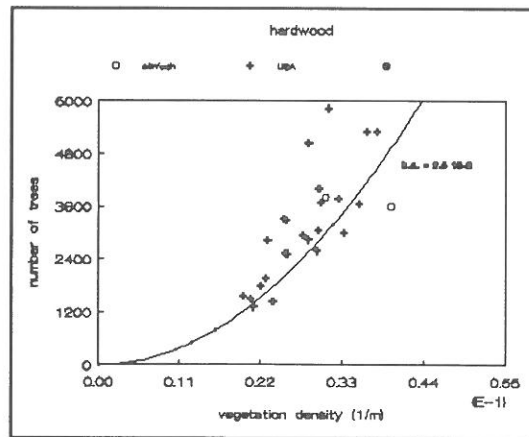


Figure 2 Relation vegetation density/number of trees (hardwood)

The domain of the vegetation density is large (0.01 - 0.055). Which vegetation density should be chosen is dependent on many factors. An important one is the age of the forest. In figure 3 the relation between the age and the vegetation density is given for the white willow. Remarkable is the decreasing vegetation density with increasing age.

The question remains if it is possible to use the vegetation density from an inventory in formula 4. If this is done, then the following roughness coefficients have been calculated at a water depth of 3 m and a drag coefficient of 1.65.:

white willow: $C(\text{hezy})$ 24 - 9 $\text{m}^{1/2}/\text{s}$
 poplar: $C(\text{hezy})$ 21 - 24 $\text{m}^{1/2}/\text{s}$

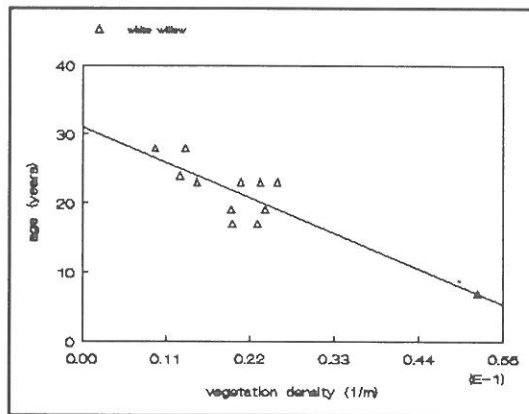


Figure 3 Relation age/vegetation density

ROUGHNESS FIELD DATA

Field data of roughness coefficients are scarce. Most of the data used in resistance formulas are based on laboratory experiments. For analyzing the roughness coefficients of floodplain forest, the following data have been used:

Arcement	[1987]	An extensive field survey in hardwood floodplain forest in the US (24 different floodplains).
Laczay	[VITUKI, 1991]	39 discharge measurements in the river Tisza (Hungary) in 1970 and July 1974.
VITUKI	[VITUKI, 1991]	3 discharge measurements in floodplains of the Danube at Baja (Hungary).

Legend:

- I Tisza 1970
- II Tisza 1974
- III different rivers USA
- IV Darube (Gemenc)

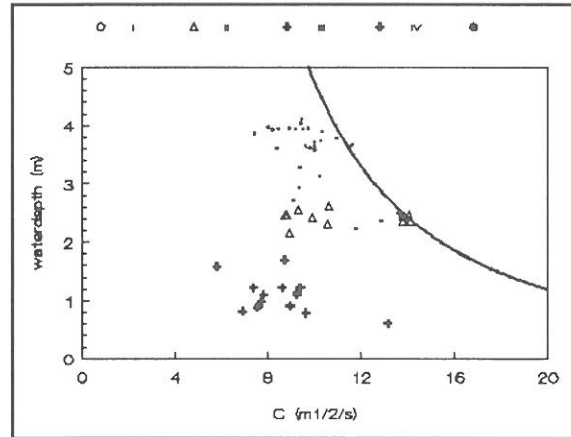


Figure 4 Measured C-values

In fig. 4 the roughness coefficients C , calculated on the basis of discharge measurements, are given as a function of the water depth. In all the cases the mean vegetation density was roughly 0.025 with a large spreading. With formula 4 and a vegetation density of 0.025, the drawn line in fig. 4 has been calculated. The differences between the calculated and the measured roughness coefficient are considerable. Causes for the difference could be:

- underestimating the vegetation density in the field probably partly caused by neglecting the undergrowth in the inventories of the vegetation density.
- surface irregularities.
- obstacles, e.g. fallen trees.
- a much larger value of the drag coefficient C_d (used 1.65).

From a physical point of view the latter is not very probable. Surface irregularities and obstacles could be important but they cannot explain the substantial difference between calculated and measured C (hezy)-values.

In accordance with Arcement [1987] for the drag coefficient, an effective vegetation density has been defined as (see formula 4):

$$veg.density * = \frac{2g}{h_w C_{meas}^2} \quad (7)$$

In fig. 5 the effective vegetation density calculated with (7) is given, computed from the data given in fig. 4. The vegetation density increases with decreasing water depth. In contrast with the results of Petryk and Bosmajian [1975], the vegetation density is not constant with the water depth. Especially at very small water depths the vegetation density increases substantially (undergrowth?).

If the drawn line in fig. 5 is used as the relation between water depth and vegetation density then the drawn line in fig. 6 could be deduced (formula 4) as the relation between the C (hezy)-value of densely wooded floodplains and the water depth.

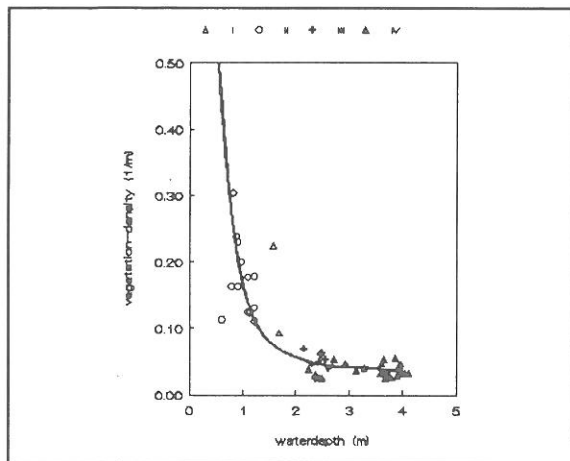


Figure 5 Deduced vegetation density

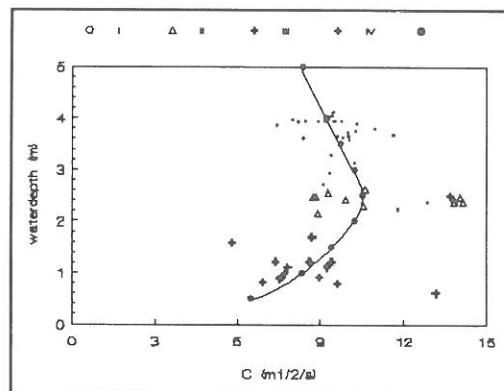


Figure 6 Calculation

CONCLUSIONS/RECOMMENDATIONS

- In the situation that the vegetation is flooded (water depth > vegetation height), there is few knowledge of the resistance due to vegetation. Further research is needed.
- The roughness coefficients C calculated with the measured vegetation density from floodplain forests (formula 4), are considerably larger than the C (hezy) coefficients deduced from discharge measurements.
- The scarce field data give the impression that the effective vegetation-density increases considerably at decreasing water depths. This is contrary to the study of Petryk and Bosmajian [1975]. They concluded a constant vegetation density at different water depths.
- More field data are needed before a reliable estimation of the roughness-coefficients of floodplain forest could be given.
- To understand the spreading in the (measured) C -values more knowledge is needed of the structure and the development stages of floodplain vegetation.

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NOTATION

A_{xy}	surface area	m^2
C	Chezy coefficient	$m^{1/2}/s$
C_d	drag coefficient	-
d	diameter of trees (branches)	m
h_w	water depth	m
F_b	force due to bottom friction	N
F_v	force due to resistance of vegetation	N
g	acceleration of gravity	m/s^2
i	slope energy level	-
R	hydraulic radius	m

GEOMORPHOLOGICAL DIFFERENCES BETWEEN RIVER REACHES: DIFFERENCES IN NATURE REHABILITATION POTENTIALS

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INTRODUCTION

In recent nature rehabilitation plans it is well accepted that on a local level the geomorphology of floodplains is an important variable in determining the potentials of nature. However, floodplains along rivers are not identical: they show an interesting variation in geomorphological pattern, among rivers and in a downstream direction as well. Therefore, this variety is also an important variable for choosing targets and locations of projects on a regional level, apart from other variables such as present nature values, land use, and developments in physical planning policies.

As part of a reconnaissance study concerning the ecological rehabilitation of floodplains in the Netherlands, the regional potentials of the natural environment for rehabilitation will be indicated. Concepts, methods and some preliminary results, mainly concerning geomorphological aspects, will be described in this paper. Final results with more emphasis on the vegetational aspects will be published in Rademakers [in prep.]. The study is financed by the Netherlands Ministry of Agriculture, Nature Management and Fisheries.

CONCEPTS

In the Netherlands large floodplains have been formed along the River Rhine and its distributaries Waal, IJssel and Neder-Rijn and along the River Meuse. Apart from the upstream part of the Meuse, these rivers originally formed an extensive fluvial environment, which can be characterized as the depositional zone of the fluvial system. During the Middle Ages the rivers in this zone have been embanked, leaving only a narrow zone of approximately 1-2 km in width to be flooded; areas which nowadays can be considered to be the floodplains of the rivers. Owing to the embankments and later canalization in the nineteenth and twentieth century the morphology of the river channels and adjacent floodplains has been completely altered, a process which is still going on. The present morphology is also severely influenced by other activities of man, of which the extraction of clay and sand for the construction industry is the most important.

The morphology of floodplains is the result of a complex interaction of several fluvial processes. In general it is determined by the stream power of the river which determines the ability to carry away and transport sediment and by the geological setting of the floodplain alluvium which determines the resistance to erosion. As a result of differences in discharge, slope and geological setting the stream power and sediment transport can differ, among rivers and in a downstream direction, so that different types of floodplains have been formed. From recent research it can be concluded that the range of processes involved in floodplain formation is very large, so that, besides the very specific types described in the early literature, there also exists a great variety of floodplain types [Nanson & Croke, 1992]. In the context of the present study it is important to realize that this is not only true on a global scale, but that even along the depositional zone of the rivers Rhine and Meuse different types can be recognized.

The development of floodplain ecosystems depends on the interrelationships between abiotic and biotic subsystems. For research and planning purposes generally a hierarchical model of

subsystems is used in which a chain of relationships can be distinguished, from the subsystem climate to the subsystems geology, relief, hydrology, soils, flora and fauna. In this sequence fauna is largely dependent on flora, flora on soils, soils on hydrology, and so on. The vegetation is considered to be the central biotic subsystem. Although in later stages of succession vegetation itself and soil development can be relevant factors in the development of vegetation communities, geomorphology can be considered to be the central abiotic subsystem, where it concerns processes and patterns on a regional level. On this level in depositional environments the relief is closely correlated to geology as they are formed by the same geomorphological processes, and next the resultant relief determines hydrological processes and subsequent soil developments. In floodplains, the influence of geomorphology on vegetation is twofold since developments are mainly determined by morphodynamics and hydrodynamics [Knaapen & Rademakers, 1990]. Morphodynamics includes the mechanical and physical influences of flowing water on substrate, vegetation and animals. These processes are reflected in the geomorphological structure. Hydrodynamics relates to the physiological or hydrological influence of water on site, vegetation and animals. It includes not only duration of inundations, but also tidal influences, chemical composition of water, turbidity of water and fluctuations in phreatic water table; variables that clearly depend on floodplain morphology.

METHODS

Since morphodynamics is reflected in the geomorphological structure of the floodplains, differences in structure are detected to give a first impression of regional differences in abiotic environment along the rivers. Geomorphological structures can be detected directly from already existing 1 : 50.000 geomorphological maps, or from soil maps on the same scale for the tidal areas which have not been mapped by geomorphologists yet. Besides information about structure these maps provide information about local land forms and deposited sediments so that processes such as aeolian sediment transport and organic deposition can also be traced. Other additional information about for instance slope, sediment texture in the river channel, and floodplain soil formation and hydrology is also used for the identification of regional variety in morphodynamics.

For each of the identified river stretches a characterization of the river hydrodynamics will be described. Next to the river regime, the most important variable that has to be traced is the duration of inundations. Information about this variable is not available but can be derived from stage/discharge relationships for each of the rivers and information about altitude of floodplains. The latter can be read from 1 : 5.000 topographic maps compiled for all floodplains in the Netherlands. For reasons of efficiency this procedure will not be executed for the complete area of the floodplains; instead only type-specific transects have been taken into account [Heinrichfreise, 1988].

Finally and again for each of the river stretches the potentials for vegetation development will be indicated. The spatial variability of each of the river stretches will be compared to the needs of specific vegetation communities. Site conditions of the floodplain vegetation are sufficiently known from literature [Knaapen & Rademakers, 1990] to be applied at this level.

PRELIMINARY RESULTS

On the basis of the most prominent differences in geomorphological structures a tentative genetic classification of floodplain types is proposed, in which the differences in morphodynamics are reflected. Some floodplain types that are readily recognized are presented in figure 1. The characteristics of all floodplain types are listed below.

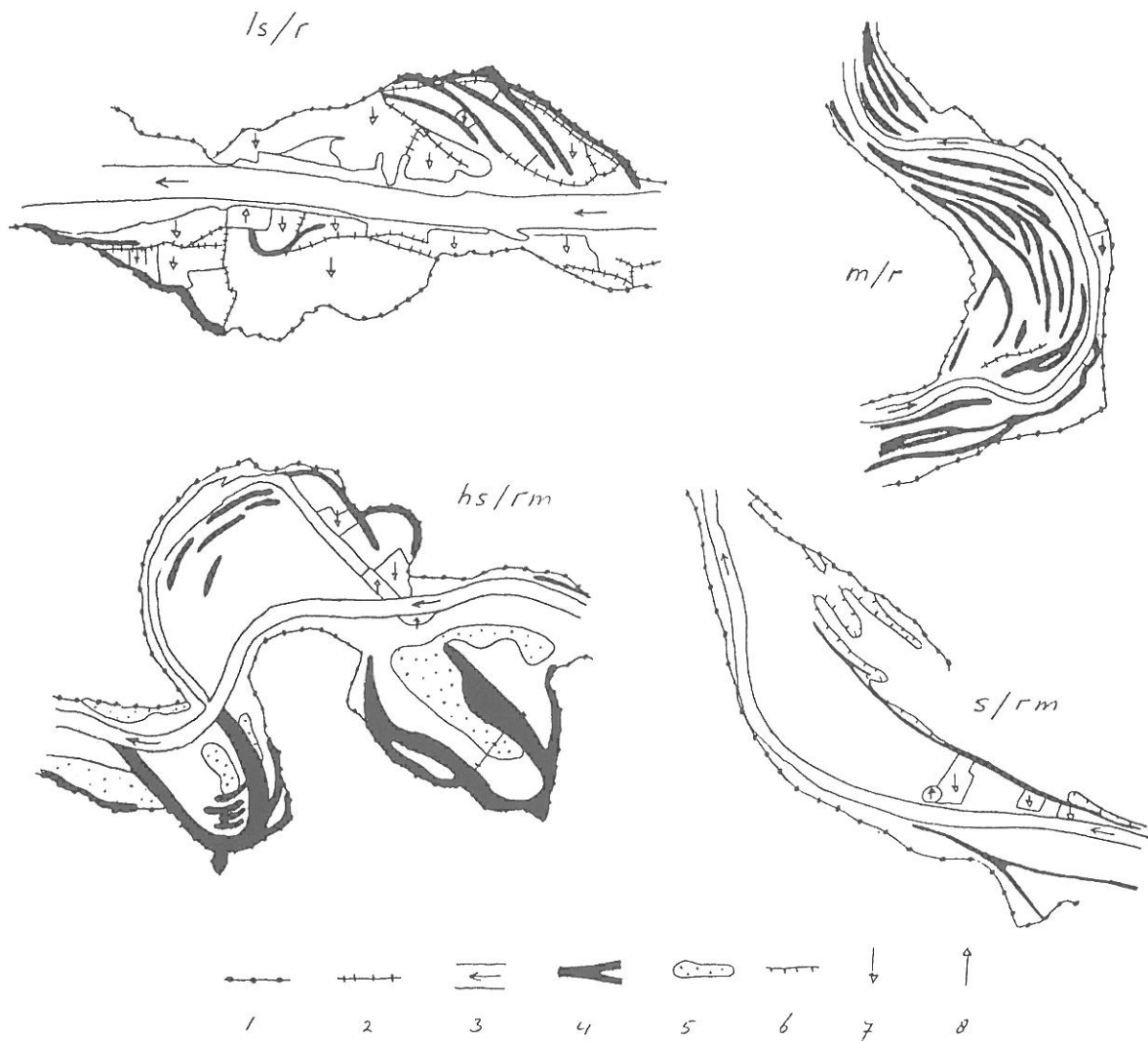


Fig. 1 Simplified geomorphological patterns of some distinguished floodplain types (1 = winter dike; 2 = summer dike; 3 = river channel with flow direction; 4 = floodplain channels; 5 = notorious floodplain elevations; 6 = terrace escarpment; 7 = clay pits; 8 = area not prone to flooding; x/y = floodplain type/floodplain regime type; see text for explanation of abbreviations)

- Large amplitude sinuous river floodplains (*la*) as can be found near Ooij. River slope is moderate. Floodplains are large and show a large variety in height as well as in land forms. River beaches, aeolian land form development on prominent levees and remnants of old river courses can be found. From their position it can be deduced that the river migrates irregularly in a downstream direction. Land forms indicate that lateral accretion as well as vertical sheet accretion are intense processes.
- Low sinuous river floodplains (*ls*) as can be found near Dodewaard. River slope is moderate. Floodplains can be small as well as large. Variety in topography is rather large: river beaches are

found along small levees with aeolian dunes; floodplain channels are found at the distal parts of floodplains. Floodplain channels are concave towards the river. The geomorphological pattern points to a longitudinal migration of the river in a downstream direction, as a result of counter-point accretion.

- *Meandering river floodplains (m)* as can be found near Doesburg. River slope is rather low, also due to the high sinuosity of the river. The complete floodplain consists of numerous ridges and swales, indicating a strong lateral migration of the river channel. Point-bar accretion is clearly the dominant floodplain forming process.
- *Gravel bed meandering river floodplains (gb)* as can be found near Grevenbicht. River slope is relatively high. Characteristics of the channel are a high sinuosity and the occurrence of gravel bars. Floodplains are moderate in width and show a ridge and swale topography. Point-bars and ridge and swale topography indicate that point-bar accretion is the dominant floodplain forming process; lateral migration of the river channel however is moderate.
- *Highly sinuous river floodplains (hs)* as can be found near Megen. River slope is rather low, also due to the high sinuosity of the river. A ridge and swale topography is found near to the convex river bends only. Some parts of the floodplains show a high elevation. The floodplain forming process is believed to be a combination of point-bar accretion inducing moderate lateral channel migration and strong sedimentation of suspended material.
- *Straight river floodplains (s)* as can be found near Cuijk. River slope is moderate. The river channel is nearly straight. Floodplains are relatively small and without prominent land forms. The very flat topography and the absence of indications of lateral channel movements indicate that sedimentation of suspended material is the only floodplain forming process.
- *Tidal island river floodplains (ti)* as can be found near Krimpen. Part of the floodplains consists of unripened soils. The topography of floodplains is rather flat. Characteristic is the occurrence of rather large islands, separated from the floodplains by side channels. Both seem to be permanent features; the river is not migrating.
- *Straight tidal river floodplains (st)* as can be found near Drimmelen. This type of river does not have floodplains with natural characteristics, in most cases because the river is man-made. Floodplains are very small and completely flat.

The distribution of these river types along the Rhine and its distributaries shows morphodynamics to decrease clearly in a downstream direction. Several floodplain characteristics are influenced by this: in a downstream direction the width of floodplains decreases, variation in topography decreases, and soil texture decreases. Along the River Meuse this kind of trend is disrupted by tectonic crustal movements.

The analyses of river regime and flooding duration provided some additional information for a further subdivision of this classification. On the basis of hydrodynamics five river floodplain regimes are proposed to be distinguished. Their characteristics are listed below.

- *Rhine regime (r)* which is the natural regime for most of the floodplains along the Rhine and its tributaries. Floodplains can be flooded during wintertime and during summertime. The flooding duration shows a large variety: extensive parts of the floodplains are flooded more than 20 (or even more than 50) days a year.
- *Meuse regime (m)* which is the natural regime for the floodplains along the Meuse. Floodplains are seldom flooded during the summer. Flooding duration is less than 20 days a year.
- *Tidal influenced regime (t)* which occurs along the downstream parts of the river. Water levels are clearly influenced by the nearby erosion base or the tide in the estuaries situated downstream. Here changes in river discharges have only a limited influence on the floodplains: the flooding duration is mainly limited to less than 20 days a year and especially small river discharges have little effect on water levels.

- *Regulated Rhine regime (rr)* which occurs along Neder-Rijn reaches where a minimum water level is maintained by means of weirs. At larger discharges the Rhine regime characteristics remain. At small discharges, directly upstream of the weirs, the regime resembles the tidal regime very much; in an upstream direction the Rhine regime is more or less maintained. Because more than one weir is constructed there exists a variety in hydrodynamics along the river.
- *Regulated Meuse regime (rm)* which occurs along Meuse reaches where a minimum water level is maintained by means of weirs.

Floodplain types and floodplain regime types are mapped in figure 2, giving a combination of both classifications. It appears that 11 different combinations can be indicated along the large rivers in the Netherlands.



Fig. 2 Floodplain types and regime types in the Netherlands (x/y = floodplain type/floodplain regime type; see text for explanation of abbreviations)

APPLICATION: TARGET PHYSIOTOPE SIDE CHANNELS

The differences between river reaches as described above are large enough to be reckoned with when making plans for nature rehabilitation projects. Knowledge of this variety can be applied to describe references for nature rehabilitation targets to indicate the criteria which have to be fulfilled in order to develop these targets, to select areas which have the potentials for such a development, and finally to design the geographical lay-out of projects. Some aspects of this application will be exemplified by one of the target physiotope: side channels. Side channels (or lateral channels) are an important target physiotope in several floodplain rehabilitation projects. At present in the Netherlands there are no natural side channels left, due to former embankments and channelization.

In the past side channels occurred in three floodplain types: the low sinuous river floodplain, the gravel bed meandering river floodplain and the tidal island river floodplain. Their occurrence in three morphodynamically and hydrodynamically different environments indicates that three side channel types should be referred to, instead of one. It should be stressed, for instance, that side channels in tidal island river floodplain types are stable (long-term) features, whereas side channels in low sinuous floodplain types are short-term features. The life cycle of the latter is well depicted in figure 3 [after Van Urk & Smit, 1989].

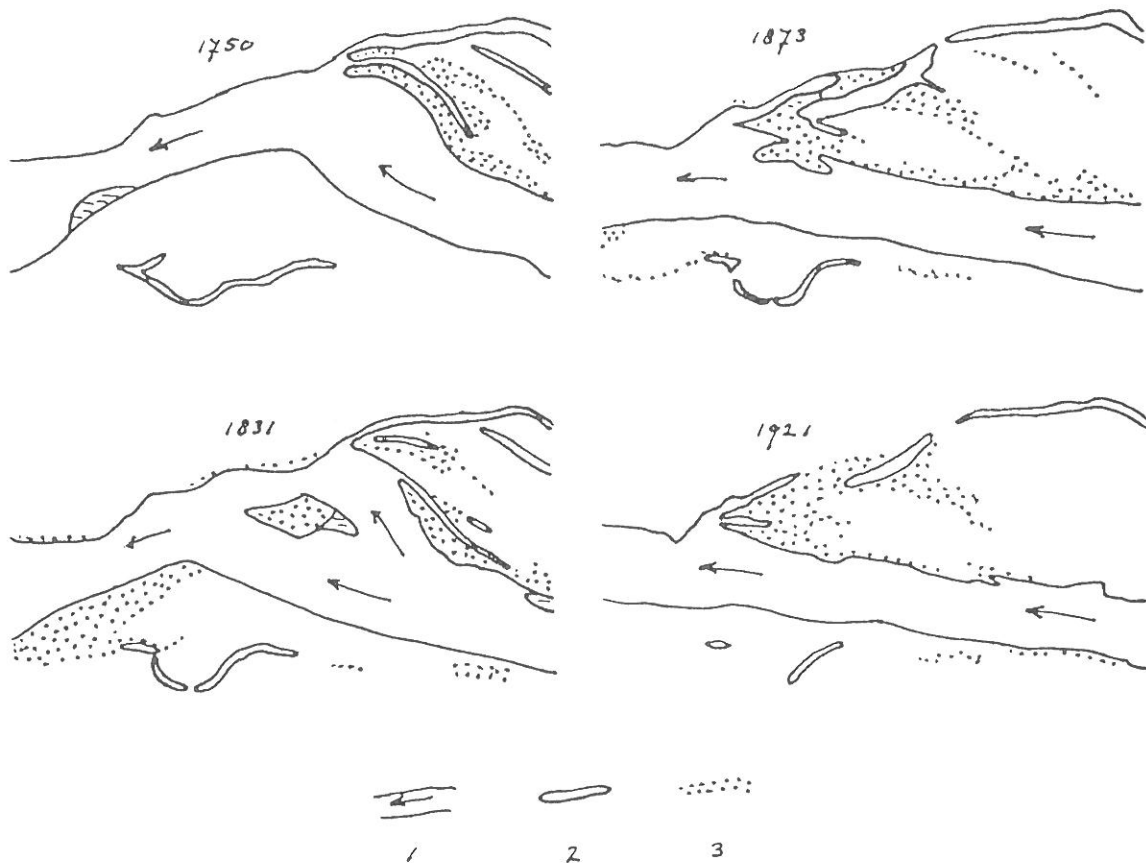


Fig. 3 The life cycle of side channels in low sinuous river floodplains [after Van Urk & Smit, 1989]
(1 = river channel with flow direction; 2 = floodplain channel; 3 = floodplain forest)

As a result of erosion of the southern river bank the river widens, causing divergent flow and the formation of a mid channel bar. One of the two channels separated by the bar will develop into a side channel. The entrance to this channel will be blocked by sandy sediment; the side channel thus changes into a floodplain channel, and will be filled up later on by the deposition of fines from suspension. This sedimentation process should also be taken into account in the reference; in practice it implies that one should not concentrate on the prevention of sedimentation, on possibilities for the creation of new side channels to replace the first one as a habitat, when silted up after a period of 30-50 years.

From figure 3 it can also be learned that an important criterion for a natural development is a widening of the river channel. This however causes sedimentation in the channel itself, whereas any sedimentation process in the channel is unacceptable, because for navigation a minimum water depth of ca. 4 m has to be guaranteed. This leads to the conclusion that the natural formation of a side channel is unrealistic under the present circumstances. The side channel physiotope has to be created artificially.

The appointment of the occurrence of side channels to several floodplain types also gives an indication of possible locations for the creation of side channels. Tidal influenced river floodplains are a potential location for the development of long-term side channels; short-term side channels are to be situated in low sinuous or gravel bed meandering river floodplains. These locations are indicated in figure 2 as ti/r, ls/r, ls/m, ls/rr and gb/m.

Finally, the study of geomorphological patterns gives an idea of how side channels have to be designed. A correct design guarantees that, although artificially created, the channels can perform as a habitat in a correct and natural way.

DISCUSSION AND CONCLUSIONS

From the preliminary results it can be concluded that a study of the variety in geomorphological floodplain patterns and processes can be very useful in the identification and description of references for nature rehabilitation targets, the identification of criteria that should be fulfilled in order to develop these targets, the selection of areas that have the potentials for such a development, and finally in the geographical design of projects.

Dealing with a national reconnaissance this study does not incorporate an analysis of processes that cause the variation in morphodynamics, hydrodynamics, vegetational succession or potentials for floodplain rehabilitation. When plans have to be worked out in more detail, this information is probably also relevant, so that additional research will be needed. Geomorphological research on a more detailed level will certainly benefit from additional studies on historical channel changes from old topographic maps and on the analysis of the sedimentological record.

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7. SWITZERLAND

SEDIMENT REGIME AND RIVER RESTORATION

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INTRODUCTION

For a long time, the sediment load of rivers has been a major problem. Aggradation has reduced the discharge capacity which had been obtained by early regulation works. Only major changes imposed on the river courses and cross sections helped to overcome this difficulty (see [Meyer-Peter and Lichtenhahn, 1963]).

River restoration demands an environmentally more attractive river geometry. The problem arises, if there will not be a new sediment problem resulting from such envisaged changes. On the other hand, since it is known that sediment regime of many rivers is still not satisfactory, river restoration postulates could be combined with solutions for the sediment problem.

RIVER CHANNEL DESIGN AND SEDIMENT TRANSPORT CAPACITY

Channel geometry, sediment characteristics and the discharge regime of a given time period define the sediment transport capacity of this river channel, expressed as sediment yield for this period [Jaeggi, 1992]. As shown in figure 1, for a given slope there is a maximum transport capacity obtained for a certain channel width, called later the optimum width. Narrower channels are less effective in terms of sediment transport, since wall drag will be predominant. Wider channels are less effective again due to the decrease of mean flow depth and thus shear stress. Extremely wide channels tend to braid, and their sediment transport capacity becomes independent of total width, but on a low level.

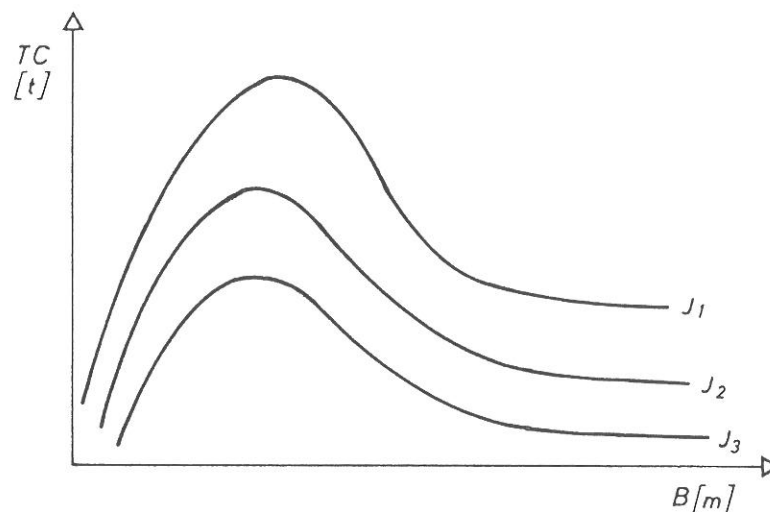


Fig. 1 Bedload yield as a function of channel width B for different slopes for given discharge duration curve ($J_1 > J_2 > J_3$)

For different slopes different curves of this type can be found, each presenting a maximum transport capacity and a corresponding optimum width. Thus, the latter is defined as the channel width for which a river is the most efficient concerning sediment transport. Most of the regulation works on rivers where sediment problems occurred resulted in channels presenting more or less this optimum width (mainly gravel rivers).

Quite often this maximum transport capacity corresponded to an overcapacity which was used to evacuate the excess bed material which had to be evacuated to obtain the desired flood capacity or the necessary depth for navigation. Examples are the Emme river or the Danube downstream of Vienna [Jaeggi, 1992; VAW/GIUB, 1987; VAW, 1989]. Also, buffering effects resulted in comparatively small changes in river bed elevation and hid the fact that the desired dynamic equilibrium between sediment supply and local transport capacity had by far not been obtained.

TRENDS IN RIVER ENGINEERING BEFORE THE RESTORATION MOVEMENT

The sediment transport overcapacity was often compensated by building sills, check dams or weirs. They control the longitudinal profile of a river through a local energy dissipation, thus allowing a flatter slope to develop in between. As figure 2 shows, such stepped channels can cope with a wide range of sediment inputs. From a pure engineering point of view, the problem is solved. But the impact on these rivers is high (see figure 3). Especially the low flow conditions are dramatically changed compared to natural conditions.

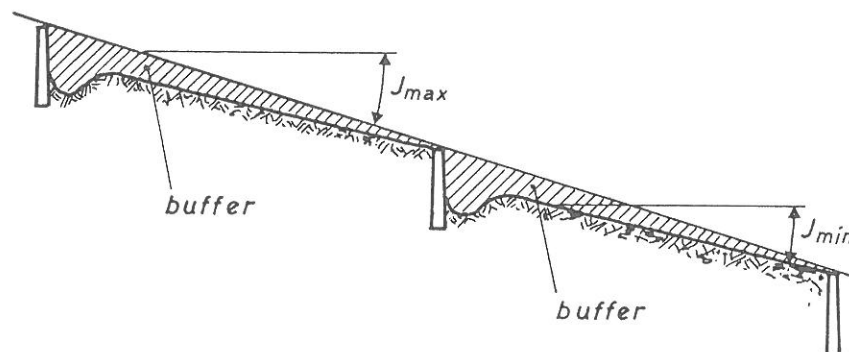


Fig. 2 Stepped channels presenting a substantial storage capacity defined as the difference in sediment transport capacity (function of J_{max} and J_{min})



Fig. 3 Heavily trained stepped channel

THE CONSEQUENCES OF RIVER RESTORATION FOR SEDIMENT TRANSPORT

The aims of river restoration are often defined in very different ways according to the interests involved. In a very general way, river restoration may be considered as the purpose to transform a river channel as much as possible back into its natural shape. This can practically never be realized to a full extent, unless land use near the rivers is completely given up. But if it is understood what the morphology of the original river was like, then natural morphological elements can be reintroduced.

Most of the Swiss rivers were naturally braided. Alternate bars exhibit low flow conditions (riffle pool sequences) which are characteristic of braided rivers. To obtain alternate bars or braids a river channel trained to the optimum width must normally be widened. The channel will then become less effective in terms of sediment transport. This loss in sediment transport capacity is not necessarily a deficiency, but it must be carefully examined, if a restoration project does not result in a new sediment problem. As shown below, different reactions of a river to a restoration may be expected (see also [Jaeggi, 1990]).

Figures 4 and 5 illustrate an example of a restoration aiming only at an improvement of low flow conditions. The original regulation of the Sihl river had resulted in a uniform channel with a plane armoured bed. Because of the presence of quite coarse material the armour layer is expected to move only at about a 50 year flood. A rearranged bed as in fig. 4 presents the same stability. Since alternate bars do not affect sediment transport capacity for high flows, the sediment transport capacity of the Sihl river has not been substantially affected by this restoration.



Fig. 4 Sihl river near Zurich. Low flow conditions in the regulated channel



Fig. 5 Sihl river near Zurich. Low flow conditions after the bed topography has been remodelled into alternate bars.

Although the conditions for this restoration on the Sihl river may be a bit particular, some general conclusions may be drawn. If the bed presents a high stability because flow conditions for most of the discharges are below incipient motion conditions, then the reaction of the river bed to imposed morphological changes will be weak. Sediment motion during rare events will not result in dramatic bed level changes. This applies to many small creeks.

In lowland rivers, the buffering effect of the river bed is important. The reaction of a river bed to a disequilibrium between sediment input and sediment transport capacity may be extremely slow (see [McMurray and Jaeggi, 1990]). In such situations, river restoration projects will not induce major sediment problems.

The Reuss delta project [Lang, 1985; Jaeggi and Peter, 1983] (see fig. 6) is an example of a situation where the decrease in transport capacity induced by the change in river morphology was compensated by an increase in slope. Before the restoration, as a consequence of different regulation phases and the induced lake shore erosion, which was later increased by gravel dredging, the river mouth pointed 300 m into the lake. Supply of fine sediment to the shore to compensate shore erosion was the main objective of this restoration project.



Fig. 6 The Reuss delta project (Mouth of the Reuss river at the Lake of Lucerne, Switzerland) after restoration (April 1991)



Fig. 7 Rhone river in the Pfywald reach, Switzerland. Increasing human impact (flood protection, gravel mining) called for a more efficient protection of this scenic environment



Fig. 8 Sediment input into the Pfywald portion of the Rhone river by debris flows from the Illgraben catchment

As in the Pfynwald project (figures 7 and 8) [Bezzola, 1990], the sediment problem may be so important that it cannot be solved by means of river regulation only. In fact, the heavy sediment loads from the Illgraben debris flows (fig. 8) prevented any major regulation scheme to be applied to the Rhone river and the local environment remained quite natural. However, over the last years there was an increasing impact also on this river reach. Flood protection levees have been built, but leaving the river in a quite natural stage since the width remained far bigger than the optimum one. Calculations showed that removing these levees would result in a decrease of transport capacity of only about 10%.

The sediment input exceeds the transport capacity 2 or 3 times. The sediment problem must therefore be solved by means of dredging anyway. In particular, a regulation changing the cross section to the optimum width would not solve the problem. In this particular case, a sediment management policy can be combined with a restoration project, where the dredging has to cope with the extra load resulting from the restoration.

A reduction of the transport capacity may be an alternative to the insertion of erosion control checkpoints. If an overcapacity was introduced during the regulation to evacuate an extra load as in the quoted example of the Emme, this overcapacity is not needed any more once the desired flood capacity has been achieved.

It is difficult to reduce the transport capacity regularly and to find the one which just fits the usually unknown sediment input. For the Emme river, a proposal was made to replace sills needed in the future by local widenings [Jaeggi and Pellandini, 1988; Zarn, 1992]. If in a reach between existing sills about one third of the existing uniform channel is widened in the central portion, it can be expected that a steeper slope will develop there, which will prevent excessive erosion. A first widening of this type has just been realized early 1992 (fig. 9).



Fig. 9 Local widening in the Emme river (April 1992), an erosion control measure which is at the same time a river restoration

As fig. 10 shows, very often the slope to be expected in an equilibrium situation for the optimum width is smaller than the valley slope, but for a very wide channel the equilibrium slope is higher. In an appropriate sequence of narrow and wide portions, it could be achieved that the final longitudinal profile will alternate around the desired level (fig. 11). This may need an adapting of the length of the heavily trained portion, according to the supply conditions and the bed level reactions. Adaptings can be movements in both directions, whereas the traditional approach with inserting more and more sills is a movement into one direction only, which is the total fixation of the river channel including many environmental disadvantages.

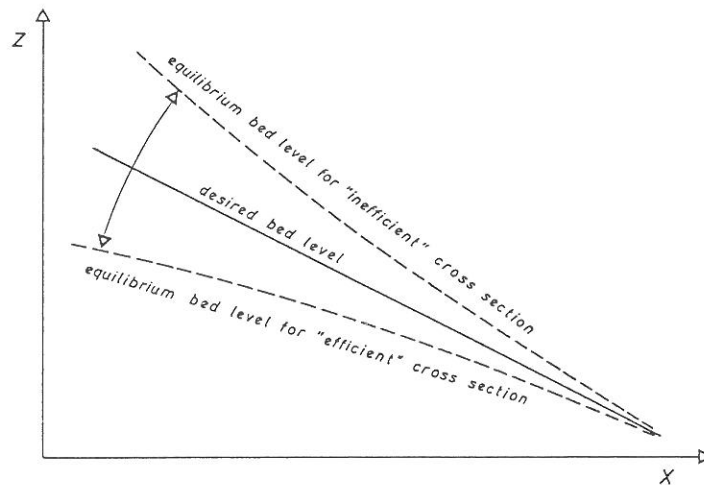


Fig. 10 Equilibrium longitudinal profiles for a channel with optimum width and a wide channel

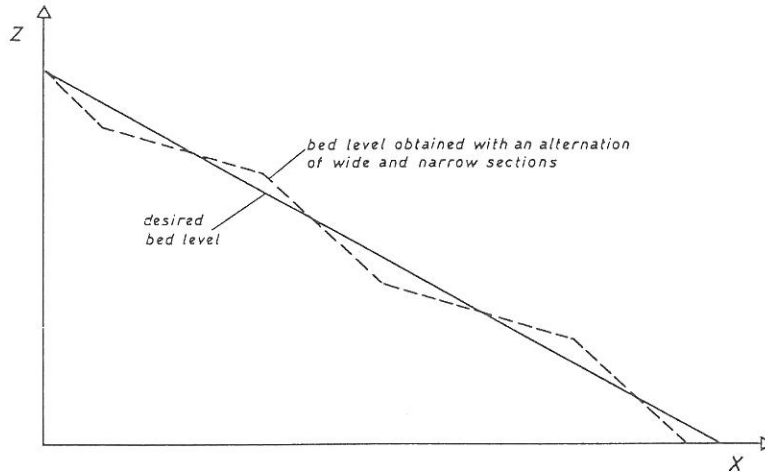


Fig. 11 Longitudinal profile in a river presenting alternatively narrow and wide stretches

SUMMARY AND CONCLUSIONS

Traditional river engineering has always aimed at a maximum sediment transport capacity of the trained rivers. River restoration, at least if it is orientated towards natural river morphology,

mostly means a loss in sediment transport capacity. If the river is not very active, then this may not be a major problem. In other situations, river training alone may not solve the sediment problem. River restoration can then be part of an optimized solution. Finally, a reduction of transport capacity through a river restoration can be a valuable project component in strongly eroding rivers.

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PROTECTION AGAINST FLOODS, CASE STUDIES IN SWITZERLAND

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ABSTRACT

The Thur, a tributary of the Rhine, is used as an example to show how an important project is developed nowadays in Switzerland. It will be shown how different interests can be brought together under one roof.

SURVEY OF CONDITIONS IN SWITZERLAND

Our small country with its total surface of 41,293 square kilometres is characterized by a high degree of variety. Switzerland is first and foremost a land of hills and mountains and contains the central part of the Alps, roughly a fifth of the total range. The central Alpine region with its highest peaks reaching up to 4,500 metres forms the watershed of Europe.

In general, Switzerland has more rainfall than most other regions in Europe, but the amount of rainfall varies greatly from region to region. The mean annual precipitation is 1,476 mm, of which on average 978 mm (1,280 m³/s) flows off from the surface. The running waters form a closely knit network. The total length of our rivers reaches 40,000 km.

With an average of 192 inhabitants per square kilometre, Switzerland is very densely populated. Taking into account uninhabited areas, this density increases to 256 people per square kilometre.

Changes over the past few decades with respect to life-style, space demands and infrastructural improvements (traffic) have given rise to the fact, that floods which occur today are generally more costly than before. It is therefore not surprising that high demands are made on the safety of our waters. Another important change must be respected. Ecological connections are being recognized and acknowledged to an ever greater extent. Awareness of the environment has increased. New laws governing river training policies are now resulting from this newly won knowledge. Nowadays the development of a project is much more difficult, because the different interests need to be brought together under one roof.

Survey of newer laws:

- | | |
|------|---|
| 1966 | Federal law on nature conservation |
| 1979 | Federal law on land development |
| 1983 | Federal law on the protection of the environment |
| 1991 | Federal fishing law |
| 1991 | Federal law on protection measures against floods (the old law has been in force for 120 years!). |
| 1992 | Federal law on the prevention of water pollution (water protection law). |

The protection measures have to be as natural as possible; that means that geometrical uniform constructions are no longer desired.

It becomes apparent that it is not just the protection criterion which is decisive for a given project, but that a whole range of legal stipulations also have to be complied with. The federal State provides

financial support to the cantons for the realization of protection constructions and reviews projects from a technical point of view. The Swiss Federal Office for Water Economy is the responsible department for water protection measures, in collaboration with other federal offices connected with environment questions which will determine in a joint report procedure whether a project complies with the laws or not. If shortcomings are ascertained in a project, appropriate directions can be issued and subsidies can be cut or refused.

May I show you now the problems concerning the Thur, a tributary of the Rhine.

THE THUR

The Thur is a larger tributary of the Rhine. Its catchment reaches 1,724 square kilometres and is situated in the eastern part of Switzerland. The highest peaks reach up to 2,500 m. The average height is estimated at 770 m above sea-level. The discharge regime is typically pre-alpine. High peaks during floods and low run-off rates during dry periods. The one hundred year event is calculated at 1,450 m³/s. The annual average reaches 27.6 m³/s and the low water only 9.2 m³/s. In the whole catchment there is not one lake with a regulating effect. It is typical for a river like the Thur that floods can occur during the whole year. But the flood risk during the summer is higher than in the other seasons.

Often flood events are the reason why protection measures have to be planned. The actual project of the Thur is no exception. At the end of the last century, the Thur was redeveloped for the first time in a geometrical, systematical way.

The reduced technical knowledge led to a uniform cross section and longitudinal profile which have been conserved up to today.

FLOOD PROTECTION PROBLEMS AT THE THUR

First of all the stability of the dams is insufficient. Different geotechnical analyses show that the security factor is too low. Dam breaches are possible anytime. During the floods of 1910, 1965, 1977 and 1978 dams have collapsed and caused large inundations. It is like playing 'Russian roulette', because we do not know where the next dam breach will occur. During the past 100 years not only the embanked floodplain rose by 2 metres but also the bed of the main stream itself by 1 metre. The flow capacity is now reduced by this effect. In the upper part of the Thur the bed erosion reaches 2 metres. The changing point between erosion and aggradation moves by 1 - 2 kilometres from upstream to downstream in one year. The sediment regime never has been balanced.

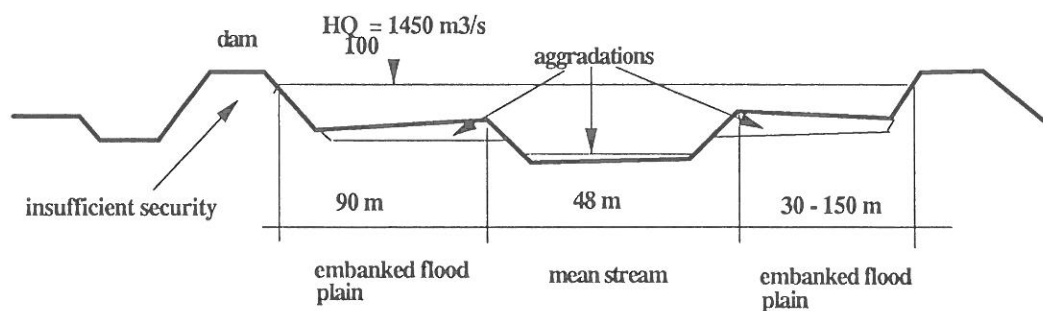


Figure 1 Typical cross section

DEVELOPMENT OF THE PROJECT

After the event of 1978 the government of the canton installed an interdisciplinary project team. The objective of this team was to elaborate a general project. It contains the definition of the demanded flow capacity and the principal measurements. Not only local protection measures were necessary but also a redevelopment of whole river parts. In a next step based on the developed concept a construction project has been completed for the first part (11 kilometres). After a long period of negotiations with the communes concerned, which defended foremost the interests of the farmers, a project has been submitted to the federal State. During a visit on site shortcomings concerning nature conservation were noted. That is why the project was refused by the federal offices. 9000 signatures were collected, which shows how much the project has met with resistance.

After 10 years of planning - it has been a political, financial and social disaster!

A NEW PROJECT

The government of the canton has decided to work out a new project in a comprehensive way. All the different interests have to be complied with, especially:

- the protection of the inhabited zones, roads, bridges and railways;
- typical ecological systems, for example alluvial forest etc. have to be protected or restored;
- the different nature conservation areas should be connected;
- a certain agricultural production should be guaranteed;
- the groundwater has to be protected (drinking-water);
- the river as a zone for recreation has to be respected;
- the project has to be economic.

An elaborate analysis shows that different conflicts still exist:

- agricultural interests have dominated needs of nature;
- a natural river with more liberty needs more space;
- an important part of the floodplain is the property of private persons with private interests;
- difficulty in buying landed property;
- less intensive agricultural production leads to a loss of profit for the farmers;
- the farmers demand an exchange of landed property to guarantee their income.

The result of this conflict analysis is that important basic information has to be completed. The following reports and investigations have been used or especially worked out:

- impact report with a global abstract of the environmental problems.
- hydraulic and river-morphological studies (vegetation influence on the flow capacity, sediment regime, stability of the river bed);
- geotechnical report concerning the dam stability;
- hydrological report concerning the Thur catchment;
- groundwater simulation, special report;
- report concerning the economic and environmental influence of the reduced agricultural production (without fertilizer);
- investigation of the actual conditions for flora and fauna, macroinvertebrates, fish, amphibians, reptilians, insects, dragonflies, birds and mammals.

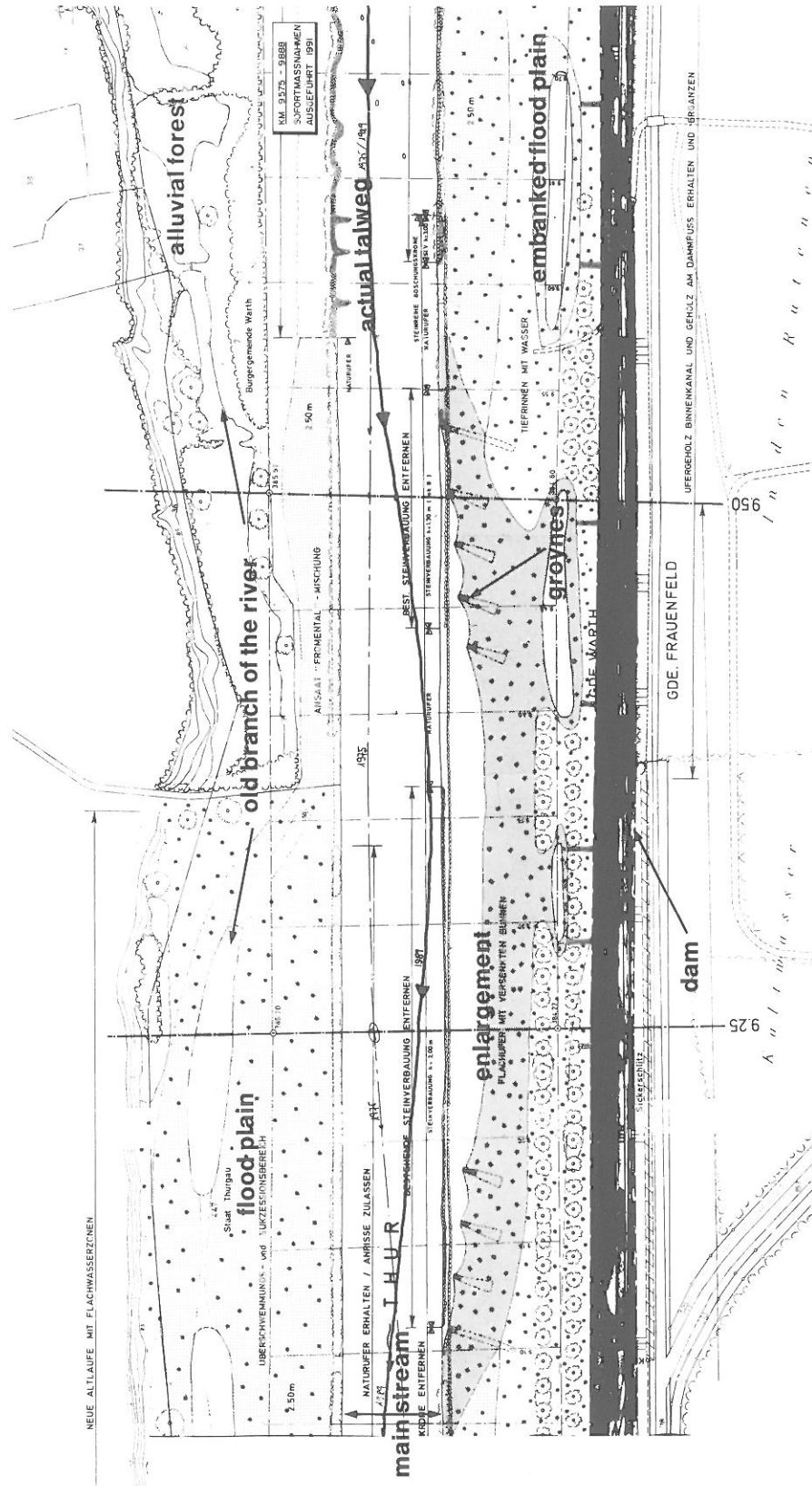


Figure 2 Section of the project

A careful objective consideration of all interests concerned leads to a good project (fig. 2). For this accepted project sufficient mutual understanding and willingness to compromise has been necessary.

What now is the difference between the two projects?

- A controlled dynamic development is accepted. Based on the existing natural river morphology, alternating enlargements of the cross sections are planned. This leads to a higher diversity of the river bed structure.
- Bank erosion will be controlled foremost by groynes which gives a better diversity at the river banks.
- No dredging in the bed of the main stream; in consequence the dams must be elevated.
- The different nature conservation areas will be connected.
- The existing valuable ecological systems will be protected as much as possible.
- An optimized construction procedure limits the impacts during the realization.
- Agricultural production will be reduced (without fertilizer) on more than 60% of the embanked floodplain, an important gain for the water protection and the different ecosystems.

The larger liberty for the main stream leads to a higher risk of uncontrolled morphological changes (bank erosion). A periodical check is necessary because the security of the dams must be guaranteed. The practical experiences downstream, where different enlargements have been realized, shows that groynes especially can have an important influence on the meanders (translation of meanders). Groynes must be carefully planned and their effects observed. The enlargements have to be in relation to the sediment regime (danger of aggradation).

The canton has decided to start a monitoring programme on the one hand to safeguard the dam security and on the other hand to document the success of the different ecological ameliorations.

CONCLUSIONS

The example shows, that at the beginning of a project the definition of the objectives is necessary. All interests have to be complied with. An intensive communication and information between the organisations concerned must be secured. The probable conflicts must be analyzed as soon as possible. The decision fundamentals must be completed. Often special investigations, depending on the possible impacts, have to be worked out. It is not an easy way but the shortest one to achieve the objectives.

8. UNITED KINGDOM

RIVER RESTORATION AS AN INTEGRAL PART OF RIVER MANAGEMENT IN ENGLAND & WALES

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INTRODUCTION AND HISTORICAL BACKGROUND

Larger rivers in England & Wales are 'managed', but very rarely owned, by the National Rivers Authority (NRA). These are statutorily designated by Parliament as 'Main Rivers'. Around 42,000 km are designated in England and Wales. In wild rural areas rivers up to 10 m wide are not designated but much smaller watercourses which have important urban flood alleviation or agricultural drainage functions are. Management on non-main rivers, if undertaken, is the responsibility of Local Authorities, Internal Drainage Boards and landowners. The NRA cannot influence the way these smaller watercourses are managed unless it involves abstractions, culverting or major improvements.

Under various statutes the NRA inherited duties to safeguard habitats, flora and fauna associated with rivers. Associated with the formation of the NRA as a regulatory body in 1989 came more duties to promote and improve wildlife interests.

In the 1940s, 50s and 60s there were limited statutes and minimal care for environmental damage associated with wholesale 'improvements' to watercourses. This was the era of dramatic and incentive deepening, widening and straightening of many of our lowland rivers [Brookes, 1988]. Horrendous losses in river, riparian and floodplain habitats, plants and animals occurred. This has been especially apparent for plants and animals of floodplains and wetlands rather than for aquatic biota. For example dramatic losses in waders were reported [RSPB, 1983] and a 30% extinction of wetland plants in a single English County [Dony, 1977].

In 1976, just 16 years ago, the Land Drainage Act consolidated drainage powers and called for the 10 Regional Water Authorities (WAs) to seek out areas of wet floodplain for drainage, and draw up programmes to implement river 'improvements' to enable intensive agricultural production from these floodplains. However the Act did bring some environmental consideration. There was a duty imposed requiring 'due regard for fauna and flora'. Since the majority of people involved with land drainage at that time were very closely allied to the farmers, in practice a "minutes silence" before the last plant and animal disappeared under the dredging bucket ensured legal responsibilities had been adhered to.

Dismay about the rapid loss of wetlands and river habitats led in 1981 to amendments to previous drainage statutes. The Wildlife and Countryside Act now required the WAs to not only safeguard fisheries but also 'further the conservation of flora, fauna and physiographic features'. However this had the caveat that it was only required providing it was 'consistent with their other duties'. Protection, let alone improvements, to rivers and their floodplain interest was not spontaneous and one insensitive scheme continued to follow another well into the 1980s. Concerns about the effects led to the production of many documents showing how river works could be undertaken without causing excessive ecological damage i.e. WASC [1983], Newbold et al. [1983], Lewis & Williams [1984], MAFF et al. [1988] and Newbold et al. [1989].

It is difficult to comprehend how dramatic the turn-around has been over the past six to seven years. Real political pressure began ten years ago [RSPB, 1983] and the House of Lords Select

Committee in 1982 highlighted that the legislation to 'further flora and fauna' was 'inoperable' because of the lack of any adequate survey information about our rivers. Without such baseline information, they argued that it would be impossible to 'further' wildlife interest; indeed, features of interest would be destroyed before anyone knew they were there.

A review of land drainage activities in 1986 [Holmes, 1986] highlighted the extent of management work on rivers. Data showed that more than 2,000 km of Main river were dredged every year. However another part of the report indicated that only three of the ten regions had staff with full-time responsibilities for conservation. In the early 1980s their role was to ameliorate the impacts of current drainage improvements; however in the latter part of the decade they embarked upon programmes of rehabilitating rivers which had been 'environmentally destroyed' by past schemes.

Restoring rivers to past glories has been slow and very few have had extensive lengths upgraded. Even very small-scale enhancements to short lengths were resisted for a long time despite the proven minimal costs involved. It cannot be pretended that major enhancements are being undertaken on Britain's rivers; they are not. Many small improvements are occurring and as the benefits and cost implications are realized, it is predicted to increase dramatically over the next 10 years. There are many things to give encouragement. These include:

- (1) Changes in agricultural policies within the EC which are encouraging land out of production and Statutory Instruments requiring scrutiny of all major river works.
- (2) The splitting of the WA functions in 1989 and formation of the NRA with powers to 'promote' conservation and protect water and water-related flora, fauna and habitats.
- (3) Public pressure for improvements to the environment and formation of organizations dedicated to restoring rivers and river corridors.
- (4) Better awareness of river engineers and a desire to integrate with the aspirations of many river corridor interest groups.
- (5) Learning from the experiences of those involved with small-scale examples at home and the more ambitious schemes of restoration in Denmark, Bavaria, Switzerland etc.

WHAT IS RIVER RESTORATION?

River Restoration means many different things to different people and interest groups. For some it is restoring or improving water quality whilst for others it may be reversing the impacts of engineering or other activities on fishery, landscape, recreation or ecological interests. In some cases the public perception is simply the need for removal of urban rubbish. The examples cited above apply to rivers which are still located in, or close to, their original courses. River restoration is also an important concept where rivers are moved, either temporarily or permanently; this is of importance to mining and other mineral working interests as well as diversions for roads, railways and large developments.

A key concept is that many rivers have lost their 'corridor' interest and their channels have been degraded by engineering works. The effect is two-fold. Firstly the in-stream character no longer supports diverse or desirable habitat structure; this is because natural river processes (fluviogeomorphological) have been suppressed, constraining or even halting completely the self-

cleansing abilities which create and rejuvenate habitats. Secondly floodplain interests have been degraded (usually totally lost) by exploiting their 'value' - drainage, ploughing or 'development' of one sort or another.

Real 'River Restoration' often requires major 'projects' involving large sums of money or wholesale changes in land-use within a floodplain. Re-habilitation or restorative works which are undertaken in tandem with maintenance and other management activities are likely to be much more widely undertaken, cost little more (if any) than a previously insensitive approach, and be of particular value in improving wider-countryside interest to many river valleys throughout the country.

Work of a major restorative nature is likely to be associated with four main areas.

1. **URBAN.** In such situations works are primarily in very constrained corridors so that restoration of wildlife habitats in floodplains is very limited (but there is often some scope for recreational enhancements). In-stream and bank ecotones can be enhanced through improved quality of those that exist and creation of many new ones through manipulation of existing materials imports of new ones, and bio-technical engineering of reeds, shrubs etc. for bank stabilization. Benefits may relate to water quality, fisheries, visual amenity re-creation. ecology and a whole host of others with educational aspects of importance too.
2. **RESTORING STRAIGHTENED CHANNELS.** This is a prime target in intensively farmed rural areas where straightened rivers with trapezoidal banks give way immediately to cropped land of no ecological interest. Restoration includes restoring meanders and all the ecological features associated with them, and forming a wide river corridor and associated natural habitats. Swedish 'Lego' idea comes in [Petersen et al., 1991].
3. **RIVER DIVERSIONS.** This is of most interest for road building programmes and some developments. The key aspect here is that the river has to be moved, and how can its re-location incorporate 'stability' and the needs to allow fluvial processes to continue to shape and maintain habitats?
4. **RESTORATION IN ORIGINAL LOCATION FOLLOWING TEMPORARY DIVERSION.** This has greatest interest for those involved in mineral winning such as gravel or opencast coaling; it is also of interest in some road and construction building programmes. Here the need is to mimic the existing (assuming it is good already) or improve upon this if it is degraded. There are usually great opportunities for river, bank and FLOODPLAIN restoration, much more so than in 1 and 3, and usually greater than 2 also.

PREPARATION FOR ENHANCEMENT THROUGH RIVER MAINTENANCE

It is now a standard practice adopted by the NRA to undertake an ecological survey of a river prior to embarking upon dredging operations. Until 1985 no such surveys were standardly undertaken. The methodology [NCC, 1985] was developed by the statutory conservation agency, the Nature Conservancy Council (NCC) in conjunction with voluntary conservation bodies and the water industry.

The river corridor survey methodology aims to provide background information on the habitats and obvious macro-biota associated with the length of river to be affected by the works. Information is mapped or sketched for variable lengths of river, usually 0.5 km. Data pertaining to

in-stream, bank and floodplain interest is detailed. Once these data have been gathered, the surveyor normally recommends the most sympathetic approach to be adopted, and whether enhancement or restoration opportunities exist.

In 1985 only a few lengths of river were surveyed, always those to be dredged. Efforts were concentrated here since it was realized that of all the regular maintenance activities, this posed the greatest risk of adverse impacts as well as offering the best opportunities to restore lost habitats. From the humble beginning of about 100 km of 'trial' surveys in 1986, more than 3,000 km per annum are now being covered. The expansion has resulted from not only having surveys undertaken as a reaction to a dredging proposal (reactive surveys), but the commissioning of corridor surveys of whole river systems to provide data to influence future management (strategic surveys).

The reactive surveys thus illustrate that the identification of opportunities for restoration are supposedly considered 'part and parcel' of major river works; the ingrained drainage background of some personnel however often precludes this in practice. Another major limitation of the present system is that reactive surveys generally look at only the stretch of river to be directly affected by the works. Lack of survey upstream and downstream leads to a failure to appreciate the potential for indirect adverse impacts. It may also result in totally inappropriate enhancement proposals being executed.

Dialogue with, and questioning of, river engineers responsible for promoting works is vital. It is very important for the ecologist to understand the reasons why the engineer wishes works to be carried out; conversely the engineer needs to know why certain features are being recommended for safeguard or creation. Both should be encouraged to ask the question WHY? and both MUST be able to justify their demands.

DRAWING UP ENHANCEMENT/RESTORATION PROPOSALS

In drawing up enhancement or restoration proposals it is vital to look to the past present and future. When looking to enhance a degraded stretch of lowland river anywhere in England or Wales there are a number of important points to consider.

National surveys of macrophytes executed by the NCC between 1978-82 has enabled a classification of British rivers to be developed to aid the conservation of the finest examples [Holmes, 1983]. Reference to simple physical features such as geology, slope and substrate types enables a comparison of the degraded river's flora with the assemblages found in the best examples of their type. The NCC has also produced two other valuable documents to help determine what might be the most useful restoration proposals to make. In Palmer & Newbold [1981] aquatic, wetland and riparian plants are listed for each region of the country and recommendations made regarding the need to give special attention to rare or declining species. A publication which catalogues the loss of habitats throughout Britain [NCC, 1984] is particularly valuable since it gives an insight into which are the most important habitats to attempt to restore.

Historical searches are important when proposing major restorations. Enhancements can be achieved without this if a very degraded river is to be modified to improve habitats and thus enabling plants and animals to take advantage of the increased diversity. To RESTORE, however, requires considerable data gathering to determine what the river and its environs was like before it was degraded. Information on channel plan-form and physical features needs to be supported by information about the plants and animals it supported and the floodplain habitats it created.

Consultation with landowners, user groups, local authority representatives, regional representatives of voluntary and statutory conservation bodies and pressure groups is vital if long-term restorations are to succeed. Many of these bodies have been responsible for bringing about changes in the attitude towards river engineering works and they often have much to offer in both determining the appropriate enhancements to undertake and assuring their future.

In looking forward it is important to understand river processes which can both shape and destroy valuable features. Without an understanding of fluvial-geomorphology, and the impacts of catchment developments, it is likely that totally inappropriate enhancements will be proposed and executed only to be destroyed by the river's natural processes. Sadly few NRA regions have staff with geomorphology expertise. An encouraging development on the forward planning horizon is 'catchment planning'. The NRA is beginning to develop their strategy on this and Gardiner [1991] has highlighted the importance of an holistic approach to river management.

Enhancement and restoration projects which are carried out when undertaking river works for other purposes thus must have very clear objectives if they are to succeed. The objectives must relate to the need to restore to a river corridor the habitats and species it has lost, not diversify it with alien ones. It is vital that greatest efforts are concentrated on habitats and biota which have declined most dramatically. In addition future maintenance requirements of the habitats created need to be considered. Alongside this, spare a thought too for the river's natural processes which can be both self-maintaining and self-destructive.

A recent investigation into post-project appraisal of enhancement works undertaken by the NRA [Holmes, 1991] highlighted that minimal appraisal is executed. Most conservation staff are confident that benefits to wildlife are arising from such efforts but there are neither quantitative nor qualitative data to support this view. Efforts are to be made to substantiate the benefits to help in the process of improving option selection and execution. This is a positive step which is to be applauded.

The same study also revealed that thousands of small-scale enhancements have been carried out on many rivers over the past five years during the execution of routine maintenance. The main area for improvement is the creation of bank and in-stream habitats by a variety of physical manipulations and plantings. Such projects have resulted in many stretches of uniform channels being revitalized by both creating longitudinal and cross-sectional variation. Gone are the uniform deep slacks and steep trapezoidal banks and in their place are pool/riffle sequences and shallow water margins flanked by richer communities of wetland plants on regraded low banks. In contrast restoration of characteristic floodplain features is very limited. There is a tendency for tree planting and pond creation to predominate with exceedingly few examples of washlands being restored or water tables raised.

At a River Restoration Workshop in Lund (Sweden) in 1991 a working group on 'restoration technology' made a number of important recommendations. A few key examples are cited below:

1. Restoration should concentrate on creating self-sustaining stable and diverse ecosystems (ie not concentrate on single species except at the local level).
2. Restoring natural processes for self-maintenance of a natural system should be the main goal.
3. Different scales of restoration must be considered, looking at short and long-term goals, local as well as catchment benefits, local/regional/national government involvement etc.

4. All restoration goals must be defined from the start so that everyone understands the aims and when they have been reached.
5. Users, river managers, land owners and interest groups need to be involved to give collective ownership to restorative efforts.
6. Monitoring of schemes is essential and informing others of successes and failures is vital.

CASE EXAMPLE - THE RIVER TORNE

The River Torne is a tributary of the Trent near the Humber estuary in Central England. Much of its lower reaches are in the form of a historical straight, artificial and embanked channel. It is bordered by valued peat farmland, all of which is low-lying which requires pump drainage to the Torne. The responsibility for maintaining an efficient drainage system lies with Severn Trent Region of the NRA.

More than a decade ago it was realized that maintenance of the floodbanks was required. Severe under-drainage of the land (much of it below sea-level) over many years had resulted in peat shrinkage and a severe drop in the height of parts of the floodbanks. The proposal was to gain material from the bed of the river to raise the height of the floodbanks. When work began in the mid 1980s very little restoration of river habitats occurred.

Major changes in the approach to the work occurred half way through the project, coordinated by the Area Conservation & Recreation Officer of the NRA Region. These plans were the subject of detailed consultation with external bodies with interest in the river. These included angling, recreation, rambling and horse riding interests as well as statutory and voluntary landscape and wildlife bodies.

When engineering works were completed in 1990 massive changes had occurred to the river and land between the two floodbanks. Instead of gaining material for raising the banks by merely deepening the river the majority of spoil was taken from the edges or on land between the river and the bank. This had the effect of transforming previously monotonous steep trapezoidal banks into diverse and attractive habitats. Shallow underwater shelves were weaved between low wet banks so that both emergent and wetland plants could both thrive and provide the ideal environment for many animals. Where space allowed, pools and wetlands of varying sizes and depths were created by winning material from here for the floodbanks.

Natural colonization has exceeded all expectations. Many plants and animals rarely, if ever, seen along this stretch previously have already become commonplace. Local people are also quick to acknowledge a resounding improvement in the corridor environment. Planting of aquatic and wetland plants is taking place locally to establish species known to have occurred there previously but which may not be able to recolonize naturally. It is also proposed that a major ecological post project appraisal should be undertaken to determine more precisely the value to wildlife of the restoration works.

CONCLUSION

River enhancements are now being undertaken on British rivers during the operation of maintenance by the NRA. The majority of these are small-scale but appear to be making a significant contribution for redressing wildlife losses brought about by past engineering works.

Enhancements through maintenance programmes cannot be expected to truly restore rivers to their former glories but the value to wildlife of many minor enhancements is considerable. It is now important to spread this message and to ensure that simple opportunities are not lost because of an uneven response to the challenge nationally. Finally it is imperative that neither small nor large restoration projects allow a complacent attitude towards protecting the very best examples of lowland rivers.

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RESTORATION OF FLOODPLAINS: A U.K. PERSPECTIVE

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INTRODUCTION

This paper provides information regarding the approach of the Freshwater Environments Group (FEG) and the International Centre of Landscape Ecology (ICOLE) in the Department of Geography at Loughborough University of Technology to assessing the conservation value of fluvial hydrosystems, and in particular floodplains, in a range of U.K. situations. The information gained from these studies is directed towards developing ecologically-sound management strategies for rehabilitating river corridors. The approach of the FEG is set in context through two examples of work carried out on floodplains of two rivers in the U.K.:

- (a) the lowland River Trent in England
- (b) the upland River Spey in Scotland

These floodplains provide good illustrations of the range of the FEG's work as they constitute two very different systems. The Trent is characterized by having a long cultural history, with evidence of reclamation taking place as far back as the 12th century. The Insh Marshes form a major wetland site of recognized international importance, yet are still the focus of conflict as a result of proposed flood management plans.

BACKGROUND

The basis of much of the teaching in the Department of Geography at Loughborough is through the medium of freshwater systems. The FEG was set up in 1987 in order to provide a vehicle for research work on aquatic ecosystems, and in particular to provide a focus for interdisciplinary research in the Department. Six members of staff are involved, along with several post-doctoral research assistants. Historical geographers were also directly involved in the research on the River Trent floodplain, reflecting the importance of man in influencing these systems over what is often a considerable period of time.

In 1990, the increasing emphasis on ecological study in the Department of Geography was reflected in the creation of a new research centre, having as its central focus incorporation of international expertise and ideas on the landscape ecology of both aquatic and terrestrial ecosystems. This is achieved through regular granting of Research Fellowships to internationally-recognized workers. The International Centre of Landscape Ecology (ICOLE) has already benefited from the experience of colleagues from Czechoslovakia, Venezuela, the USA and Australia. The work of the FEG has been, to a large extent, incorporated in the remit of ICOLE resulting in a strong research body in freshwater and a range of terrestrial ecosystems. At present ICOLE is involved in research projects on several chalk streams in lowland England as well as in the use of buffer zones for nature conservation on floodplains in England and Wales.

THE RIVER TRENT: LINKING HYDROGEOMORPHOLOGY AND ECOLOGY

The interdisciplinary approach of the FEG to the study of fluvial hydrosystems and floodplains in particular is based on that developed by researchers at the University of Lyon 1, France (e.g. [Amoros et al., 1987], [Roux et al., 1989]). The approach involves three stages (i) description and

classification, (ii) investigation of successional sequences and (iii) assessment of conservation value [Petts et al., 1992], and incorporates fluvial geomorphology, ecology, hydrology, palaeoecology and historical geographical studies across a range of spatial and temporal scales.

Between 1989 and 1991 the FEG carried out research on the floodplain of the River Trent (fig. 1), with the primary aim of the work being to develop a model of the ecological development of the Trent river corridor. The focus of the research was on the influence of hydrogeomorphology on ecology, and more specifically on the structuring of the floodplain ecotone [Holland, 1988] - the boundary between the true aquatic ecosystem and the true terrestrial ecosystem. The Trent along the reach studied has been shown to be divided into discrete stable and unstable sectors [Petts et al., 1992]. In addition, the fact that the Trent has been extensively regulated since the 18th Century has meant the consequent degradation of the range of ecological habitats normally associated with a geomorphologically-active lowland river corridor.

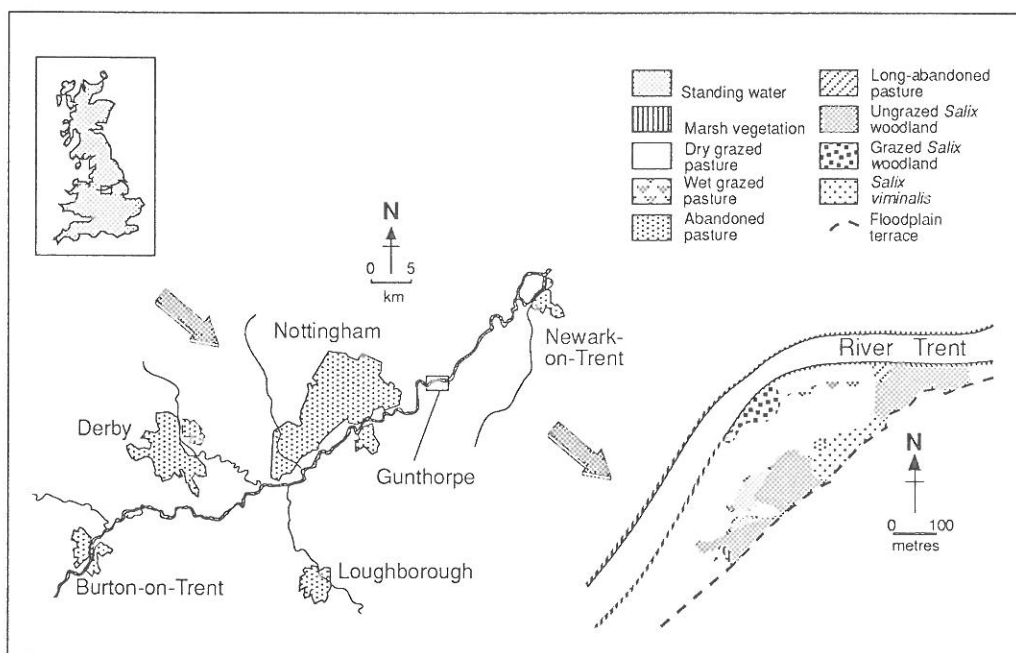


Fig. 1 Reach of the River Trent studied, showing site of detailed study at Gunthorpe, Nottinghamshire (after [Prach & Large, 1992]).

Functional units were defined according to vegetation type and geomorphological setting. This in turn influenced frequency and duration of inundation and permeability. By combining water-quality and vegetation classifications the complete successional sequence from initial cut-off to complete terrestrialization could be defined for the Trent. However, the successions have been modified and interrupted by various management practices over an historic timescale. Woodland generation has been restricted and today is largely confined to areas of former osier (*Salix viminalis*) beds, while silted parts of cut-off channels have been incorporated into the floodplain pasture.

Invertebrate assemblages have commonly been used as functional describers in freshwater systems, being useful in assessing environmental quality and change in lentic habitats, in determining anthropogenic impact and in quantifying conservation value. Seventeen vegetation patches were defined and divided into five units of different geomorphological origin or land use setting - riparian zone, woodland, pasture, arable and wetland. Three conservation scores (rarity, typicalness, and specialism) were employed [Greenwood et al., 1992], [Petts et al., 1992]. These showed pasture and arable units to have low species richness in comparison with the more natural wetland, woodland and riparian units. Of these, the riparian units were shown to have particularly important faunal assemblages. Further work is being undertaken on fossil beetle assemblage distribution in a palaeochannel of the Trent dated to 9500 BP to elucidate further the patterns of succession along the Trent floodplain [Greenwood & Large, 1992].

The approach has resulted in the adaptation of the model developed by Amoros et al. [1987] to the contemporary floristic distribution on the Trent floodplain. It can be seen that the ecotones or ecological boundaries between patches have diminished in extent [Large et al., 1992], but that patches still exist on the floodplain which act as refugia for a variety of plant and animal species. The model can be used to explain the factors behind vegetation dynamics on the floodplain, and has been used to recommend the most suitable management strategies for the ecological rehabilitation of the floodplain [Prach & Large, in press].

The results from the Trent study indicate strongly that, in conserving and rehabilitating river corridors, consideration must be given to areas beyond the riparian zone (cf. Summary section). This approach will include floodplain wetland units, especially cut-off channels, and include examples of each stage in the successional sequence (cf. [Amoros et al., 1987], [Petts et al., 1992]). Given variable siltation rates around cut-off channels a variety of aquatic and wetland units can be maintained by management, or even created artificially within the floodplain itself. This is important as seasonally flooded areas, including wetlands and woodlands, are of particular importance for nature conservation. The conclusion from this study was that while floodplain ecotones containing a mosaic of units appear to have high conservation values, their effective restoration and management depends on sustaining hydrological and geomorphological dynamics [Petts et al., 1992].

THE INSH MARSHES: LINKING HYDROLOGY AND LANDSCAPE ECOLOGY

The Insh Marshes form one of the largest single units of poor fen floodplain mire in the British Isles and, despite piecemeal reclamation, still cover some 3,000 hectares (figure 2). They lie on the floodplain of the River Spey in Inverness-shire, Scotland at an altitude of some 200 metres between the towns of Kincaig and Kingussie. The low gradient of the River Spey upstream of Loch Insh produces slow water velocities and, during periods of high rainfall and snowmelt from the Cairngorm mountain range, the marshes flood extensively. The biotic diversity of the area reflects the large variety of riverine habitats present and the aquatic and marsh vegetation is of exceptional interest and extent with a rich associated fauna. One of the most important features of this area is the rich assemblage of wetland birds, and while the vegetation consists mainly of *Carex*-dominated fen communities, reed bed, herb-rich swamp and *Salix*-carr wetland habitats are well represented. Loch Insh and the Insh Marshes form therefore a major wetland site and, as well as being classed as a Nature Review Site of International Importance, are identified for designation under the Ramsar Convention.

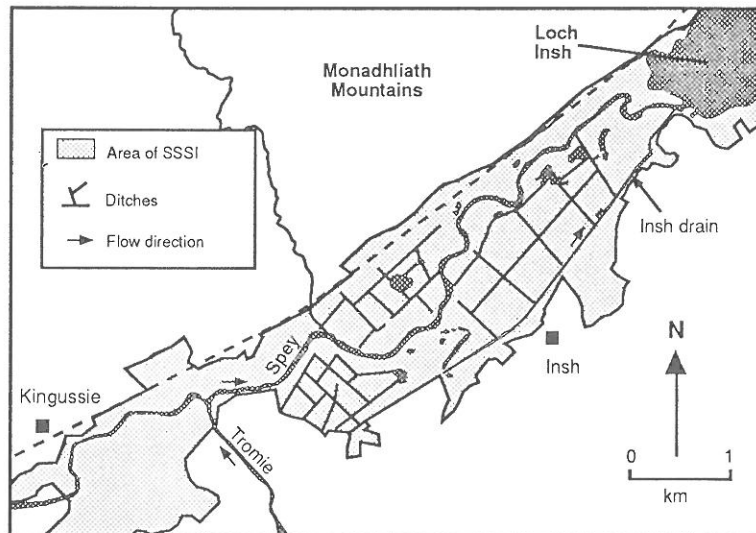


Fig. 2 Location map of the Insh Marshes, Inverness-shire, showing extent of SSSI (after [Petts et al., 1991]).

The River Spey is one of the largest, least polluted and unmodified river systems in Britain. Substantial tracts of the Spey and its tributary, the River Feshie, have been designated as Sites of Special Scientific Interest (SSSI). The special characteristics are related fundamentally to their hydrological regime - the Spey being unusually sluggish for an upland river, while the Feshie, running off the Cairngorms, is prone to an extremely flashy regime. The Feshie confluence with the Spey is the finest example of a dynamic, wooded fluvial hydrosystem in Britain and is one of only a few remaining in Europe [Petts et al., 1990]. Increased duration of high water levels upstream of Loch Insh, increased flooding along the Spey between Loch Insh and the Feshie and the lateral movement of the Feshie are perceived as a hazard by local landowners. Engineering works could be employed to mitigate these hazards, but are not recommended as the major works necessary would have a catastrophic effect on the ecosystem. A number of scenarios for environmental manipulation have been suggested with the most favoured option being dredging of the Spey channel, drawing down water levels on the Insh Marshes and upgrading existing sluice facilities on the marsh at the inlet of the Spey to Loch Insh.

This site therefore is very different from the example of the River Trent, in that the features present already have an extremely high nature conservation value. In order to protect the site however, the ecosystem must be understood both biologically and mechanically, as must the autecological requirements of its constituent parts, the species and communities themselves.

A range of methodologies were used by the FEG in this study, but can be divided into two main sections:

- (a) Hydrological modelling of the Insh Marshes and the immediate catchment area to define a 'normal' flow regime for the area.
- (b) Investigations into plant species distribution in relation to the hydrological information gained from (a) in order to determine the sensitivity of the mire ecology to change in the flow regime.

Analysis of monthly precipitation data (1951-90) revealed that, over this 40 year period, there has been a linear increase in monthly rainfall totals of approximately 10% (or +10.7 mm since 1951). The most distinct period of increase was from 1978-90. A corresponding increase in runoff of 34% (or +16.4 mm since 1951) was found to occur, with the most rapid change occurring from 1978 onwards. A second part of this component of the study investigated stage variation in the Spey and related this to water levels on the marshes both (i) as a surface water component during the winter months and (ii) as a groundwater component during the summer low flow period. From this, it was possible to relate the ecology of the mire complex to variation in water level.

Three main units were apparent on the southern part of the Spey (i) a drained unit characterized by a lack of surface water on the marsh, (ii) a unit with greater incidence of standing water in late winter and early spring, with the main feature being marsh water levels higher than those in the Spey, and (iii) a marsh unit slightly drier than that described in (ii). A flow duration curve derived from water level readings on the marsh since 1973 shows even the higher sections of the marsh to be flooded for approximately 40% of the time (150 days per annum on average). Within these units, two dominant communities reflected well the influence of water-table fluctuation. Tall sedge communities (*Carex aquatilis*, *C. vesicaria*, *C. rostrata*) were adapted to unpredictable water regimes with many minor fluctuations, while short sedge communities (*C. nigra*) were more sensitive to fluctuations and adapted to a regime of winter flooding with constant moisture conditions in the summer months.

Detailed consideration of the autecological requirements of individual species highlighted the fact that continued maintenance of a high water-table appears to be the most ecologically sound management strategy for the sections of the marsh examined. Extreme high flows can be eliminated, but low flows should be maintained at the 95% level to avoid severe drought stress on the marsh [Petts et al., 1991]. The study therefore demonstrates the usefulness of combining hydrological modelling of floodplain systems with ecological investigations.

Many species present in these systems are at the limits of their ecological tolerances [Large & Wade, 1992], and thus changes in hydraulic regime (anthropogenic or otherwise) will have potentially important influences on species distribution. It is important that information on ecological requirements of plant and animal species is gathered in order to assist in the ecological rehabilitation of these floodplain systems, and this is therefore an on-going priority of the research being carried out by the FEG and ICOLE.

SUMMARY/CONCLUSIONS

The majority of the floodplains found in lowland situations in the UK differ from those in Europe in that they are much less geomorphologically active - in many cases the gravel layer of the floodplain is overlain by a layer of alluvial silt several metres thick. Thus, the movement of the river in its floodplain is often restricted, even without taking account of the influence of regulation works over time. Opportunities for environmental enhancement will relate to specific targets. The FEG have been recently examining the potential for buffer zones in enhancing the nature conservation value of Britain's floodplains [Large & Petts, 1992]. This research has highlighted six general targets (figure 3):

1. If water storage is the target, the habitat composition will necessarily be dictated by this functional role.
2. For water-quality management the structure of the buffer and its potential for ecological enhancement will again be dictated by this functional role.
3. In some situations target habitats (e.g. 'woodland', 'wetland' etc.) can be defined for restorati-

- on. The main aim here is to improve general habitat diversity and perhaps amenity value.
4. A target species may be defined (e.g. otter) in which case very specific habitats would be designated (e.g [Greenwood et al., 1992]).
 5. In many cases (e.g [Petts et al., 1992]) the target may be to conserve a historic landscape. Here land usages as well as relict geomorphological features in the riparian landscape may be targeted.
 6. In the final case, the target may be a specific human activity (recreation or amenity). This target may however conflict with several of the targets outlined above.

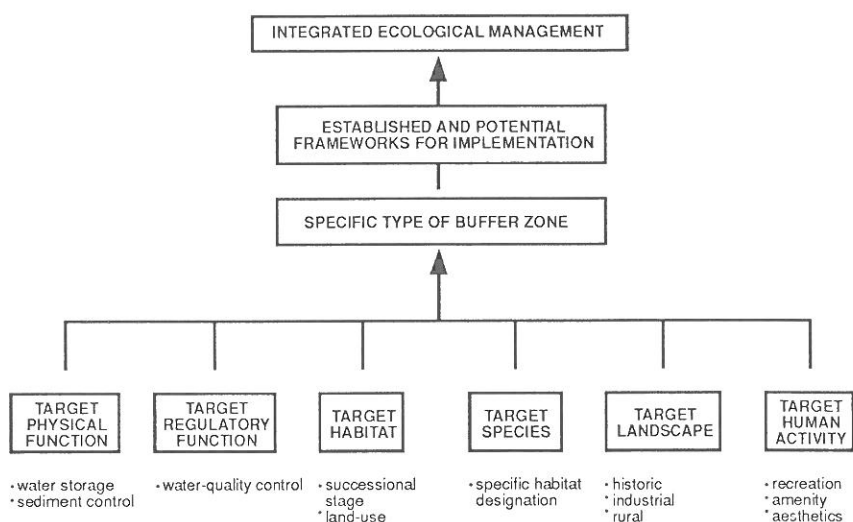


Fig. 3 Targets for buffer implementation in the U.K. (after [Large & Petts, 1992]).

There is a growing body of evidence to suggest that riparian buffer zones can play a major role in landscape management. Evidence provided by a synthesis of material contained in over 220 publications [Large & Petts, 1992] clearly establishes the importance of riparian buffer zones for nature conservation in the three main areas of a drainage network - (i) the headwater channels within the production zone (1st-3rd order streams), (ii) the channel within the transfer zone and (iii) the floodplain (the storage zone). These features provide valuable habitats for a diversity of wetland and terrestrial flora and fauna as well as providing cover, shade and organic matter to the aquatic system. Rehabilitation of floodplains using buffers must principally use relict features, as along the channel margin, primary habitats of gravel bars, sand banks, eroding banks of alluvium and cutoff channels and backwaters linked to the main channel are of particular importance. This is due to the fact that, in Britain, these habitats have been the most severely affected by historic and more recent river management.

An analogy of a "string of beads" in the landscape is particularly useful here. Floodplain wetlands and woodlands have particularly high conservation value in that they can extend the active zone of conservation or rehabilitation away from the river itself. Along large rivers, a buffer zone comprising woodland or wetland "islands" and ponds connected by ditches, hedgerows, the riparian strip or rough grassland creates valuable wildlife habitats [Large & Petts, 1992]. This is also due to the fact that for a river to be effectively buffered for other purposes (in particular water quality

control) all streams and ditches especially within the production zone need to be buffered. This represents a considerable amount of channel length - land which will not always be readily made available.

Buffers offer a multi-functional role in river floodplain management. They offer considerable opportunities for enhancing conservation values and improving water-quality, especially where problems are caused by overland or diffuse sub-surface flow, and in addition offer benefits for recreation and amenity. The FEG have identified a range of targets for reconstructed buffer zones in Britain, and have recommended that a number of pilot schemes be implemented in the U.K. to include representative examples of different river types and situations.

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9. SUMMARY

ECOLOGICAL REHABILITATION OF FLOODPLAINS, THE STATE OF THE ART A synthesis of the workshop in Arnhem, September 1992

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INTRODUCTION

During the last decade politicians, among others, realized that European rivers are transformed into straightened sewage gutters with mainly an economic function, whereas the ecological function is so much neglected that the quality of our environment is threatened. An integrated rehabilitation of the rivers is needed and the first steps in restoration processes are made, as for example in the Rhine Action Programme. The main question in these restoration processes is to find reference situations of an ecologically 'sound' river. In the last 500 years most European rivers have been restructured to protect the people against flooding and to use the river for navigation and agriculture. The original character of braided rivers with a highly dynamic morphology and hydrology is completely lost in most European countries and only some remains are found. Of course it is impossible to go back 500 years and therefore we have to set arbitrary objectives to design our target landscape. These objectives differ between countries and depend on the size and the functions of the river.

In the Arnhem workshop the theme was 'Rehabilitation of floodplains', emphasizing the importance of the floodplain in the ecological functioning of the river. The contributions of some 30 participants from The Netherlands, Germany, Switzerland, Hungary, Austria, France, Belgium and the United Kingdom reflect very well the state of the art of ideas and plans how to restore the rivers and what the importance of floodplains is in this process. They focused on the different objectives of restoration, the elaboration of these objectives into plans, the development of methods and instruments for the execution of these plans and the specific research to describe components and processes in floodplains. Of course there is a gradual shift between these four categories, but for the sake of clarity we will use this structure to give an overview.

OBJECTIVES OF RESTORATION

In the Netherlands plans have been developed by the government to create an infrastructure of ecologically 'sound' areas with interconnecting corridors for an easy exchange of populations. In this target landscape (*Aukes*) particularly rivers play a main role, because they act as natural corridors. Within these corridors the most promising stretches of the rivers are selected for nature development areas. Historical descriptions and reference areas in less disturbed places in Europe are the basis for the target landscape. This nature development may conflict with the economic function of the river (*Havinga*), because these target landscapes may have an effect on the water level and flow velocity of the river. Therefore, the primary functions of safety against flooding and navigation have to be considered and usually measures will have to be taken to compensate for the effects of vegetation development. In most other countries there is a problem of conflicting functions, especially when dealing with large rivers (*Goetghebeur*).

For small rivers as there are many in the United Kingdom, the same objectives for river restoration are used: 'the rivers have lost their "corridor" interest and their channels have degraded by engineering works' (*Holmes*). Since 1985 'river corridor surveys' are undertaken in the U.K. before engineering works as dredging are executed. By classification of degraded and less degraded parts of British rivers and historical searches information is collected of the (possible or wanted) structure of

the habitat. Restoring must be done with knowledge about the river processes, otherwise natural processes will destroy it (*Large*).

PROJECT PLANS

Most project plans in the Netherlands are based on the Stork Plan. Stork refers to the black stork, a bird specifically associated with floodplain forests. This bird is a 'target species': when it has returned as a breeding bird, the floodplains are considered ecologically sound. According to the Stork Plan natural processes such as a high frequency of flooding and extensive grazing have to be reintroduced by partly removing of the summer dikes and replacing agriculture by extensive grazing by original grazers, from goose to elk. The most promising projects are Gelderse Poort, Blauwe Kamer, Fort St. Andries, Duurse Waarden and are located on the Rivers Rhine and IJssel (*Litjens, Gerritsen*). These projects are financed by government, province and the World Wildlife Fund. In the Stork Plan the natural processes will structure the environment; however, in the floodplain of the Meuse this is not feasible. Inundations during summer are very scarce and the main channel is deeply incised. Therefore a plan is made to restructure the river to extend the channel 2-3 times, making gently sloping planes by excavating and spilling the excavated material into the main channel. Afterwards there will be an infrastructure for natural processes (*Silva*). A similar proposal is made for the River Scheldt (*Meire*).

In other countries as well pilot projects are started to gain experience with the recovery potentials of the floodplains. In Austria the lower part of the Leitha has been chosen as a promising area. The project is still in an inventory phase in which aims must be developed and approved by the authorities responsible for agriculture, forestry, conservation and fishing. A model will be developed with short-, medium and long-time measures (*Rojacz*). The Gemenc area along the Danube is more or less comparable. This area is still beautiful, but it is rapidly degrading, because of desiccation and intensive grazing by deer. Here both conservation and restoration processes are needed, but measures still have to be discussed and approved (*Hajos, Marchand*). The Szigetköz area is also part of the Danube floodplain and is rapidly degrading because of desiccation. As in the Gemenc area a plan has to be worked out to prevent further degradation (*Lang*). In the Körös rivers the flood control is applied by a combination of dikes, protection forests and a free zone of 100-200 m within the floodplain. These flood beds were made at the end of the seventies and provide a habitat for many animals. Although they have not been developed in a natural process, but artificially planted, they still have a value as habitats for animals (*Galbats*). *Willi* shows that the definition of the objectives is very essential in project plans and how different interests can be brought together. As an example he mentions protection measures for the River Thur in Switzerland.

METHODS AND INSTRUMENTS

Before the start of a project plan scenarios have to be analyzed regarding their effect on safety against floods and navigation. The development of forests must be feasible from a viewpoint of both ecology and safety and navigation. Therefore methods are developed to evaluate the potentials for nature development. Using geomorphological and soil maps the morpho- and hydrodynamics of the area can be determined and the potentials for development of vegetation indicated. Particularly the flooding frequency is an important predictor of the potential for vegetation development. The inhomogeneity in height and soil composition determines the variation and attractiveness of the area (*Wolfert*). Forests, however, are not to be allowed to develop freely, because they will cause an increase in the water level, unless their effect on the water level is compensated. The Netherlands Public Works Department uses a two-dimensional model (WAQUA) to calculate the height and velocity of the water flow. An important parameter in this model is the roughness caused by vegetation. However, still much research is needed to translate the possible vegetation types into roughness coefficients. There are still

great differences between measured and calculated data, particularly in relation to water depth, but it is not yet clear whether formulas or measurements are incorrect (*van Velzen*).

Apart from the change in structure because of vegetation development in the existing not modified geomorphological structures, it may be necessary to change the morphology of the main channel to create a better potential for nature development. Models are available to determine the optimal sediment transport in relation to channel geometry and the composition of sediment. Nature development usually means widening the main channel and thus decreasing the sediment transport capacity. It is especially useful when erosion has to be prevented or when the sediment is not critical (*Jaeggi*). The potential for diversity of floodplains is strongly increased by construction of lateral channels. This technique is still in an experimental phase and will be implemented at Fort St-Andries. The water and sand discharge have to be regulated by a construction at the entrance, otherwise sedimentation will occur in the main or lateral channel. The stability of the lateral channel is not predictable either, because without groynes or stable structure the channel will start meandering (*de Haas*). A plan for reopening and reconnection of old side arms as an integrated part of the creation of the national park Donau-Auen was proposed and the new distribution of discharges modelled (*Bernhart*).

RESEARCH

The basis for nature development must be solid and the natural processes in the floodplains must be fairly known, otherwise the project will be destroyed by natural processes. Research in the floodplains must supply the information about the components and processes in the floodplain. An important starting point is the pollution of the floodplains with heavy metals and organic pollutants, although little is known about the effects of these substances on an ecosystem level. Particularly floodplains are sensitive to pollution, because sedimentation is one of the natural processes in floodplains and these pollutants accumulate here. In Rhineland-Palatinate such a survey has been done and values were compared with those from non-flooded areas. Although the amount of pollutants was much higher than in the non-flooded areas, the values did not surpass the limits and guide values. If the Rhine Action Programme is successful in reducing these pollutants to 50%, the threat will be relatively low in this area (*Meuser*).

The development of a floodplain is a very dynamic process, in which physical and biological processes are integrated by mutual interactions. Silting up of lateral channels or oxbows is a very natural process and is reflected in the succession of the vegetation. When a lateral channel is cut off from the river, macrophytes will develop more easily in the stagnant water. Unless there is a flow-through to replace the nutrient-rich water with nutrient-poor water the succession to a terrestrial habitat will continue. *Amoros* showed in an experimental situation, that a flow-through slowed down the succession. When the oxbows or channels are filled up the succession continues until forests have developed. *Csanyi* demonstrated that the phytoplankton, zooplankton and bottom fauna changes rapidly at periods of low water discharge and stagnant water. The eutrophication process increases rapidly and changes the diversity negatively.

The morphology of the floodplain is very dynamic and changes continuously because of meandering channels and permanent sedimentation. The terrestrial succession from pioneer vegetation up to forest is only possible when the floodplain increases in height. If not the vegetation remains in a pioneer stage, but usually the development of vegetation will increase sedimentation and therefore the preparation for the next stage. *Schoor* showed that the vegetation in Gemenc could be divided in six zones and was dependent on height and soil composition. She formulated a hypothesis how succession developed within the floodplain, which is important to get insight in the processes in the

floodplain.

The vegetation on the floodplain influences the water level, because at least the volume of the vegetation will be the increase in water level apart from the indirect effects which are caused by the change in water velocity. *Laczay* demonstrated that partial deforestation of the floodplain caused a decrease in the flood levels up to 30 cm depending on the size of the deforested stretch and the size of the channel. Reforestation would therefore have the opposite effect.

ÖKOLOGISCHE WIEDERHERSTELLUNG VON ÜBERSCHWEMMUNGSGEBIETEN, EINE ÜBERSICHT

Eine Zusammenfassung des Workshops in Arnheim, September 1992

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EINLEITUNG

In den vergangenen zehn Jahren sind u.a. Politiker sich der Tatsache bewußt geworden, daß die europäischen Flüsse sich allmählich in begradigte Abwasserkanäle mit einer hauptsächlich wirtschaftlichen Funktion verwandelt haben, während ihre ökologische Funktion dermaßen vernachlässigt wurde, daß dadurch die Qualität unserer Umwelt bedroht wird. Eine integrale Wiederherstellung der Flüsse ist notwendig und die ersten Schritte in diesem Prozeß sind bereits gemacht worden, z.B. im Aktionsprogramm Rhein. Das größte Problem bei diesem Wiederherstellungsprozeß ist die Suche nach einem ökologisch "gesunden" Fluß, der als Bezugssituation dienen kann. In den letzten 500 Jahren sind die meisten europäischen Flüssen neu strukturiert worden, mit dem Ziel, die Anlieger gegen Überschwemmung zu schützen und den Fluß für die Schifffahrt und Landwirtschaft zu nutzen. Der ursprüngliche Charakter des verästelten Flusses mit einer sehr dynamischen Morphologie und Hydrologie ist in den meisten europäischen Ländern total verloren gegangen; nur einige Reste sind übriggeblieben. Natürlich ist es unmöglich 500 Jahre in die Zeit zurückzugehen und deshalb müssen wir nach eigenem Ermessen Ziele für den Entwurf unserer Wunschlandschaft setzen. Diese Ziele sind von Land zu Land verschieden und hängen mit der Größe und den Funktionen des Flusses zusammen.

Das Thema des Arnheimer Workshops war "Renaturierung von Überschwemmungsgebieten", womit die Bedeutung der Überschwemmungsgebiete für das ökologische Funktionieren des Flusses betont wurde. Die Beiträge von etwa 30 Teilnehmern aus den Niederlanden, Deutschland, der Schweiz, Ungarn, Österreich, Frankreich, Belgien und Großbritannien verschaffen einen guten Überblick über Ideen und Pläne auf dem Gebiet der Flußrenaturierung und zeigen wie bedeutend die Überschwemmungsgebiete in diesem Prozeß sind. Die Beiträge konzentrieren sich auf die verschiedenen Zielsetzungen der Renaturierung, die Umsetzung dieser Zielsetzungen in Pläne, die Entwicklung von Methoden und Instrumenten für die Durchführung dieser Pläne und die spezifische Forschung für die Beschreibung von Bestandteilen und Prozessen in Überschwemmungsgebieten. Selbstverständlich gibt es zwischen diesen vier Kategorien keine scharfe Trennung, aber der Deutlichkeit halber werden wir in der nachfolgenden Übersicht diese Struktur benutzen.

ZIELSETZUNGEN DER RENATURIERUNG

In den Niederlanden hat die Regierung Pläne für die Schaffung einer Infrastruktur von ökologisch "gesunden" Gebieten entwickelt. Diese Gebiete müssen mittels Passagen gegenseitig verbunden sein, um einen ungehinderten Austausch von Populationen zu ermöglichen. In dieser Ziellandschaft (*Aukes*) spielen insbesondere die Flüsse eine Hauptrolle, da sie eine natürliche Passage darstellen. Aus diesen Passagen werden die aussichtsreichsten Teile des Flusses gewählt und als Naturentwicklungsgebiete bestimmt. Historische Beschreibungen und Bezugsgebiete in weniger gestörten Gebieten Europas bilden die Grundlage für die Ziellandschaft. Diese Naturentwicklung kann zur wirtschaftlichen Funktion des Flusses im Widerspruch stehen (*Havinga*), da diese Ziellandschaften sich auf den Wasserstand und die Fließgeschwindigkeit des Flusses auswirken können. Demzufolge müssen die primären Funktionen, Schutz gegen Überschwemmung

und Schifffahrt, berücksichtigt werden und wird es in den meisten Fällen notwendig sein, die Auswirkungen der Vegetationsentwicklung auszugleichen. In fast allen anderen Ländern gibt es solche Probleme von strittigen Funktionen, insbesondere wenn es sich um große Flüsse handelt (*Goetghebeur*).

Für kleine Flüsse, von denen es in Großbritannien viele gibt, gelten die gleichen Zielsetzungen für Flußrenaturierung: 'Die Flüsse haben ihre "Passage"-Funktion verloren und ihre Läufe sind von Wasserbauten angegriffen worden' (*Holmes*). Seit 1985 werden in Großbritannien "Flußpassage-Forschungen" durchgeführt, bevor mit wasserbaulichen Maßnahmen, wie z.B. Baggern, angefangen wird. Mittels einer Klassifizierung der angegriffenen und weniger angegriffenen Teile von britischen Flüssen sowie historischer Untersuchungen werden Informationen über die (mögliche oder gewünschte) Struktur des Habitats gesammelt. Renaturierung muß mit Sachkenntnis über die Flußprozesse durchgeführt werden, da sie sonst von den natürlichen Prozessen vernichtet wird (*Large*).

PROJEKTPLÄNE

Die meisten Projekte in den Niederlanden basieren auf den "Plan Ooievaar (=Storch)". Storch bezieht sich auf den schwarzen Storch, einen Vogel, der insbesondere mit Auenwäldern assoziiert wird. Dieser Vogel gilt als "maßgebende Art": Wenn er als brütender Vogel zurückgekehrt ist, werden die Überschwemmungsgebiete als ökologisch gesund betrachtet. Nach dem Plan Ooievaar müssen natürliche Prozesse, wie hochfrequente Überschwemmungen und extensive Abgrasung, wiedereingeführt werden mittels der teilweisen Entfernung von Sommerdeichen und des Ersatzes von Landwirtschaft durch originale Gräser, von Gans bis Elch. Die aussichtsreichsten Projekte sind Gelderse Poort, Blauwe Kamer, Fort St. Andries und Duurse Waarden. Sie befinden sich an den Flüssen Rhein und IJssel (*Litjens, Gerritsen*). Diese Projekte werden von der Regierung, der Provinz und dem Weltnaturschutzverband finanziert. Im Plan Ooievaar wird die Umgebung von den natürlichen Prozessen gebildet; die Überschwemmungsgebiete der Maas eignen sich hierzu jedoch nicht. Während des Sommers sind Überschwemmungen hier besonders rar und die Hauptrinne hat sich tief im Gelände eingeschnitten. Demzufolge wurde ein Plan entwickelt, um den Fluß neu zu strukturieren. Dazu soll die Rinne um das 2 bis 3-fache verbreitert werden. Daneben werden, durch Abgrabung und Schütten des abgegrabenen Materials in die Hauptrinne, gleichmäßig abfallende Überschwemmungsgebiete geschaffen. Anschließend wird es eine Infrastruktur für natürliche Prozesse geben (*Silva*). Ein ähnlicher Vorschlag wurde für die Schelde gemacht (*Meire*).

Auch in anderen Ländern sind Versuchsprojekte eingeleitet worden, um Erfahrungen mit dem Wiederherstellungspotential der Überschwemmungsgebiete zu sammeln. In Österreich wurde der Unterlauf der Leitha als vielversprechendes Gebiet gewählt. Das Projekt befindet sich noch in einer Inventarisierungsphase, in der Zielsetzungen entwickelt werden, die von den für Land- und Forstwirtschaft, Fischerei und Umwelt zuständigen Behörden genehmigt werden müssen. Es wird ein Modell für kurz-, mittel- und langfristige Maßnahmen entwickelt (*Rojacz*). Das Gemenc-Gebiet an der Donau ist mehr oder weniger vergleichbar. Dieses Gebiet ist noch immer sehr schön, verschlechtert jedoch rapide wegen Vertrocknung und intensiver Abgrasung durch Hirsche. Hier sind sowohl Umweltschutz- als auch Wiederherstellungsmaßnahmen notwendig, aber solche Maßnahmen müssen noch diskutiert und genehmigt werden (*Hajos, Marchand*). Auch das Szigetköz-Gebiet ist Teil des Donau-Überschwemmungsgebiet und verschlechtert schnell wegen Vertrocknung. Wie im Gemenc-Gebiet muß ein Plan ausgearbeitet werden, um den weiteren Rückgang entgegenzutreten (*Lang*). In den Körös-Flüssen findet Hochwasserkontrolle statt durch eine Kombination von Deichen, Schutzwäldern und einer 100 bis 200 m breiten Freizone im

Überschwemmungsgebiet. Dieses Hochwasserbett wurde Ende der siebziger Jahre eingerichtet und bildet ein Habitat für viele Tiere. Obwohl nicht in einem natürlichen Prozeß entstanden sind, sondern künstlich eingerichtet, ist es doch wertvoll als Habitat für Tiere (*Galbats*). *Willi* zeigte, daß die Definition der Zielsetzungen ein wesentlicher Teil eines Projektplanes ist. Anhand eines Beispiels, Schutzmaßnahmen für den schweizerischen Fluß die Thur, erläuterte er, wie unterschiedliche Interessen vereinigt werden können.

METHODEN UND INSTRUMENTE

Bevor ein Projekt gestartet wird, müssen zuerst die verschiedenen Szenarien auf ihre Auswirkung auf den Hochwasserschutz und die Schifffahrt analysiert werden. Die Entwicklung von Wäldern muß sowohl vom ökologischen Blickpunkt aus, als auch angesichts des Hochwasserschutzes und der Schifffahrt durchführbar sein. Deshalb sind Methoden zur Bestimmung der Naturentwicklungspotentiale entwickelt worden. Mit Hilfe von geomorphologischen und Bodenkarten lassen sich die Morpho- und Hydrodynamik des Gebietes bestimmen und das Potential für Vegetationsentwicklung andeuten. Insbesondere die Überschwemmungsfrequenz ist ein wichtiger Faktor um die Möglichkeiten für Vegetationsentwicklung vorhersagen zu können. Die Heterogenität in Höhe und Bodenzusammensetzung bestimmt die Variabilität und Attraktivität des Gebietes (*Wolfert*). Man kann der Entwicklung von Wäldern jedoch nicht freie Hand lassen, da sie eine Steigung des Wasserstandes verursachen wird, es sei denn diese Auswirkung wird ausgeglichen. Der niederländische Rijkswaterstaat benutzt ein zwei-dimensionales Modell (WAQUA) für die Berechnung von Wasserständen und Fließgeschwindigkeiten. Ein wichtiger Parameter in diesem Modell ist die durch Vegetation verursachte Rauigkeit. Es müssen jedoch noch viele Untersuchungen durchgeführt werden, um alle möglichen Vegetationstypen in Rauigkeitsbeiwerte umzusetzen. Die Unterschiede zwischen gemessenen und berechneten Werten sind noch immer beträchtlich, insbesondere im Verhältnis zur Wassertiefe, aber es ist nicht deutlich, ob das Modell oder die Messungen falsch sind (*Van Velzen*).

Neben einer Änderung der Struktur durch die Entwicklung von Vegetation in den vorhandenen, nicht modifizierten geomorphologischen Strukturen, könnte es notwendig sein, die Morphologie der Hauptrinne zu verändern, um ein besseres Potential für Naturentwicklung zu schaffen. Es gibt Modelle um den optimalen Sedimenttransport im Verhältnis zu der Geometrie der Rinne und der Zusammensetzung des Sediments zu bestimmen. Naturentwicklung bedeutet in den meisten Fällen eine Verbreiterung der Hauptrinne und somit eine Abnahme der Sedimenttransportkapazität. Dies ist vor allem nützlich, wenn Erosion vorgebeugt werden sollte oder wenn der Sedimenttransport nicht von überwiegender Bedeutung ist (*Jaeggi*). Durch den Bau von Nebenrinnen nehmen die Variabilitätsmöglichkeiten von Überschwemmungsgebieten in hohem Maße zu. Dieses Verfahren befindet sich noch in einer experimentellen Phase und soll bei Fort St. Andries angewandt werden. Der Transport von Wasser und Sand muß mittels einer Konstruktion am Anfang der Nebenrinne reguliert werden, da sonst Sedimentation in der Haupt- oder Nebenrinne stattfindet. Die Stabilität der Nebenrinne ist ebenfalls ein unsicherer Faktor, da die Rinne ohne Buhnen oder feste Struktur anfangen wird zu mäandern (*De Haas*). *Bernhart* erläuterte einen Plan, um alte Nebenrinnen neu zu öffnen und mit der Hauptrinne zu verbinden als integrierenden Teil der Entwicklung des Nationalparks Donau-Auen. Dieser Plan umfaßt auch die Modellierung der neuen Abflußverteilung.

FORSCHUNG

Naturentwicklung erfordert eine feste Grundlage und die natürlichen Prozesse in den Überschwemmungsgebieten müssen einigermaßen bekannt sein. Wenn dies nicht der Fall ist, wird das

Projekt von den natürlichen Prozessen vernichtet. Die Informationen über Bestandteile und Prozesse in den Überschwemmungsgebieten müssen durch Forschung herbeigeführt werden. Ein wichtiger Ausgangspunkt ist die Verschmutzung der Überschwemmungsgebiete mit Schwermetallen und organischen Verunreinigungen, obwohl über die Auswirkungen dieser Substanzen auf das Ökosystem wenig bekannt ist. Überschwemmungsgebiete sind besonders verschmutzungsempfindlich, da Sedimentation in den Überschwemmungsgebieten ein natürlicher Prozeß ist und diese Verunreinigungen sich hier anhäufen. In Rheinland-Pfalz wurde eine solche Studie durchgeführt, wobei Meßwerte mit denen von nicht-überschwemmten Gebieten verglichen wurden. Obwohl die Verunreinigungsmengen viel höher waren als in nicht-überschwemmten Gebieten, blieben die Werte innerhalb der gesetzten Grenzen und Richtlinien. Wenn es dem Aktionsprogramm Rhein gelingt, diese Verunreinigungen um 50% zu verringern, ist die Bedrohung in diesem Gebiet relativ klein (*Meuser*).

Die Entwicklung eines Überschwemmungsgebietes ist ein dynamischer Prozeß, in dem physikalische und biologische Prozesse in gegenseitiger Interaktion integriert sind. Die Verschlammung von Nebenrinnen oder Mäanderkurven ist ein sehr natürlicher Prozeß, was auch aus der anschließenden Vegetationssukzession hervorgeht. Wenn eine Nebenrinne vom Fluß getrennt wird, werden sich Makrophyten leichter im stagnanten Wasser entwickeln. Wenn kein Durchfluß stattfindet, wodurch das nährstoffreiche Wasser durch nährstoffarmes ersetzt wird, schreitet die Sukzession in Richtung eines Landhabitats fort. *Amoros* zeigte in einer Testsituation, daß ein Durchfluß zu einer Verzögerung der Sukzession geführt hat. Wenn die Mäanderkurven oder Nebenrinnen verschlammte sind, geht die Sukzession weiter bis sich Wälder entwickelt haben. *Csanyi* zeigte, daß sich Phytoplankton, Zooplankton und Bodenfauna in Zeiten von niedriger Wasserführung oder stagnantem Wasser schnell verändern. Das Eutrophierungsprozeß geht immer schneller voran und hat einen negativen Einfluß auf die Verschiedenartigkeit.

Die Morphologie des Überschwemmungsgebietes ist besonders dynamisch und verändert sich ständig durch mäandernde Rinnen und kontinuierliche Sedimentation. Die Landsukzession von der allerersten Vegetation bis zu Wäldern ist nur bei einer zunehmenden Höhe des Überschwemmungsgebietes möglich. Wenn dies nicht der Fall ist, bleibt die Vegetation in der Anfangsstufe. In den meisten Fällen wird die Vegetation zu einer Zunahme der Sedimentation und somit zu einer Vorbereitung auf die nächste Stufe führen. *Schoor* zeigte, daß die Vegetation im Gemenc-Gebiet in sechs Zonen, abhängig von Geländehöhe und Bodenzusammensetzung, unterteilt werden kann. Sie formulierte eine Hypothese über die Entwicklung der Sukzession im Überschwemmungsgebiet. Dies ist für den Einblick in die Prozesse im Überschwemmungsgebiet von Bedeutung.

Die Vegetation im Überschwemmungsgebiet beeinflusst den Wasserstand, weil zumindest das Volumen der Vegetation zu einer Wasserstandserhöhung führen wird, abgesehen von den durch eine veränderte Fließgeschwindigkeit verursachten indirekten Folgen. *Laczay* zeigte, daß eine teilweise Entwaldung des Überschwemmungsgebietes zu einer Abnahme der Hochwasserscheitel um maximal 30 cm hat geführt, abhängig von der Abmessung des entwaldeten Geländes und der Größe der Rinne. Es ist klar, daß Wiederaufforstung eine entgegengesetzte Auswirkung haben würde.

RÉHABILITATION ÉCOLOGIQUE DES PLAINES ALLUVIALES, L'ÉTAT ACTUEL DE LA TECHNIQUE

Synthèse de l'atelier de septembre 1992 à Arnhem

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INTRODUCTION

Pendant la dernière décennie, les politiques ont réalisé, et d'autres avec eux, que les cours d'eau européens se sont transformés en caniveaux d'égout rectilignes ayant une fonction principalement économique, leur fonction écologique étant négligée à tel point que même la qualité de notre environnement est menacée. Un programme de rétablissement intégré des cours d'eau s'impose, et les premières étapes en matière de processus de rétablissement ont déjà été entreprises, comme par exemple dans le Programme d'Action Rhin. La principale question, dans ces processus de rétablissement, est de savoir où trouver des situations de référence d'un cours d'eau en bon équilibre écologique, c.à.d 'écologiquement sain'. Dans les dernières 500 années, la plupart des cours d'eau européens ont été restructurés pour la protection des populations contre les inondations, ainsi que pour la navigation et l'agriculture. Le caractère original des cours d'eau ramifiés ayant une morphologie et une hydrologie hautement dynamiques, a complètement disparu dans la plupart des pays européens. Seulement quelques restes subsistent. Naturellement, on ne peut revenir 500 années en arrière, aussi devons-nous établir des objectifs à notre gré pour concevoir notre propre paysage d'avenir. Ces objectifs varient de pays en pays et dépendent de la taille et des fonctions du cours d'eau.

Lors de l'atelier d'Arnhem, le thème était 'Le rétablissement des plaines alluviales', l'accent étant mis sur l'importance de la plaine alluviale dans le fonctionnement écologique du cours d'eau. Les contributions de quelque 30 participants des Pays-Bas, d'Allemagne, de Suisse, de Hongrie, d'Autriche, de France, de Belgique et du Royaume-Uni, ont très bien reflété l'état de la technique dans les idées et plans sur la façon de rétablir les cours d'eau, et sur l'importance des plaines alluviales dans ce processus. Ils se sont concentrés sur les différents objectifs de rétablissement, l'élaboration de ces objectifs en plans, le développement de méthodes et d'instruments devant permettre leur exécution, et les recherches spécifiques à faire pour pouvoir décrire les éléments et processus inhérents aux plaines alluviales. Bien entendu, ces quatre catégories s'imbriquent, mais pour la clarté, nous utiliserons cette structure pour donner un aperçu.

OBJECTIFS DE RÉHABILITATION

Aux Pays-Bas, les pouvoirs publics ont développé des plans destinés à créer une infrastructure des zones dites écologiquement saines au moyen de couloirs de communication devant faciliter les échanges entre les populations. Dans ce paysage d'avenir (*Aukes*), les cours d'eau jouent un rôle essentiel puisqu'ils ont une fonction de couloir naturel. Dans ces couloirs, les étendues les plus prometteuses des cours d'eau reçoivent une vocation de zone naturelle. Le paysage d'avenir se base sur des descriptions historiques et sur des zones de référence dans des sites moins perturbés en Europe. Ce développement naturel peut s'opposer à la fonction économique du cours d'eau (*Havinga*), ces paysages d'avenir pouvant influencer sur le niveau d'eau et la vitesse d'écoulement. Par conséquent, les fonctions primaires de protection contre les

inondations et de navigation devront être prises en compte, et il faudra souvent prendre des mesures pour compenser les effets du développement végétal. La plupart des autres pays ont à faire à un tel conflit de fonctions, spécialement lorsqu'il s'agit de cours d'eau importants (*Goetghebeur*).

Pour les petits cours d'eau, dont le Royaume-Uni p.ex. est riche, on part des mêmes objectifs de rétablissement de cours d'eau: 'les cours d'eau ont perdu leur intérêt de «couloir» et se sont dégradés suite aux travaux hydrauliques' (*Holmes*). Au Royaume-Uni, depuis 1985, on entreprend une 'étude de couloir de cours d'eau' avant d'entamer des travaux hydrauliques tels que le dragage. En classant les parties plus ou moins dégradées des cours d'eau britanniques, et en faisant des recherches historiques, on rassemble des informations sur la structure (possible ou souhaitée) de l'habitat. La réhabilitation devra se fonder sur la connaissance des processus qui régissent le cours d'eau, sinon tout progrès sera réduit à rien par les processus naturels (*Large*).

PROJETS

La plupart des projets aux Pays-Bas se basent sur le «Plan Ooievaar». Ooievaar réfère à la cigogne noire, un oiseau dont la présence est liée aux zones boisées des plaines alluviales. Cet oiseau fait fonction de critère, car s'il revient pour faire son nid, c'est signe que les plaines alluviales sont écologiquement saines. Selon le Plan Ooievaar, les processus naturels tels que les inondations fréquentes et les pâtures extensives, doivent être réintroduits en supprimant partiellement les digues d'été et en remplaçant l'agriculture par des pâtures extensives peuplées par les animaux d'origine, tels les oies et les élans. Les projets les plus prometteurs sont Gelderse Poort, Blauwe Kamer, Fort St. Andries, Duurse Waarden, et sont situés sur le Rhin et l'IJssel (*Litjens, Gerritsen*). Ces projets sont financés par les pouvoirs publics, les provinces et le World Wildlife Fund. Dans le Plan Ooievaar, ce sont les processus naturels qui structurent l'environnement; cependant, dans les plaines alluviales de la Meuse, cela n'est pas faisable. Elles sont rarement inondées pendant l'été et le chenal principal est profondément incisé. Aussi a-t-on conçu un plan de restructuration du fleuve pour élargir de 2 à 3 fois le lit, en faisant des surfaces en pente douce par excavation et en utilisant le matériau d'excavation dans le chenal principal. Il s'ensuivra ultérieurement une bonne infrastructure pour les processus naturels (*Silva*). Une proposition comparable a été faite pour l'Escaut (*Meire*).

Dans d'autres pays également, on a démarré des projets pilotes afin d'acquérir des connaissances empiriques sur les facultés de récupération des plaines alluviales. En Autriche, le cours inférieur de la Leitha a été choisie comme zone prometteuse. Le projet en est encore à sa phase d'inventaire, qui implique la mise au point et l'approbation des buts par les autorités responsables de l'agriculture, des forêts, de l'environnement et de la pêche. Un modèle sera développé avec des mesures à court, moyen et long terme (*Rojacz*). La zone de Gemenc située le long du Danube est plus ou moins comparable. C'est encore une belle région, mais elle se dégrade rapidement à cause de la dessiccation et de la pâture intensive des chevreuils. Ici, la préservation de l'environnement et les travaux de réhabilitation sont nécessaires, mais les mesures à prendre devront d'abord être discutées et approuvées (*Hajos, Marchand*). La zone de Szigetköz fait elle aussi partie de la plaine alluviale du Danube et se dégrade rapidement à cause de la dessiccation. Comme dans la zone de Gemenc, il faudra établir un plan pour stopper la dégradation (*Lang*). Dans les cours d'eau de Körös, la maîtrise des crues s'effectue par une combinaison de digues, de zones boisées de protection et d'une zone libre de 100-200 m dans la plaine alluviale. Ce lit de crue a été aménagé à la fin des années soixante-dix et procure un habitat à nombre d'animaux. Bien qu'il ne se soit pas développé de façon naturelle, mais ait été planté artificiellement, il forme un habitat de valeur pour les animaux (*Galbats*). *Willi* montre que

la définition des buts est une partie essentielle d'un plan de projet. Au moyen de l'exemple des mesures de protection sur le Thur en Suisse, il indique également comment réunir des intérêts différents.

MÉTHODES ET INSTRUMENTS

Avant le démarrage d'un projet, il faut analyser les divers scénarios concernant les effets de sa réalisation sur la sécurité et la navigation. Le développement des zones boisées doit s'avérer faisable tant du point de vue de l'écologie que de celui de la sécurité et de la navigation. Aussi des méthodes ont-elles été développées pour évaluer les possibilités de développement naturel. En utilisant des cartes géomorphologiques et des sols, on peut déterminer la morpho- et l'hydrodynamique de la région et les potentiels de développement de la végétation. La fréquence des inondations, notamment, est un important indicateur du potentiel de développement de la végétation. L'hétérogénéité dans la hauteur et la composition du sol est un facteur de variation et d'attrait de la zone (*Wolfert*). Les zones boisées ne peuvent cependant pas se développer librement, car elles font monter le niveau de l'eau, à moins que cet effet soit compensé. La direction néerlandaise des Travaux Publics utilise un modèle bidimensionnel (WAQUA) pour calculer la hauteur et la vitesse d'écoulement. Dans ce modèle, un important paramètre est la rugosité due à la végétation. Cependant, on devra encore faire de nombreuses recherches pour traduire les types de végétation possibles en coefficients de rugosité. Il y a encore de grandes différences entre les valeurs mesurées et celles calculées, notamment en relation avec la profondeur de l'eau, mais on ignore encore si ce sont les formules utilisées ou les mesures qui sont incorrectes (*van Velzen*).

Outre la modification de structure due au développement de la végétation, qui intervient dans les structures géomorphologiques existantes non modifiées, une modification de la morphologie du chenal principal peut s'avérer nécessaire pour améliorer le potentiel de développement naturel. On dispose de modèles pour déterminer le transport optimal de sédiments en relation avec la géométrie du chenal et la composition des sédiments. Le développement naturel signifie normalement un élargissement du chenal principal et donc une diminution de la capacité de transport de sédiments. Cela est utile spécialement lorsqu'il faut prévenir l'érosion ou que la condition du transport de sédiment n'est pas critique (*Jaeggi*). Le potentiel de diversité des plaines alluviales est fortement accru par la construction de chenaux secondaires. Cette technique en est encore à un stade expérimental et sera implémentée à Fort St. Andries. Le transport d'eau et de sable doit être régularisé par un ouvrage à l'entrée du chenal secondaire, sans quoi la sédimentation se produira dans le chenal principal ou secondaire. La stabilité du chenal secondaire n'est pas prévisible non plus, car sans épis ou structure stable, il y aura début de formation de méandres (*de Haas*). *Bernhart* présente un plan concernant la réouverture et réunion d'anciens chenaux secondaires comme partie intégrante du développement du parc national Donau-Auen. Ce plan comprend également la modélisation de la nouvelle répartition des débits.

RECHERCHE

Le développement naturel doit s'appuyer sur une base solide, et les processus naturels qui régissent les plaines alluviales doivent être bien connus, sans quoi le projet sera détruit par ces mêmes processus. La recherche en matière de plaines alluviales devra fournir des informations sur les éléments et processus qui influent sur les plaines alluviales. Un important point de départ est la pollution des plaines alluviales par des métaux lourds et des polluants organiques, bien qu'on sache peu de choses sur les effets de ces substances au niveau de l'écosystème. Les plaines

alluviales sont particulièrement sensibles à la pollution, car la sédimentation est l'un des processus naturels de ces plaines et les polluants s'y accumulent. Dans le Rhénanie-Palatinat, une telle étude a été effectuée et des valeurs ont été comparées avec celles des zones non inondées. Bien que la quantité de polluants y fût beaucoup plus importante que dans les zones non inondées, les valeurs ne dépassaient pas les limites et valeurs indicatives. Si le Programme d'Action Rhin réussit à réduire ces polluants de 50%, la menace sera relativement faible dans cette zone (*Meuser*).

Le développement d'une plaine alluviale est un processus très dynamique, dans lequel des processus physiques et biologiques s'intègrent par interactions mutuelles. L'ensablement des chenaux secondaires ou d'anses est un processus tout à fait naturel et se reflète dans la succession de la végétation. Si un chenal secondaire est coupé du cours d'eau, les macrophytes se développeront plus facilement dans les eaux stagnantes. A moins qu'il y ait un écoulement pour assurer le remplacement de l'eau riche en éléments nutritifs en eau pauvre en éléments nutritifs, la succession d'un habitat terrestre continuera. *Amoros* a montré dans une situation expérimentale que l'écoulement ralentit la succession. Lorsque les anses ou chenaux secondaires sont ensablés, la succession continue jusqu'à ce que se soient développées des zones boisées. *Csanyi* a démontré que le phytoplancton, le zooplancton et la faune des fonds se modifient rapidement en période de faible débit et des eaux stagnantes. Le processus d'eutrophisation s'accroît rapidement et nuit à la diversité.

La morphologie de la plaine alluviale est très dynamique et se modifie continuellement en raison de la formation de méandres et de la sédimentation permanente. La succession terrestre allant de la végétation pionnière jusqu'au boisement, n'est possible que si la hauteur de la plaine alluviale augmente. Sinon, la végétation restera au stade primaire. Mais normalement, le développement de la végétation favorisera la sédimentation et par conséquent, préparera au stade suivant. *Schoor* a montré que la végétation en Gemenc pourrait se diviser en six zones et qu'elle dépendait de la hauteur et de la composition du sol. Elle a formulé une hypothèse sur la façon dont la succession se développe dans la plaine alluviale, laquelle est essentielle pour comprendre les processus qui régissent la plaine alluviale.

Dans les plaines alluviales, la végétation influe sur le niveau d'eau qui augmente avec le volume de la végétation, outre les effets indirects dus à une modification de la vitesse d'écoulement. *Laczay* a démontré que le déboisement partiel de la plaine alluviale a provoqué une baisse des niveaux de crue jusqu'à 30 cm en fonction de l'étendue de la zone concernée et des dimensions du chenal. Le reboisement devrait par conséquent produire l'effet inverse.

ECOLOGISCH HERSTEL VAN UITERWAARDEN, DE STAND VAN ZAKEN Synthese van de workshop in Arnhem, september 1992

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INLEIDING

In de afgelopen tien jaar zijn o.a. politici zich ervan bewust geworden dat de Europese rivieren langzamerhand veranderen in kaarsrechte rioolgoten met vooral een economische functie, terwijl hun ecologische functie dermate wordt verwaarloosd dat zelfs de kwaliteit van ons milieu wordt bedreigd. Een integrale aanpak van de rivieren is noodzakelijk. De eerste stappen in dit herstelproces zijn al genomen, bijvoorbeeld in het Rijn Actie Programma. De belangrijkste vraag in dit herstelproces is waar we een ecologisch "gezonde" rivier kunnen vinden die als referentie kan dienen. In de afgelopen 500 jaar zijn vrijwel alle Europese rivieren geherstructureerd om de bevolking te beschermen tegen overstromingen en gebruik van de rivier voor scheepvaart en landbouw mogelijk te maken. Het oorspronkelijke karakter van de vlechtende rivier met een hoogst dynamische morfologie en hydrologie is in de meeste Europese landen volkomen verloren gegaan. Slechts enkele restanten zijn overgebleven. Natuurlijk kunnen we niet 500 jaar teruggaan in de tijd en daarom moeten we naar eigen goeddunken doelstellingen formuleren voor het door ons gewenste landschap. Deze doelstellingen zullen van land tot land verschillen en zijn afhankelijk van de grootte en de functies van de rivier.

Het thema van de workshop in Arnhem was "Herstel van uiterwaarden", waarmee nog eens de nadruk werd gelegd op het belang van de uiterwaarden voor het ecologisch functioneren van de rivier. De bijdragen van circa 30 deelnemers uit Nederland, Duitsland, Zwitserland, Hongarije, Oostenrijk, Frankrijk, België en Groot-Brittannië gaven een duidelijk overzicht van de plannen en denkbeelden voor herstel van de rivieren en van het belang van de uiterwaarden in dit geheel. De bijdragen concentreerden zich op de diverse doelstellingen voor herstel, de uitwerking van deze doelstellingen in plannen, de ontwikkeling van methoden en instrumenten voor de uitvoering van deze plannen en het specifieke onderzoek naar een beschrijving van elementen en processen in de uiterwaarden. Het spreekt vanzelf dat deze vier categorieën in elkaar overlopen, maar voor de duidelijkheid hebben we toch van deze structuur gebruik gemaakt bij het opstellen van een overzicht.

DOELSTELLINGEN VOOR HERSTEL

In Nederland heeft de regering plannen ontwikkeld voor het scheppen van een infrastructuur van ecologisch "gezonde" gebieden die met elkaar zijn verbonden door middel van corridors die de uitwisseling van populaties moeten bevorderen. In dit doel-landschap (*Aukes*) spelen vooral de rivieren een hoofdrol, omdat zij kunnen functioneren als natuurlijke corridor. Uit deze corridors worden die stukken rivier geselecteerd die het meest veelbelovend zijn. Zij worden aangewezen als natuurontwikkelingsgebied. De basis voor het doel-landschap wordt gevormd door historische beschrijvingen en referentiegebieden in Europa waar het milieu minder verstoord is. Deze natuurontwikkeling kan strijdig zijn met de economische functie van de rivier (*Havinga*), omdat een doel-landschap gevolgen kan hebben voor het waterpeil en de stroomsnelheid van de rivier. Dit betekent dus, dat rekening gehouden moet worden met de belangrijkste functies van de rivier, nl. beveiliging tegen overstroming en scheepvaart, en dat veelal maatregelen moeten worden genomen om de gevolgen van de vegetatieaanwas te compenseren. In vrijwel alle andere landen is dit

probleem van strijdige functies aanwezig, vooral als het gaat om grotere rivieren (*Goetghebeur*).

Voor kleinere rivieren, zoals er bijvoorbeeld veel in Groot-Brittannië zijn, gelden dezelfde doelstellingen voor herstel: "de rivieren hebben hun belang als "corridor" verloren en de geulen zijn aangetast door waterbouwkundige werken" (*Holmes*). Sedert 1985 wordt in Groot-Brittannië eerst "rivier corridor onderzoek" verricht voordat waterbouwkundige werkzaamheden zoals baggeren worden uitgevoerd. Via het classificeren van aangetaste en minder ernstig aangetaste delen van de Britse rivieren en historisch onderzoek worden gegevens verzameld over de (haalbare of gewenste) structuur van de natuurlijke omgeving. Herstel dient plaats te vinden met kennis van zaken over de processen die gaande zijn in de rivier, omdat het anders teniet wordt gedaan door de natuurlijke processen (*Large*).

PROJECTEN

De meeste projectplannen in Nederland zijn gebaseerd op Plan Ooievaar, vernoemd naar de zwarte ooievaar, een vogel die speciaal in verband wordt gebracht met oibossen. Deze vogel vormt een doelsoort: als de zwarte ooievaar weer terugkeert als broedvogel, mogen we de uiterwaarden als ecologisch gezond beschouwen. Volgens Plan Ooievaar moeten natuurlijke processen, zoals regelmatige overstromingen en extensieve begrazing weer een kans krijgen, door het gedeeltelijk verwijderen van zomerdijken en in plaats van landbouw, begrazing te laten plaatsvinden door oorspronkelijke diersoorten, van gans tot eland. Het meest veelbelovend zijn de volgende projecten: Gelderse Poort, Blauwe Kamer, Fort St. Andries en Duurse Waarden, alle gelegen langs de Rijn en de IJssel (*Litjens, Gerritsen*). Deze projecten worden gefinancierd door het Rijk, de provincie en het Wereldnatuurfonds. In Plan Ooievaar geven de natuurlijke processen vorm aan de omgeving; de uiterwaarden van de Maas zijn hier echter niet geschikt voor. Overstromingen tijdens de zomermaanden komen hier maar zelden voor en de hoofdgeul is diep ingesneden. Daarom is het plan ontwikkeld om deze rivier te herstructureren door de bedding 2 tot 3 maal zo breed te maken en de uiterwaarden geleidelijk af te laten lopen door middel van afgravingen, waarna het afgegraven materiaal weer in de hoofdgeul zou moeten worden gestort. Hierna is dan de goede infrastructuur aanwezig voor natuurlijke processen (*Silva*). Een vergelijkbaar voorstel is voor de Schelde gedaan (*Meire*).

Ook in andere landen zijn proefprojecten geïnitieerd om ervaring op te doen met het herstellend potentieel van de uiterwaarden. In Oostenrijk is de benedenloop van de Leitha uitgekozen als veelbelovend gebied. Het project bevindt zich nog in de inventarisatie-fase, waarin doelstellingen moeten worden ontwikkeld en goedgekeurd door de autoriteiten die verantwoordelijk zijn voor landbouw, bosbouw, milieubeheer en visserij. Het model dat wordt ontwikkeld kent maatregelen voor de korte, middellange en lange termijn (*Rojacz*). De situatie in het Gemenc gebied langs de Donau is min of meer vergelijkbaar. Het is nog steeds een prachtig gebied, maar het gaat snel achteruit vanwege verdroging en intensieve begrazing door herten. Zowel milieubescherpende maatregelen als herstelwerkzaamheden zijn hier noodzakelijk, maar een en ander moet nog worden besproken en goedgekeurd (*Hajos, Marchand*). Ook het Szigetköz gebied behoort tot de uiterwaarden van de Donau en verslechtert in snel tempo door verdroging. Net zoals in het Gemenc gebied zijn hier maatregelen nodig om verdere achteruitgang te voorkomen (*Lang*). In de Körös rivieren wordt hoogwaterbeheersing toegepast door een combinatie van dijken, beschermende bebossing en een vrije zone van 100-200m binnen de uiterwaard. Dit hoogwaterbed werd aangelegd aan het eind van de zeventiger jaren en verschaft vele dieren een natuurlijke habitat. Hoewel niet ontstaan in een natuurlijk proces maar kunstmatig aangelegd, is het toch waardevol als natuurlijke leefomgeving voor dieren (*Galbats*). *Willi* liet zien dat de definitie van de doelstellingen een essentieel onderdeel is van een projectplan. Aan de hand

van een voorbeeld, beschermingsmaatregelen voor de Zwitserse rivier de Thur, gaf hij ook aan hoe uiteenlopende belangen bij elkaar gebracht kunnen worden.

METHODEN EN INSTRUMENTEN

Voordat een projectplan wordt opgestart moet van de scenario's worden onderzocht wat het gevolg zal zijn voor veiligheid tegen overstroming en scheepvaart. Ontwikkeling van bossen moet uitvoerbaar zijn zowel vanuit ecologisch standpunt als vanuit het oogpunt van veiligheid en scheepvaart. Derhalve worden methoden ontwikkeld om de mogelijkheden voor natuurontwikkeling te onderzoeken. Met behulp van geomorfologische en bodemkaarten kan de morfo- en hydrodynamiek van het gebied worden vastgesteld en een indicatie worden gegeven van de mogelijkheden voor vegetatieontwikkeling. Met name aan de hand van de overstromingsfrequentie kan worden voorspeld welke mogelijkheden er zijn voor vegetatieontwikkeling. Naarmate de heterogeniteit in hoogte en bodemsamenstelling toeneemt, wordt het gebied gevarieerder en aantrekkelijker (*Wolfert*). Men kan de ontwikkeling van bebossing echter niet de vrije hand laten, omdat ze het waterpeil doet stijgen, tenzij deze gevolgen voor het waterpeil worden gecompenseerd. Rijkswaterstaat maakt gebruik van een twee-dimensionaal model (WAQUA) waarmee hoogte en stroomsnelheid worden berekend. Een belangrijke parameter in dit model is de ruwheid die wordt veroorzaakt door de vegetatie. Er is echter nog veel onderzoek nodig om alle mogelijke vegetatiesoorten om te zetten in ruwheidscoëfficiënten. Er bestaan nog grote verschillen tussen de gemeten en de berekende waarden, vooral met betrekking tot de waterdiepte, maar het is nog niet duidelijk of dit komt door het gebruik van onjuiste formules of door onjuiste metingen (*van Velzen*).

Naast de wijziging in structuur door de ontwikkeling van vegetatie in de bestaande, onveranderde geomorfologische structuren, kan het nodig zijn de morfologie van de hoofdgeul te wijzigen om een beter klimaat voor natuurontwikkeling te scheppen. Er bestaan modellen voor het bepalen van het optimale sedimenttransport in relatie tot de geometrie van de geul en de samenstelling van het sediment. Natuurontwikkeling betekent gewoonlijk, dat de hoofdgeul wordt verbreed, waardoor de capaciteit voor sedimenttransport afneemt. Dit is vooral nuttig wanneer erosie moet worden voorkomen of wanneer de toestand van het sedimenttransport niet kritiek is (*Jaeggi*). De potentiële diversiteit van uiterwaarden wordt aanzienlijk uitgebreid door de aanleg van nevengeulen. Deze techniek bevindt zich nog in de experimentele fase en zal worden toegepast in Fort St. Andries. De afvoer van water en zand moet worden geregeld door een constructie bij de ingang van de nevengeul, omdat anders sedimentatie plaatsvindt in de hoofd- of nevengeul. De stabiliteit van de nevengeul is evenmin voorspelbaar; door de afwezigheid van kribben of een vaste structuur gaat de geul meanderen (*de Haas*). *Bernhart* presenteerde een plan om oude nevengeulen opnieuw te openen en met de hoofdgeul te verbinden als integrerend deel van de ontwikkeling van het nationale park Donau-Auen. Dit plan omvat ook de modellering van de nieuwe afvoerverdeling.

ONDERZOEK

Natuurontwikkeling moet een stevige basis hebben en kennis van de natuurlijke processen in de uiterwaard is daarbij noodzakelijk, omdat het project anders juist zal mislukken door die natuurlijke processen. Onderzoek in de uiterwaarden zal gegevens moeten opleveren over elementen en processen in die uiterwaarden. Een belangrijk uitgangspunt is de vervuiling van de uiterwaarden met zware metalen en organische verontreiniging, hoewel er nog weinig bekend is over de gevolgen van deze stoffen op ecosysteemniveau. Uiterwaarden zijn vooral gevoelig voor vervuiling, omdat sedimentatie een van de natuurlijke processen in deze uiterwaarden is en de

verontreiniging zich hierin ophoopt. In Rheinland-Pfalz is hiernaar onderzoek gedaan, waarbij de gegevens werden vergeleken met die van niet overstroomde gebieden. De hoeveelheid verontreiniging was weliswaar veel hoger dan in de niet overstroomde gebieden, maar bleef binnen de gestelde grenswaarden en richtlijnen. Als het Rijn Actie Programma erin slaagt deze verontreiniging met 50% terug te dringen, is het gevaar in dit gebied betrekkelijk klein (*Meuser*).

De ontwikkeling van een uiterwaard is een zeer dynamisch proces, waarin fysische en biologische processen in wederzijdse interactie geïntegreerd zijn. Het dichtslibben van nevengeulen of meanderbochten is een heel natuurlijk fenomeen, en wordt weerspiegeld in de vegetatiesuccessie. Als een nevengeul wordt afgesloten van de rivier, komen in het stilstaande water gemakkelijker macrofyten tot ontwikkeling. Tenzij er doorstroming aanwezig is, waardoor het voedselrijke water wordt vervangen door voedselarm water, zal de successie naar een terrestrische habitat zich voortzetten. In een testsituatie toonde *Amoros* aan, dat doorstroming de successie vertraagde. Als meanderbochten of nevengeulen dichtgeslibd zijn, gaat de successie door totdat bebossing is ontstaan. *Csanyi* liet zien dat fytoplankton, zoöplankton en bodemfauna snel veranderen tijdens perioden van lage afvoer en stilstaand water. Het eutrofiëringsproces neemt snel in tempo toe en heeft een negatief effect op de diversiteit.

De morfologie van de uiterwaard is zeer dynamisch en verandert voortdurend vanwege meanderende geulen en voortdurende sedimentatie. De terrestrische successie van pioniersvegetatie tot bos is alleen mogelijk als de uiterwaard hoger wordt. Als dit niet het geval is, blijft de vegetatie in de pioniersfase steken. Meestal wordt echter door ontwikkeling van de vegetatie de sedimentatie groter, hetgeen een voorbereiding betekent voor de volgende fase. *Schoor* liet zien, dat de vegetatie in het Gemenc gebied onderverdeeld kon worden in zes zones, afhankelijk van de hoogte van het terrein en de samenstelling van de bodem. Zij formuleerde een hypothese over successie in de uiterwaard, een belangrijk hulpmiddel bij het verkrijgen van inzicht in de processen in de uiterwaarden.

De vegetatie op de uiterwaard is van invloed op de waterstand, alleen al omdat het volume van die vegetatie het peil doet stijgen, afgezien nog van de indirecte gevolgen die worden veroorzaakt door de verandering in stroomsnelheid. *Laczay* toonde aan dat gedeeltelijke ontbossing van de uiterwaard leidde tot een verlaging van de hoogwaterstanden met maximaal 30 cm, afhankelijk van de omvang van het ontboste terrein en de afmeting van de geul. Het moge duidelijk zijn dat herbebossing hier het tegenovergestelde effect zou hebben.

APPENDIX
List of participants in the workshop

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PUBLICATIONS OF THE CHR

CHR/KHR (1978): Das Rheingebiet, Hydrologische Monographie. Staatsuitgeverij, Den Haag/
Le bassin du Rhin. Monographie Hydrologique. Staatsuitgeverij, La Haye.
ISBN 90-1201-775-0

CHR reports

- I-1 GREBNER, D. (1982): Objektive quantitative Niederschlagsvorhersagen im Rheingebiet. Stand 1982 (nicht mehr lieferbar)/
Prévisions objectives et quantitatives des précipitations dans le bassin du Rhin. Etat de la question en 1982 (édition épuisée)
- I-2 GERHARD, H.; MADE, J.W. VAN DER; REIFF, J.; VREES, L.P.M. DE (1983): Die Trocken- und Niedrigwasserperiode 1976. (2. Auflage 1985)/
La sécheresse et les basses eaux de 1976 (2ème édition, 1985). ISBN 90-7098-001-0
- I-3 HOFIUS, K. (1985): Hydrologische Untersuchungsgebiete im Rheingebiet/
Bassins de recherches hydrologiques dans le bassin du Rhin. ISBN 90-7098-002-9
- I-4 BUCK, W.; KIPGEN, R.; MADE, J.W. VAN DER; MONTMOLLIN, F. DE; ZETTL, H.; ZUMSTEIN, J.F. (1986): Berechnung von Hoch- und Niedrigwasserwahrscheinlichkeit im Rheingebiet/
Estimation des probabilités de crues et d'étiages dans le bassin du Rhin. ISBN 90-7098-003-7
- I-5 TEUBER, W.; VERAART, A.J. (1986): Abflußermittlung am Rhein im deutsch-niederländischen Grenzbereich/
La détermination des débits du Rhin dans la région frontalière germano-hollandaise. ISBN 90-7098-004-5
- I-6 TEUBER, W. (1987): Einfluß der Kalibrierung hydrometrischer Meßflügel auf die Unsicherheit der Abflußermittlung. Ergebnisse eines Ringversuchs/
Influence de l'étalonnage des moulinets hydrométriques sur l'incertitude des déterminations de débits. Résultats d'une étude comparative. ISBN 90-7098-005-3
- I-7 MENDEL, H.G. (1988): Beschreibung hydrologischer Vorhersagemodelle im Rheineinzugsgebiet/
Description de modèles de prévision hydrologiques dans le bassin du Rhin. ISBN 90-7098-006-1
- I-8 ENGEL, H.; SCHREIBER, H.; SPREAFICO, M.; TEUBER, W.; ZUMSTEIN, J.F. (1990): Abflußermittlung im Rheingebiet im Bereich der Landesgrenzen/
Détermination des débits dans les régions frontalières du bassin du Rhin. ISBN 90-7098-001-x
- I-9 CHR/KHR (1990): Das Hochwasser 1988 im Rheingebiet/
La crue de 1988 dans le bassin du Rhin. ISBN 90-7098-011-8
- I-10 NIPPES, K.-R. (1991): Bibliographie des Rheingebietes/
Bibliographie du bassin du Rhin. ISBN 90-7098-013-4
- Katalog/Catalogue 1 SPROKKEREEF, E. (1989): Verzeichnis der für internationale Organisationen wichtigen Meßstellen im Rheingebiet/
Tableau de stations de mesure importantes pour les organismes internationaux dans le bassin du Rhin. ISBN 90-7098-008-8

Reports under the auspices of the CHR

- II-1 MADE, J.W. VAN DER (1982): Quantitative Analyse der Abflüsse (nicht mehr lieferbar)/
Analyse quantitative des débits (édition épuisée)
- II-2 GRIFFIOEN, P.S. (1989): Alarmmodell für den Rhein/
Modèle d'alerte pour le Rhin. ISBN 90-7098-007-x
- II-3 SCHRÖDER, U. (1990): Die Hochwasser an Rhein und Mosel im April und Mai 1983/
Les crues sur les bassins du Rhin et de la Moselle en avril et mai 1983. ISBN 90-7098-009-6

- II-4 MAZIK, A. VAN; VERWOERDT, P.; MIERLO, J. VAN; BREMICKER, M.; WIESNER, H. (1991): Rhein-
alarmmodell Version 2.0 - Kalibrierung und Verifikation/
Modèle d'alerte pour le Rhin version 2.0 - Calibration et vérification. ISBN 90-7098-012-6
- II-5 MADE, J.W. VAN DER (1991): Kosten-Nutzen-Analyse für den Entwurf hydrometrischer
Meßnetze/Analyse des coûts et des bénéfices pour le projet d'un réseau hydrométrique.
ISBN 90-7098-014-2
- II-6 CHR/KHR (1992): Contributions to the European workshop Ecological Rehabilitation of
Floodplains, Arnhem, The Netherlands, 22-24 September 1992. ISBN 90-70980-15-0

Some information on the:

**INTERNATIONAL COMMISSION FOR
THE HYDROLOGY OF THE RHINE BASIN
(CHR)**

Foundation

1970 Within the framework of UNESCO's International Hydrological Decade (IHD).

1975 Continuation of activities within the framework of UNESCO's International Hydrological Programme (IHP) and the Operational Hydrology Programme (OHP) of WMO.

1978 Support of the Commission's activities by exchange of a verbal note between the participating countries.

Tasks

- Support of co-operation between hydrological institutes and services active in the catchment area of the Rhine.
- Executing hydrological studies in the Rhine basin and exchange of research results.
- Promoting the exchange of hydrological data and information in the Rhine basin (e.g. current data, forecasts).
- Development of standardized methods for collecting and processing hydrological data in the Rhine riparian states.

Participating countries

Switzerland, Austria, Federal Republic of Germany, France, Luxembourg, the Netherlands

Working languages

German and French

Enige gegevens betreffende de:

**INTERNATIONALE COMMISSIE VOOR
DE HYDROLOGIE VAN HET RIJNGEBIED
(CHR)**

Oprichting

1970 In het kader van het Internationaal Hydrologisch Decennium (IHD) van de UNESCO.

1975 Voortzetting van de werkzaamheden in het kader van het Internationaal Hydrologisch Programma (IHP) van de UNESCO en het Operationeel Hydrologisch Programma (OHP) van de WMO.

1978 Ondersteuning van het werk van de Commissie door een nota-uitwisseling tussen de samenwerkende landen.

Taken

- Bevordering van samenwerking tussen hydrologische instituten en diensten in het stroomgebied van de Rijn.
- Uitvoeren van hydrologische studies in het Rijngebied en uitwisseling van de onderzoeksresultaten.
- Bevorderen van de uitwisseling van hydrologische gegevens en informatie in het Rijngebied (bijv. actuele gegevens, voorspellingen).
- Ontwikkeling van standaardmethoden voor het verzamelen en bewerken van hydrologische gegevens in de Rijnsoeverstaten.

Deelnemende landen

Zwitserland, Oostenrijk, Bondsrepubliek Duitsland, Frankrijk, Luxemburg, Nederland

Voertalen

Duits en Frans

Organization

Permanent representatives (meetings twice a year) supported by a permanent secretariat. Studies are carried out by rapporteurs and international working groups.

Selection of current subjects

'Changes in the discharge regime'

- Description of the impact of human activities on the Rhine discharges.
- Determination of the effect of changes in land use and climate on the discharge regime of the Rhine.
- Research into the effects of forest on the hydrology of the basin.

'Travel times'

- Determination of the travel times and constituent transport in the Rhine for the improvement of the alarm model for the Rhine (in co-operation with CIPR/IKSR).

'Sediment'

- Improvement and standardization of methods to measure suspended load and bed-load transport.
- Description of sediment characteristics of the river.

'Continuation of the Monograph'

- Hydrological data for the periods 1971-1980 and 1981-1990 as a continuation of the hydrological monograph 'The Rhine basin' published in 1978.

Completed projects

see list of publications, p. 204.

Organisatie

Vaste vertegenwoordigers (vergaderingen tweemaal per jaar) ondersteund door een permanent secretariaat. Onderzoeken worden door rapporteurs en internationale werkgroepen uitgevoerd.

Belangrijkste lopende onderzoeken

„Veranderingen in het afvoerregime”

- Beschrijving van de invloed van menselijke activiteiten op de Rijnafvoeren
- Bepaling van de invloed van veranderingen in bodemgebruik en klimaat op het afvoerregime van de Rijn.
- Onderzoek naar de invloed van bos op de waterhuishouding.

„Stroomtijden”

- Bepaling van de stroomtijden en stoftransport in de Rijn ter verbetering van het alarmmodel voor de Rijn (in samenwerking met de IRC).

„Sediment”

- Verbetering en standaardisering van meetmethoden voor gehalten aan zwevend materiaal en bodemtransport.
- Beschrijving van de sedimenthuishouding in de rivier.

„Voortzetting Monografie”

- Overzicht van hydrologische gegevens over de perioden 1971-1980 en 1981-1990 als voortzetting van de in 1978 uitgegeven hydrologische monografie „Het stroomgebied van de Rijn”.

Afgesloten onderwerpen

zie lijst van publikaties, blz. 204.

Einige Informationen über die:

**INTERNATIONALE KOMMISSION FÜR
DIE HYDROLOGIE DES RHEINGEBIETES
(KHR)**

Gründung

- 1970 Im Rahmen der Internationalen Hydrologischen Dekade (IHD) der UNESCO.
- 1975 Fortsetzung der Arbeiten im Rahmen des Internationalen Hydrologischen Programms (IHP) der UNESCO und des Operationellen Hydrologie-Programms (OHP) der WMO.
- 1978 Unterstützung der Arbeiten der Kommission durch Austausch einer Verbalnote zwischen den mitarbeitenden Ländern.

Aufgaben

- Förderung der Zusammenarbeit hydrologischer Institutionen und Dienste im Einzugsgebiet des Rheins.
- Durchführung von Untersuchungen über die Hydrologie des Rheingebietes und Austausch der Ergebnisse diesbezüglicher Studien.
- Förderung des Austausches von hydrologischen Daten und Informationen im Rheingebiet (z.B. aktuelle Daten, Vorhersagen).
- Entwicklung von standardisierten Verfahren für die Sammlung und Bearbeitung hydrologischer Daten in den Rheinanliegerstaaten.

Mitarbeitende Länder

Schweiz, Österreich, Bundesrepublik Deutschland, Frankreich, Luxemburg, Niederlande

Arbeitssprachen

Deutsch und Französisch

Quelques informations sur la:

**COMMISSION INTERNATIONALE DE
L'HYDROLOGIE DU BASSIN DU RHIN
(CHR)**

Institution

- 1970 Dans le cadre de la Décennie Hydrologique Internationale (DHI) de l'UNESCO.
- 1975 Poursuite des travaux dans le cadre du Programme Hydrologique International (PHI) de l'UNESCO et du Programme d'Hydrologie Opérationnelle (PHO) de l'OMM.
- 1978 Appui des travaux de la Commission par l'échange d'une note verbale entre les pays concernés.

Tâches

- Encourager la coopération entre les instituts et les services actifs dans le bassin du Rhin.
- Réalisation d'études hydrologiques dans le bassin du Rhin et échange de résultats des études concernées.
- Encourager l'échange de données et d'informations hydrologiques dans le bassin du Rhin (p.ex. données actuelles, prévisions).
- Elaboration de méthodes standardisées pour la collecte et le traitement des données hydrologiques dans les Etats riverains du Rhin.

Pays participants

la Suisse, l'Autriche, la République Fédérale d'Allemagne, la France, le Luxembourg, les Pays-Bas

Langues de travail

allemand et français

Organisation

Ständige Vertreter (Sitzungen 2mal pro Jahr) unterstützt von einem ständigen Sekretariat. Die Bearbeitung von Projekten wird von Reporteuren und internationalen Arbeitsgruppen durchgeführt.

Auswahl der laufenden Arbeiten

»Änderungen im Abflußregime«

- Beschreibung des Einflusses der menschlichen Aktivitäten auf die Rheinabflüsse.
- Bestimmung der Auswirkungen von Bodennutzungs- und Klimaänderungen auf das Abflußregime des Rheins.
- Untersuchungen über Auswirkungen des Waldes auf den Wasserhaushalt.

»Fließzeiten«

- Ermitteln von Fließzeiten und Stofftransport im Rhein zur Verbesserung des Rheinalarmmodells (in Zusammenarbeit mit der IKSR).

»Sediment«

- Verbesserung und Standardisierung der Verfahren zur Messung von Schwebstoffgehalten und Bodentransport des Sediments.
- Beschreibung des Sedimenthaushaltes im Fluß.

»Fortschreibung der Monographie«

- Übersicht hydrologischer Daten über die Perioden 1971-1980 und 1981-1990 als Fortsetzung der im Jahre 1978 veröffentlichten Monographie »Das Rheingebiet«.

Fertiggestellte Arbeiten

siehe Publikationsliste, Seite 204.

Organisation

Les représentants permanents (réunions deux fois par an) sont soutenus par le secrétariat permanent.

Les études sont réalisées par des rapporteurs et des groupes de travail internationaux.

Principaux thèmes en cours

«Changements dans le régime des débits»

- Description de l'impact des activités humaines sur le débit du Rhin.
- Détermination des effets des changements du climat et de l'utilisation du sol sur le régime des débits du Rhin.
- Etude de l'influence de la forêt sur l'hydrologie.

«Temps d'écoulement»

- Détermination des temps d'écoulement et de transport des substances dans le Rhin pour l'amélioration du modèle d'alerte du Rhin (en collaboration avec la CIPR).

«Sédiments»

- Amélioration et standardisation des méthodes pour la mesure des matières en suspension et du charriage de fond.
- Description de la situation de la sédimentation dans le fleuve.

«Actualisation de la Monographie»

- Données hydrologiques sur les périodes 1971-1980 et 1981-1990 complétant celles de la monographie hydrologique »le Bassin du Rhin« publiée en 1978.

Travaux effectués

voir la liste de publications, page 204.

