NCR-days 2001

from sediment transport, morphology and ecology to river basin management

Edied by E.Stouthamer
and A.G. van Os

December 2001

Publication of the Netherlands Centre for River Studies
NCR publication 07-2001
ISSN 1568-234X

Table of Contents

Samenvatting

Preface

NCR-days 2001: Introduction 1

River and Floodplain Process research

Co-ordination of mono-disciplinary research

W.B.M. ten Brinke: The Morphological Triangle 2

Research using field and laboratory experiments

Sediment transport & morphology

- *A. Bosch:* Lithology of the RvR project area (Using available digital data) 4
- *P. Cleveringa and W. Westerhoff:* The river clay of the Grensmaas: the cumulative result of 6000 years of human interference in the natural vegetation 6
- *P. van der Scheer, J.S. Ribberink, A. Blom and D. Kroekenstoel:* Sediment transport formulas for graded sediment 8
- *M.M. Schoor, H. Middelkoop, T. van de Ven, J. de Kramer, M. Shoubin and D. Babich:* Morphodynamics of the Lower Volga River, Southern Russia 10

Sediment transport & morphology; Bifurcations

- *W.B.M. ten Brinke:* Sediment transport and morphological processes near a river bifurcation in the Dutch Rhine 12
- *A.W.E. Wilbers:* Analyses of dune characteristics and development around a bifurcation in the Rhine from detailed echo-soundings 14
- *S.H.L.L. Gruijters:* A 3D grain size model for the subsoil at bifurcation “Pannerdensche Kop” 16

Flow

- *W.S.J. Uijttewaal:* The effects of groyne shape on river flow 18
- *B.C. van Prooijen and W.S.J. Uijttewaal:* The evolution of coherent structures in a shallow mixing layer 20

Waterquality & Ecology

- *A.J.P. Smolders, G. van der Velde and J.G.M. Roelofs:* El Niño and the Pilcomayo River (Bolivia) 22
- *F.C.J.M. Roozen, F. Bransen, G. van Geest, B. Ibelings, R. Roijackers and M. Scheffer:* Resuspension by benthivorous fish as a determinant of algal biomass in shallow floodplain lakes 24

Waterquality & ecology; Floodplains

- *I. Thonon, H. Middelkoop and M. van der Perk:* Processes determining sediment-associated heavy metal pollution on the lowland river floodplains of the Dutch Rhine-Meuse delta 26
- *H. Olde Venterink, G. van der Lee, L.W.G. Higler and J.E. Vermaat:* Impact of floodplain wetlands on nutrient retention in the river Rhine 28
- *H.J. de Lange, J. de Jonge, P.J. den Besten, E.T.H.M. Peeters and J. Oosterbaan:* Impact of sediment pollution on the carrying capacity of benthic communities in river floodplain systems 30
- *R. Grift:* How fish benefit from floodplain restoration along the lower River Rhine 32
- *F.C.J.M. Roozen, H. Vlek, E. van der Pauw-Kraan, B. Ibelings and M. Scheffer:* Physical resuspension of algal cells by fish as a mechanism to explain high phytoplankton abundances 34
- *F.C.J.M. Roozen, G. van Geest, H. Coops, A.D. Buijse, B. Ibelings, R. Roijackers and M. Scheffer:* The OER-project; Implications for floodplain lake restoration 36
- *E.C.H.E.T. Lucassen, A.J.P. Smolders and J.G.M. Roelofs:* Restoration of dessicated mires in former meanders of the river Meuse: the detrimental effects of a stagnating water layer 38

Models & modelling

Climate change effects

- *P.W. Bogaart:* Process-based modelling of landscape and fluvial system response to rapid climate change 40

Rainfall-runoff

- *P. Valkering and J. Rotmans:* A rapid rainfall-runoff model to assess human impacts on the discharge pattern of the Meuse in Limburg 42

Flow

- *H. Haas and M. Tosserams:* Restoration of the river discharge to the southern Delta: Opportunities to enhance resilience and safety 44
- *H.H. Rabbers and D.G. Meijer:* SOBEK Model of the River Mosel 46
- *M. Visser, M. Duits and W. van der Lee:* An automatic calibration method for hydraulic models 48

Ecology

- *W. Liefveld, U. Pakes and F. Schulze:* A River Habitat Simulation Model for quantification of ecological effects of low discharge on the Common Meuse 50
- *R.J.W. de Nooij and H.J.R. Lenders:* SPEAR: An audit model for ecological river bank reconstruction planning 52
- *J. van de Koppel and P. Herman:* Do alternate stable states occur in natural ecosystems? Evidence from an estuarine tidal flat. 54
- *D. Mourad and M. van der Perk:* Modelling nutrient fluxes into Lake Peipsi / Chudskoe (Russia / Estonia) 56

Stochastics and uncertainties

- *H. van der Klis:* Stochastic modelling of river morphodynamics 58
- *S. van Vuren:* Stochastic modelling of river morphology: an analysis of bathymetric data 60
- *M. Werner:* Impact of uncertain parameters in Flood Extent Estimation 62

Decision support

- *G.A. Vonk and P.P. Schot:* An impact assessment tool for participatory evaluation of dam and reservoir locations 64

River Basin Approach, Assessing the multiple value(s) of water

- *J. Heyink Leestemaker:* Balancing Water and Social Challenges in Southern Africa 66
- *M.B.A. van Asselt, H. Middelkoop, S.A. van 't Klooster, W.P.A. van Deursen, M. Haasnoot, J.C.J. Kwadijk, H. Buiteveld, G.P. Können, P. Valkering and J. Rotmans:* Integrated water management strategies for the Rhine and Meuse basins in a changing environment 68
- *J. Krywkow, P. Valkering, A. van der Veen and J. Rotmans:* From stakeholders to agents - An analysis of social behaviour of actors within a negotiation process upon a water management project 70
- *L. Hermans:* Actor analysis to support decision making for water resources management 72
- *S. Karstens and W. Thissen:* Dealing with scale issues in river basin management: A theoretical concept paper 74

Platform function

- *E. van Beek, R. Brouwer, E. Mostert and W. Thissen:* RBA Centre, Centre for Research on River Basin Administration, Analysis and Management, Delft University of Technology 76
- *M.J.R. Cals and U. Menke:* ECRR (European Centre for River Restoration) and the link with NCR; the Dutch Synergism for Rivers 78

NCR days 2001; Looking back and ahead 80

NCR-Supervisory Board 83

NCR-Programme Commission 83

Publications 84

Colophon

Preface

Without any doubt it was a challenge to organise the NCR days 2001 at Wageningen after the promising start of the first NCR days in November 2000. But the "ambiance" of the Wageningse Berg overlooking the River Rhine gave us already an excellent starting-point.

As organisers of these days we were pleased to notice a full house of one hundred young ánd (a little bit) less young, but all very committed, river scientists from universities, research institutes, river management and consultancy agencies. We saw quite some new faces and witnessed a good mixture of 20 oral presentations from different disciplines selected out of nearly 40 subscriptions. And we had also 25 poster presentations on a wide range of subjects with fruitful and lively discussions during the poster sessions. Which gave us the idea for the subtitle of this publication: "from sediment transport, morphology and ecology to river basin management".
Thirty eight of these oral and poster presentations have been compiled in this Publication of NCR.

As chairmen of the various sessions we encountered a very co-operative group of participants who didn't hesitate to promote their poster in a "two-minute-talk" in a Hyde Park Corner atmosphere or change the overall conference language into English as soon it was known that there was one foreign participant in the audience who did not understand Dutch.

Add to this the fact that at this conference the representative of the European Centre for River Restoration (ECCR) appointed "our" NCR as the national focal point of their organisation and we may venture to conclude that NCR is on the right track.

But this certainly does not suggest that there is nothing to improve in the near future !
The participants made a passionate plea for more integral river studies and more and better communication on the results of the scientific studies to the interested citizen or potential users of these results such as consultancy agencies.
And many participants also were in favour of a continuation of the successful IRMA-SPONGE research program, a co-operation of 30 organisations of 6 Rhine or Meuse bordering countries, managed by NCR, with promising and valuable results, in a new program to expand the international river basin approach.

Now we have the challenge for the NCR days 2002: one hundred very committed participants form an ideal group size for a successful conference like we had in 2001. But we also should like to expand the participation to involve selected students presenting their results and to incorporate extra disciplines like socio-economics. And we certainly don't want to lose our experienced "Eminences grises" whose contribution to the discussions and stimulating comments on the ongoing research of young scientists are highly appreciated.
The University of Nijmegen who will organise the NCR days 2002 will have to deal with this dilemma.

When you are reading this, NCR has published another document in its "NCR publications series". This series in combination with our web site (*www.ncr-web.org*) also shows the progress in our maturation towards a real national centre for river studies.

We are looking back at a very inspiring two day conference and, even more, are looking forward to November 7th and 8th, 2002 to meet you all again at Nijmegen.

Eric C.L. Marteijn,
President of the NCR scientific Programme Committee

Ad van Os,
Programming secretary of NCR

NCR-days 2001; Introduction

E. Stouthamer, National Institute for Inland Water Management and Waste Water Treatment (RIZA)
A.G. van Os, programming secretary NCR,
e-mail: ncr@wldelft.nl

The Netherlands Centre for River Studies (NCR) is a collaboration of the major developers and users of expertise in the Netherlands in the area of rivers, viz. the universities of Delft, Utrecht, Nijmegen and Twente, IHE, ALTERRA, TNO-NITG, RIZA and WL | Delft Hydraulics.
NCR's goal is to build a joint knowledge base on rivers in the Netherlands and to promote co-operation between the most important scientific institutes in the field of river studies in the Netherlands.

NCR has two key functions:
- research-orientated and educational co-operation: in which a real commitment of the partners is reflected.
- network or platform function: this function is reflected in the organisation of meetings at which expertise and experience are exchanged; other parties are very welcome to attend.

NCR's research programme is structured thematically on the basis of scale in three research foci:

1. **River Basin Approach.** This approach comprises areas in which the entire river basin is to be examined. For example: precipitation/discharge ratios, effects of changing land use on discharge, effects of climatological changes, effects of spatial planning measures in the river basin, erosion in relation to river morphology, etc. The research can be characterised as "systems research". At an NCR workshop in March 2001 two integrative research themes have been identified:

1.1. The Genesis of Floods
1.2. Assessing the multiple value(s) of water.

2. **Structuring the River area: River and Floodplain Planning.** The river is examined as a ribbon in the natural riverbed or between the dikes. Topics for research include the assessment of the various interests (safety, shipping and nature), influence of measures in the river on water levels and morphology, compensatory measures, etc. The research can be characterised as "process and behavioural research". At the NCR workshop in March 2001 two integrative research themes have been identified:

2.1. Multiple spatial planning: living in harmony with the River
2.2. Cyclic rejuvenation of Floodplains.

3. **Joint development of large-scale data and modelling systems.** Here co-operation in the development and use of the various large-scale systems of the different partners (e.g. modelling systems, databases) is sought, where each partner contributes with his specific expertise to improve the systems.

Moreover NCR focuses on both
(i) topics requiring compilation of the participating parties' expertise and/or resulting in synergy (e.g. the integrative research themes above), and
(ii) topics necessitating co-ordination of mono-disciplinary research.

In line with (ii) NCR started recently with the "Morphological Triangle". Here co-ordination on all morphological research on Rivers within NCR is sought. To that end a pilot location has been identified: the bifurcation of the Rivers Rhine and Waal.

To perform its second key function NCR aims to provide an open platform for all people interested in scientific research and communication on River issues.
To that end NCR organises once a year the so-called NCR days, where on two consecutive days scientists present their ongoing River studies. The emphasis is on ongoing studies in order to maximise the exchange of ideas and experience between the participants and to provide the researchers a sounding board for their study approach and preliminary results. Based on these contacts they can improve their approach and possibly establish additional co-operation.

NCR organised these NCR days for the second time on October 18th and 19th, 2001 in Conference Centre De Wageningse Berg in Wageningen, the Netherlands.
In this NCR publication 38 of the presentations and posters presented there are summarised: from sediment transport through morphology and ecology to river basin management.

The Morphological Triangle

W.B.M. ten Brinke,
National Institute for Inland Water Management and Waste Water Treatment (RIZA),
P.O. Box 9072, 6800 ED Arnhem.
e-mail: w.tbrinke@riza.rws.minvenw.nl

The Morphological Triangle is a collaboration of Dutch scientific institutes working on river morphology. Within the Triangle three types of partners are discriminated, each making up a point of the Triangle: institutes that develop fundamental scientific knowledge (the University of Twente, Utrecht University and Delft University of Technology), institutes that develop applied scientific knowledge (WL | Delft Hydraulics and NITG-TNO) and the institute RIZA that directs research.
The Triangle aims at improving the exchange of knowledge between these partners and aims at a mutual attunement of research programmes that focus on specific items. These items are chosen such that the expertise of the partners involved can be combined to focus on a morphological study area that has strong societal interest. Thus, the results will serve to support river engineering and nature development. Combining scientific and societal interest in these items leads to a stronger increase of our knowledge of river morphological behaviour than in the case of autonomous working of institutes on their own projects.

The collaboration is achieved by choosing research items with strong societal interest, defining the morphological issues that play a role and mapping the research that needs to be done to tackle these issues. In the present case of the Triangle these issues need to be tackled by numerical models (1D and 2D) and these models need to be improved by experiments in the laboratory and in the river itself. Different parts of this work will be done by the partners involved, all within their own expertise, to be integrated within the collaboration of the Triangle. The selected items will be worked out into research programmes for the following years. At present two items have been selected: (1) morphodynamics of the bifurcation of the Bovenrijn into the Waal and the Pannerdensch Kanaal, and (2) water and sediment exchange between the river and the floodplain, and the resulting morphological processes in the river bed.

The Morphological Triangle has been founded only recently. The first results will be the research programmes for the two items selected. In the following years the partners will come up with results within their expertise, forming part of the research programmes. These results will focus on understanding sediment transport and morphological processes from field and laboratory measurements, finding and improving quantitative relationships for (graded) sediment transport, bedform dynamics and bed roughness, and improving 1D and 2D morphological models.

Theme 'morphodynamics during floods': sand deposition at the left bank of the Ewijksche plaat in the River Waal after the flood of 1995.

Theme 'morphological behaviour bifurcation Pannerdensche Kop': aerial photo of bifurcation Pannerdensche Kop; the photo is taken in upstream direction.The sediment distribution at the bifurcation affects the large scale sediment distribution.

Lithology of the RvR project area

Using available digital data

A. Bosch[1], A. van Ruiten[1] and M. van der Meulen[2]
[1]TNO-NITG, P.O. Box 511, 8025 BM Zwolle.
[2]Directorate General of Public Works and Water Management (RWS),
Road and Hydraulic Engineering Division (DWW),
P.O. Box 5044, 2600 GA Delft.
e-mail: a.bosch@nitg.tno.nl

Introduction

In recent years, the awareness of an impending climate change, which may result in increasing river discharges and flooding riscs, has changed river management in the Netherlands profoundly. Imminent major floods of the river Meuse and the branches of the river Rhine in 1993 and 1995 have triggered plans which break with the traditional Dutch high-water protection strategies. Rather than raising the river dikes, it has been proposed to give the rivers more space within their embanked floodplains. This is to be accomplished by combinations of land surface lowerings (by approximately 2 m) and the removal of hydraulic obstacles. The land surface lowerings will yield enormous amounts of upper soil material. Obviously, the storage of these materials, often polluted and basically useless, poses a problem.

One of the proposed solutions is to create storage space within the embanked floodplains by sand extraction. In this way, useless materials can be 'exchanged' for building and industrial raw materials, which can be absorbed by the market. Planning such extractions requires geological information. The present study meets this requirement for the embanked floodplains of the rivers Waal (down to the town of Gorinchem), Nederrijn-Lek (down to the village of Schoonhoven) and IJssel. A selection of these floodplains is to be lowered in the project 'Ruimte voor Rijntakken' (RvR); the area will further be referred to as 'RvR project area'.

Our objective is to present first order indications of the occurrence of coarse sand, suitable for the production of concrete and mortar sand, and gravel, using digitally available borehole data. The work (project GSV/RvR-Grondon) was commissioned to the Dutch National Geological Survey (TNO-NITG) by the Road and Hydraulic Engineering Division (DWW) of the Directorate-General of Public Works and Water Management (RWS).

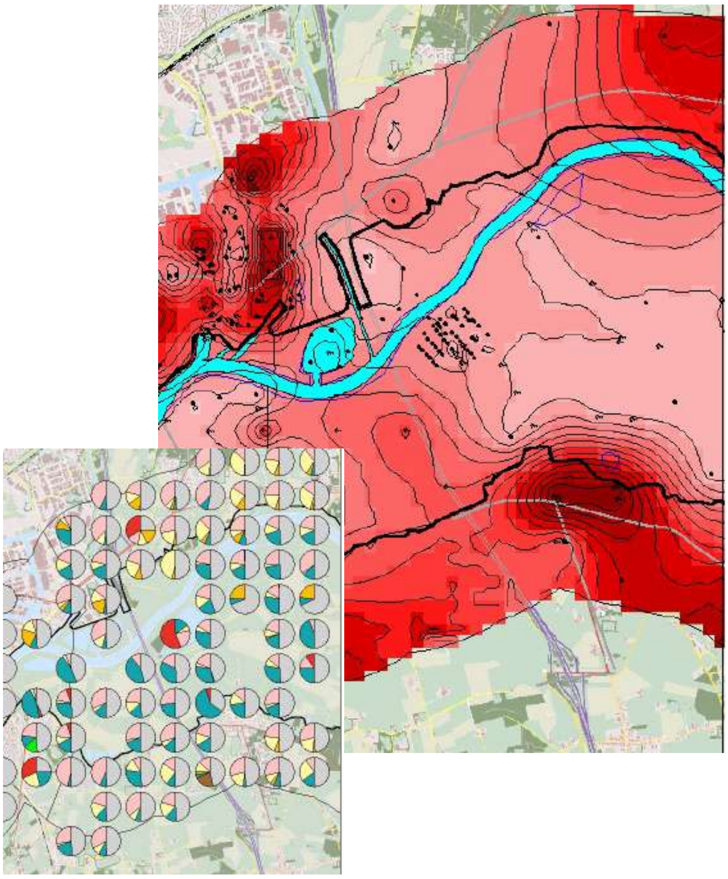
Data

The Oracle-based database DINO (Databank Information of the Netherlands' Subsoil) of TNO-NITG contains many hundreds of thousands of lithological borehole descriptions. As these descriptions have been made over a period of 150 years, they do not constitute a homogeneous set. Therefore, the database is the subject of the so called 'Quality Improvement Project (KVP)'. A first step is to check the meta-data of each borehole, such as the positioning data. Another point of attention relates to the fact that, through time, several sediment classifications have been used for borehole descriptions. Especially sand-median (M63, the median grain-size) classifications show large differences, while grain size is one of the primary parameters to be taken into account when assessing the quality and exploitability of sands. The annotation 'very coarse' ('*zeer grof*'), e.g., refers to a sand median between 300 and 420 µm in the NEN 5104 classification (Nederlands Normalisatie Instituut, Delft, 1989), and between 1000 and 2000 µm in the Wentworth classification, used worldwide.

The original classifications used for the borehole descriptions are derived from data such as the names of drilling companies, describers of the sediments and dates of drillings. Sand-median classes can subsequently be converted to the correct (numerical) sand-median ranges, which allow for further quantitative analyses. The first order identification of sands suitable for concrete and mortar sand production, for example, is accomplished by mapping sands with a median grain size of 420 µm or over.

As approximately 370.000 boreholes in DINO contain about 1.800.000 sand layers, the standardization of the data is a major operation. The database originally was of a sequential type, and was converted to a coded relational database. Errors made while entering the original borehole descriptions as well as imperfections of the conversion scripts call for special attention. Obviously, the Quality Improvement Project contributes immensely to the present study.

In a prior project (GSV/RvR-Schatkist), various digital and paper borehole-data archives were searched for borehole locations in the RvR project area. As it was considered too expensive and time-consuming to digitise data in the context of the present study, it was decided to use digital data, i.e. data stored in DINO supplemented by data provided by RWS (in



NAZCA format), only. As it turned out that the data density for the embanked floodplains was relatively low, it was recommended to incorporate data from a 1 km wide zone on either side of the RvR project area. Altogether, 17.000 boreholes (DINO as well as NAZCA) are available to the present study, showing a wide range in end depths.

Preliminary project results

The available data points have been stored into a project database and used to construct two series of maps, which visualize relevant aspects of the upper 30 to 40 meters of sediments in the RvR project area. One set of maps features pie-diagrams, showing the relative abundance of distinguished sediment types, the other consists of contour maps, indicating the tops of clay and sand occurrences below the surface.

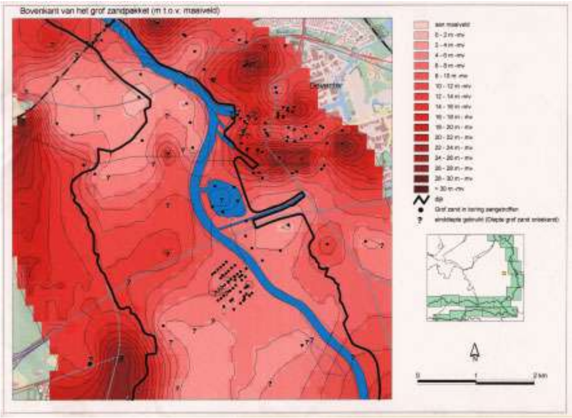
Pie-diagram maps

In order to construct the pie-diagram maps, the project area was divided into 500 × 500 m grid cells. For each cell, the relative abundance of the lithologies present was calculated from the borehole data, and represented as a volume-slice of a pie. The following lithologies have been distinguished: 1) clay and loam; 2) sand, subdivided into a fine category (63≤ M63 < 210 μm), a medium category sand (210 ≤ M63 < 420 μm) and a coarse category (420 ≤ M63 < 2000 μm); 3) gravel; 4) peat and 5) 'other'. Two subsets of pie-diagram maps are presented; one showing the composition of the upper 8 meters, the other showing the upper 30 to 40 meters below the surface.

Contour maps

For each borehole, the depths of the first occurrence (down-core) of clay, sand and coarse sand/gravel (M63 ≤ 420 μm) have been determined. Subsequently, contour maps have been made for each of these levels. These levels were, on the one hand, chosen because of the already outlined relevance of a grain-size based subdivision of the soil volume considered. On the other hand, they are expected to roughly correspond to the tops of three lithologic units which are mappable throughout the project area. These units are (1) relatively coarse-grained uppermost Pleistocene sands, overlain by (2) relatively fine-grained Pleistocene and Holocene sands and (3) a Holocene mostly clayey upper soil. Knowledge of the regional geology is used to improve and finalize the contour maps.

The combination of the two map types allows for an easy first order identification of potential sand extraction sites at a scale (1 : 50.000) and resolution sufficient for planning purposes. Potential sites are generally characterised by maximum amounts of coarse sands, which can be inferred from the pie-charts, and minimum overburdens which can be inferred from the contour maps. A final assessment of extraction possibilities at such sites would of course require more, and especially more detailed research. Further research is also called for at places where a shortage or lack of available digital data precludes a reliable map. All data will be available in ArcView.



A final remark; although the quality of the borehole data stored in DINO varies considerably, this project shows the benefits of using a national database in reconnaissance surveys, even though the data used were partly collected with a totally different goal. Therefore, the incorporation into DINO of as many borehole descriptions as possible and sensible is advocated.

References

Nederlands Normalisatie Instituut, 1989. Geotechniek: Classificatie van onverharde grondmonsters, NEN 5104. - NNI, Delft, 23 p.

The river clay of the Grensmaas: the cumulative result of 6000 years human interference in the natural vegetation

P. Cleveringa and W. Westerhoff
Netherlands Institute for Applied Geosciences TNO, Geo-Mapping South-Netherlands,
P.O. Box 35, 5670 AA Nuenen.

Sedimentation phases and age determinations of the Holocene clayey deposits in the Grensmaas area are defined by pollen analytical investigations in three continuous cores. These sediments which are situated at the surface, consist of clays and loam deposited on the coarse-grained gravel terraces bordering the present channel of the Maas. The lithology of the sediments resembles to reworked loess. The thickness of the deposit varies between 1 and 3 m and in general the transition to the underlying gravel bearing sediments is characterised by a sharp and distinct boundary.

The three investigated cores are situated near the villages of Itteren and Koeweide. They are taken as part of the large-scale soil investigations of De Maaswerken. The selection criteria for analysing the pollen content of the three cores are based on archaeological, geomorphologic and geological data. The latter are derived from DINO (the national geological databank of TNO-NITG).

Continuous and gradual sedimentation did not take place in any of the three cores. In two cores the results show that the lower part of the deposits is formed between 6000 and 5000 BP (Before Present). In the third core sedimentation of clay started shortly before the Roman Period. The larger part of the clay deposits in all three cores is formed after the Roman Period. The pollen content in one core clearly indicates that the upper 25-cm of the clay has been deposited during the last 150 years.

The pollen content of the sediments reflects the composition of the local and regional vegetation around the investigated sites. Therefore, the natural development of the vegetation as well as the impact of human interference on it can be read from a pollendiagram. The natural development of the vegetation during the Holocene is well known and dated from a great number of pollen analytical studies. The impact of man on the vegetation is known from archaeological studies. Combining this kind of information is useful in interpreting pollen analytical investigated sections.

Cutting down trees and burning of the natural vegetation was common practise in prehistoric agriculture. From archaeology it is known that the so-called Rössen and early Bandceramic cultures in southern Limburg applied this 'slash and burn' system between 5800 and 5600 BP. The short-term-effect of this method is indicated in pollendiagrams by the appearance of annual plants like willowherb and club-moss.

Changing tree populations show the long-term-effect of the 'slash and burn' practise. Which is expressed by a strong decrease of oak and lime while beech and alder increase.

The increase of alder in the investigated clays indicates a groundwater rise on the Holocene terraces of the Maas. This is attributed to a disturbance of the hydrological cycle. Loss of evapotranspiration and an increasing run-off is induced by the deforestation in the surrounding hills. As a consequence the loess cover in the hills shows a greater vulnerability to erosion. The cumulative result of this process causes sedimentation of clay and loam on the terraces of the Maas between 5000 and 3000 BP. The onset of this sedimentation seems to occur in an irregular and patchy pattern. The absence of human occupation on the lowest terraces along the Maas (there are no finds of artefacts) may be explained by the groundwater rise and the increasing sedimentation during this period.

Enlargement of the landuse clearly results in increasing sedimentation of clay and loam on the lowest terraces after the Roman Period. Pollen analysis shows that from early medieval times onwards this sedimentation can be related to peak discharges of the river. So, rather thick units of sediment can be deposited in a relatively short time. Although this general trend can be deduced from the three investigated cores it is also clear that considerable local variances may exist.

Sediment transport formulas for graded sediment

P. van der Scheer[1], J.S. Ribberink[1], A. Blom[1] and D. Kroekenstoel[2]
[1]Faculty of Civil Engineering and Management, University of Twente,
P.O. Box 217, 7500 AE Enschede.
[2]National Institute for Inland Water Management and Waste Water Treatment (RIZA),
P.O. Box 9072, 6800 ED Arnhem.

Introduction

In the last decades many sediment transport formulas have been developed. These formulas are generally used in the framework of 1D/2D morphological models for the prediction of bed-level changes in rivers. In most of the formulas the sediment is characterized by one representative grain size (uniform sediment). However, natural sediments generally consist of a mixture of different sizes (graded sediment, e.g. sand/gravel mixtures) and processes take place like selective transport, hiding / exposure and armouring which can only be described with 'graded' sediment transport formulas. In these formulas the sediment mixture is divided into several size-fractions for which the sediment transport is calculated (multi-fraction method). Some of these fractional formulas are extensions of uniform formulas, others have been derived as fractional formulas.

At the University of Twente research is taking place, which is aimed at a better understanding of graded sediment transport processes and the development of morphological models. In the present work the behaviour and the prediction capability of several graded sediment transport formulas is studied. The research is carried out in co-operation with Rijkswaterstaat-RIZA.

Graded sediment

The grain-size properties of graded sediment are generally expressed in a representative size and the size-gradation of the sediment mixture. The representative size can be expressed in the median grain size D_{50}, which denotes the grain size for which a weight percentage of 50% of the sediment mixture is smaller. The gradation of mixture is usually expressed in the geometric standard deviation:
$\sigma_g = 0.5*(D_{84}/D_{50} + D_{50}/D_{16})$.

Validity ranges

Most formulas are based on experimental-lab or field data (empirical) for certain ranges of hydraulic and sedimentologic conditions. In principle, formulas should not be applied outside their specific ranges of validity. In this research the validity ranges of a selected series of existing transport formulas were studied, using 3 characterizing parameters, i.e. the median grain size D_{50}, the geometric standard deviation σ_g, and the Shields parameter θ. The Shields parameter is a dimensionless bed shear stress parameter, which is related to the grain size. The formula of Ackers and White (with the hiding/exposure correction of Day) appeared to have the largest validity ranges. Other formulas are valid in considerably smaller ranges of hydraulic and sedimentologic conditions.

Behaviour of sediment transport formulas

The behaviour of the selected formulas was analysed by doing calculations for hypothetical cases, which are more or less representative for conditions in Dutch rivers. It is shown that all formulas are able to predict qualitatively the fining of the transported sediment for decreasing Shields numbers (lower flow regime). However, large quantitative differences are observed in predicted transport magnitudes and transport compositions especially in the lower Shields regime ($\theta < 0.2$) and for the largest sediment gradation. Figure 1 shows how different formulas behave in sediment mixtures with a strong gradation.

Verification of formulas

As a next step the selected sediment transport formulas were verified with a set of experimental lab-data, in which graded sediment was used. In total 35

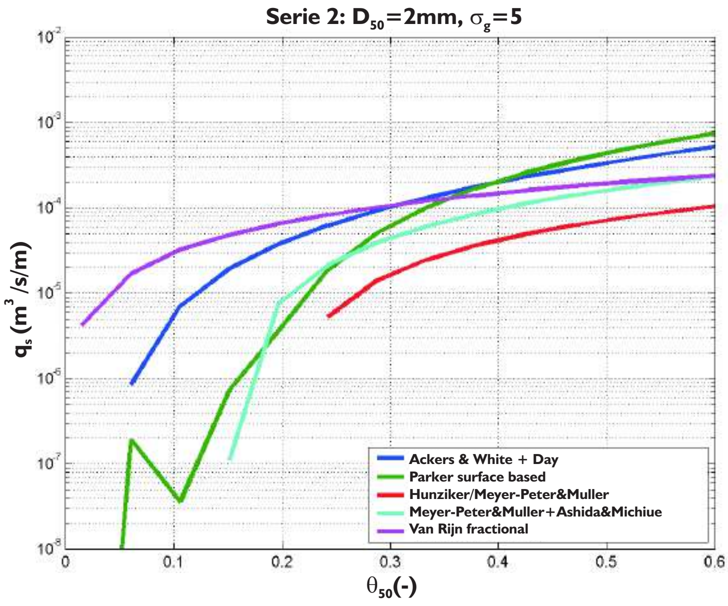


Figure 1: Sediment transport rate vs. θ_{50} for hypothetical conditions: D_{50}= 2 mm, σ_g = 5.

runs from 5 experimental series were used for this verification. All these experiments were done in flumes with a sediment recirculation system in such a way that a stable 'equilibrium' bed was reached after a certain period. It appeared that most of the formulas are able to give reasonable predictions of the transport rate and composition for the experiments with higher Shields parameters (> 0.25). At these Shields parameters all fractions are in motion. But as soon as the conditions of a run are in the small Shields parameter range (< 0.25), processes like incipient motion and selective transport play a more dominant role and large differences are observed between measured and predicted transport rates and transport compositions. Formulas based on or expanded from the formula of Meyer-Peter and Müller show a too large critical Shields number, leading to zero transport for experiments in which weak selective transport was still measured. Other formulas do not have this problem in this Shields regime but still show large differences with the data. Figure 2 shows the verification results of the formula of Ackers and White with hiding/exposure factor of Day.

Conclusions

- Multi-fraction sediment transport predictors for graded sediment are generally unreliable in the lower Shields regime. Although all studied formulas show similar qualitative behaviour, they still show large quantitative differences with measured transport rates and transport compositions in this regime (θ_{50}<0.25).
- Especially in this lower Shields regime the use of fractional formulas instead of 'uniform' formulas is important for the description of selective transport processes.
- The transport formula of Ackers and White with the hiding/exposure factor of Day shows the largest ranges of validity and gives the best transport predictions with the currently analysed and verified experiments.

Ongoing research

- The present study is extended further with additional lab and field data and with a number of formulas as developed recently. Criteria are developed for the usage of (graded) transport formulas.
- Process research is aimed at finding physical explanations for the observed differences in the lower Shields regime. Processes as bedform development, vertical bed stratification and vertical sorting (pavement layers) are considered and included in different transport model concepts (Ph.D. work Astrid Blom). This research is carried out in close co-operation with Rijkswaterstaat-RIZA and Utrecht University.

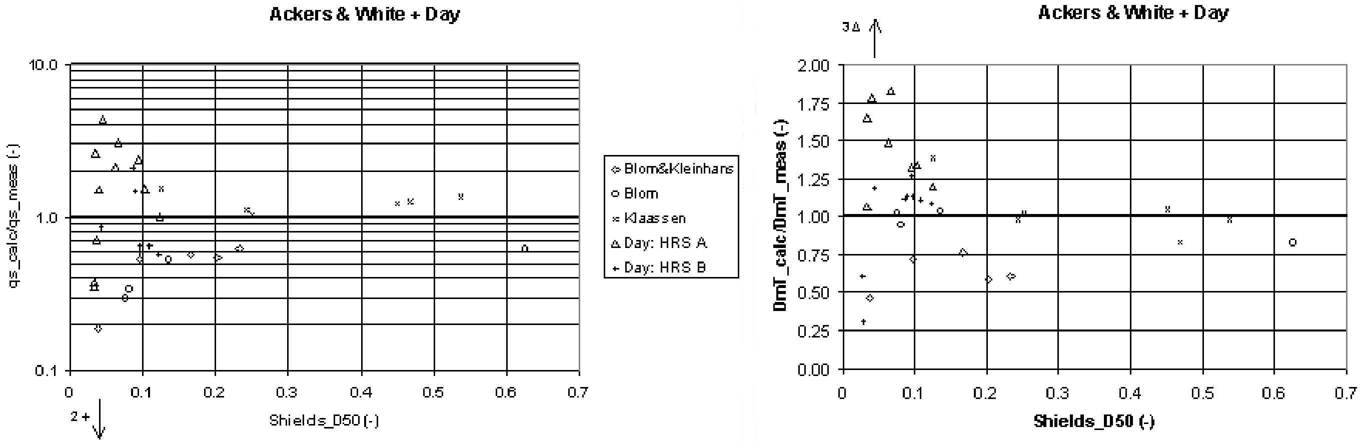


Figure 2: Verification pictures of Ackers and White, and Day: left transport rate; right transport composition.

Morphodynamics of the Lower Volga River, Southern Russia

M.M. Schoor[1], H. Middelkoop[2], T. van de Ven[2], J. de Kramer[2], M. Shoubin[3] and D. Babich[4]
[1]Ministry of Transport, Public Works and Water Management, Institute for Inland Water Management and Waste Water Treatment (RIZA), P.O. Box 9072, 6800 ED, Arnhem.
[2]Faculty of Geographical Sciences, Utrecht University, P.O. Box 80.115, 3508 TC Utrecht.
[3]Volga Water Resources Institute, Profsoyuznayastreet 30, 400001, Volgograd, Russia.
[4]Moscow State University, Geographical Faculty, Laboratory of Soil Erosion and Channel Processes, Vorobyovy Gory, 119899, Moscow, Russia.
e-mail: m.schoor@riza.rws.minvenw.nl

Background

The Lower Volga River is a large multi-channel river system with an extensive floodplain area. The Volga-Akhtuba floodplain between Volgograd and Astrakhan (Southern Russia) is about 400 km long and its width varies between 15 and 45 km. Discharge is regulated by a dam near Volgograd, but downstream of Volgograd, there are no river regulation works and the river has a very natural character. Mean discharge is about 8000 m^3/s and every spring there is a 6 weeks flood reaching peak values over 25.000 m^3/s. Although the scale is much larger than the Lower River Rhine floodplain in the Netherlands, the planform morphology of the Lower Volga is remarkably similar to the Lower Rhine as shown on 17th century Dutch historical river maps. Because of its natural river banks, low gradient and sandy sediment the Lower Volga is a good reference river for the research on river morphological processes and their interaction with vegetation dynamics. This knowledge is indispensable for river management in which safety against floods, navigation and nature rehabilitation are incorporated.

Geomorpholgy and Vegetation

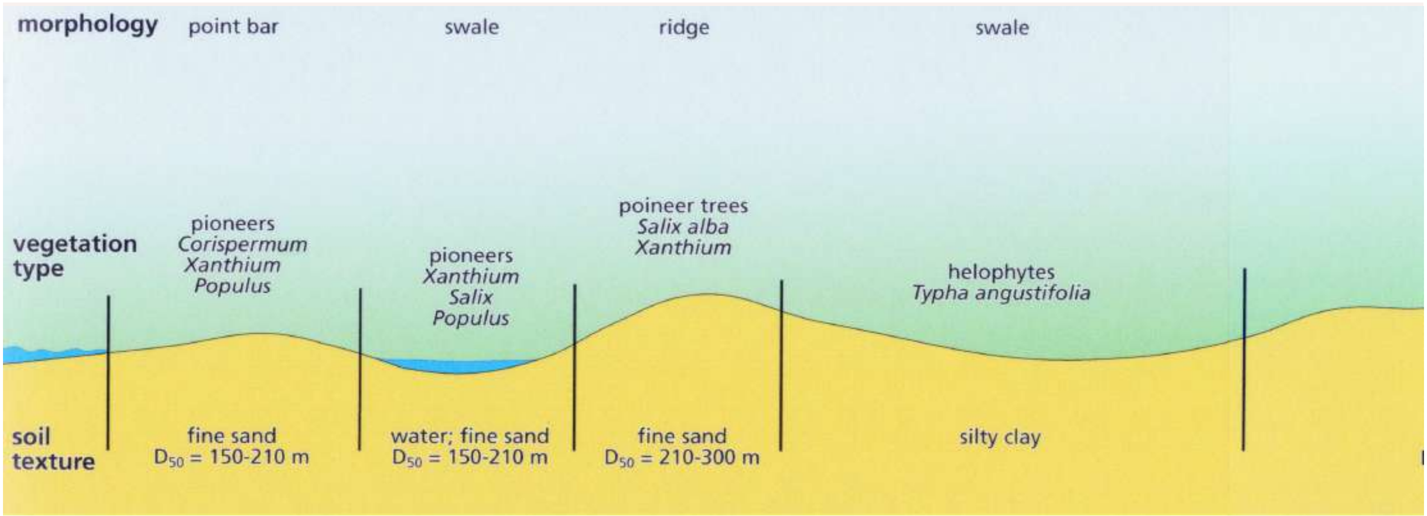
In the summer of 1999, a joint Russian-Dutch expedition was carried out to the Lower Volga River for an inventory of the morphodynamics and to investigate the relationship between vegetation and geomorphological patterns in the floodplain. Clear gradients in vegetation were found, associated with morphological elements such as former channels, bars and natural levees, backswamps and higher floodplain areas.

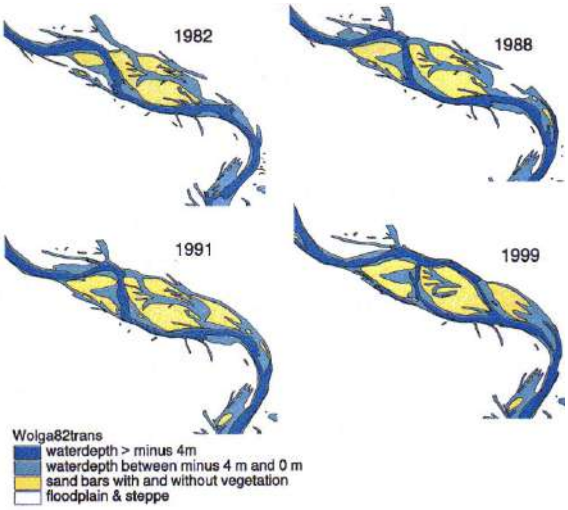
River Dynamics

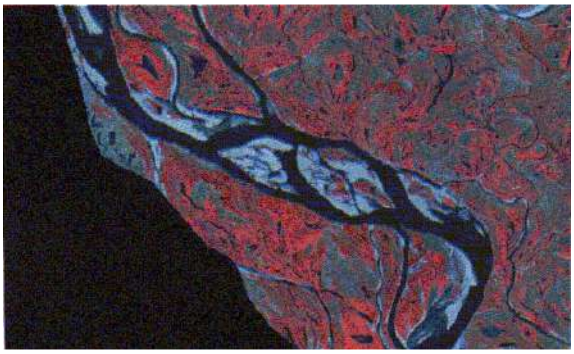
The main channel of the Volga River has been changing every year. Comparison of navigation maps of 1982, 1988, 1991 and 1999 was used to calculate migration rates and riverine parameters like width/depth ratio and stream power within different parts of the Volga River.

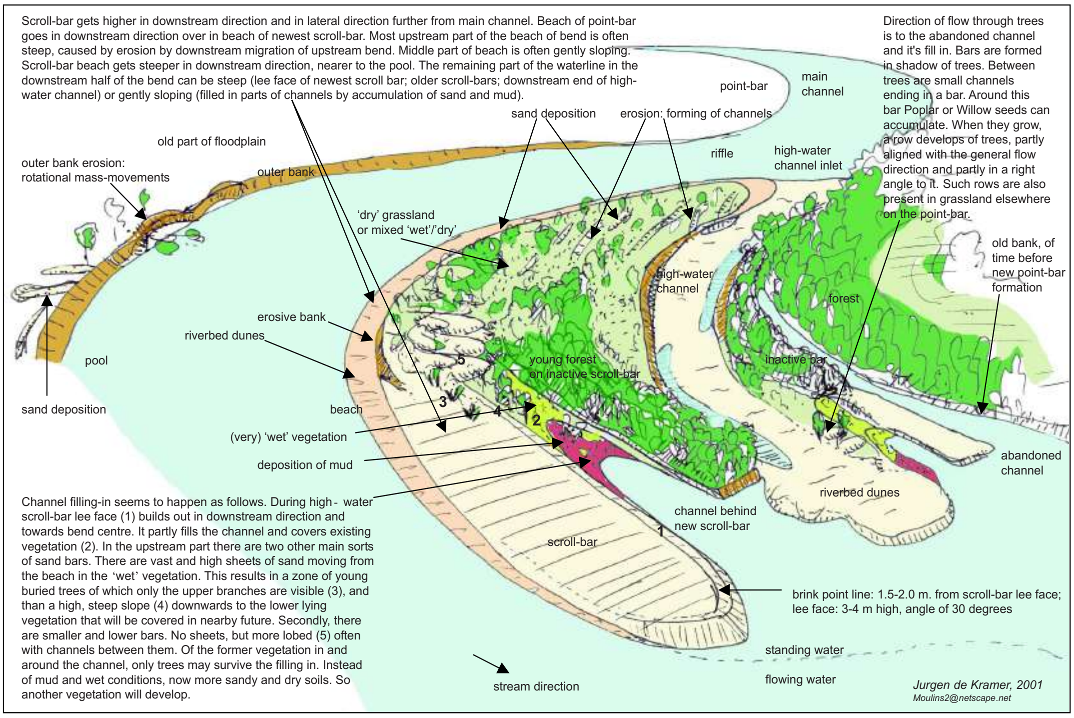
Joint fieldwork 2001

In august 2001 a joint fieldwork of Russian and Dutch partners has taken place. Subject of study was river morphodynamics and vegetation development.





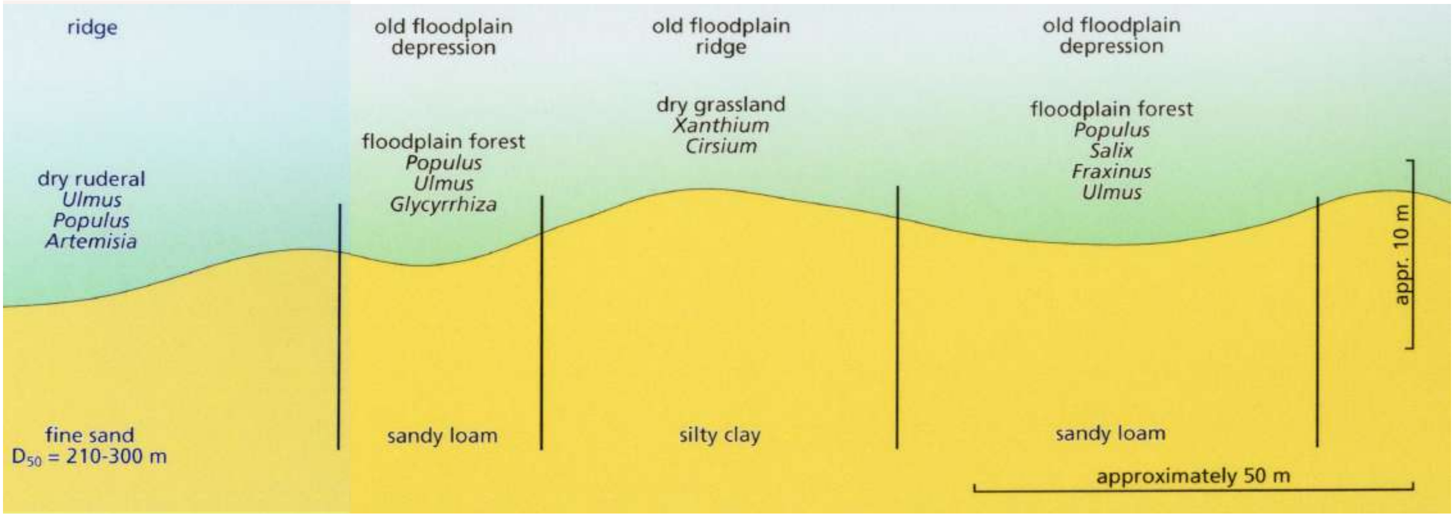




Scroll-bar gets higher in downstream direction and in lateral direction further from main channel. Beach of point-bar goes in downstream direction over in beach of newest scroll-bar. Most upstream part of the beach of bend is often steep, caused by erosion by downstream migration of upstream bend. Middle part of beach is often gently sloping. Scroll-bar beach gets steeper in downstream direction, nearer to the pool. The remaining part of the waterline in the downstream half of the bend can be steep (lee face of newest scroll bar; older scroll-bars; downstream end of high-water channel) or gently sloping (filled in parts of channels by accumulation of sand and mud).

Direction of flow through trees is to the abandoned channel and it's fill in. Bars are formed in shadow of trees. Between trees are small channels ending in a bar. Around this bar Poplar or Willow seeds can accumulate. When they grow, a row develops of trees, partly aligned with the general flow direction and partly in a right angle to it. Such rows are also present in grassland elsewhere on the point-bar.

Channel filling-in seems to happen as follows. During high- water scroll-bar lee face (1) builds out in downstream direction and towards bend centre. It partly fills the channel and covers existing vegetation (2). In the upstream part there are two other main sorts of sand bars. There are vast and high sheets of sand moving from the beach in the 'wet' vegetation. This results in a zone of young buried trees of which only the upper branches are visible (3), and than a high, steep slope (4) downwards to the lower lying vegetation that will be covered in nearby future. Secondly, there are smaller and lower bars. No sheets, but more lobed (5) often with channels between them. Of the former vegetation in and around the channel, only trees may survive the filling in. Instead of mud and wet conditions, now more sandy and dry soils. So another vegetation will develop.



Sediment transport and morphological processes near a river bifurcation in the Dutch Rhine

W.B.M. ten Brinke,
National Institute for Inland Water Management and Waste Water Treatment (RIZA),
P.O. Box 9072, 6800 ED Arnhem.
e-mail: w.tbrinke@riza.rws.minvenw.nl

In the Netherlands the Rhine bifurcates into a set of three branches. In such a densely populated country a firm control on the behaviour of river bifurcations is of utmost importance. This makes high demands upon the knowledge of sediment transport and morphological processes near river bifurcations. Thus, in The Netherlands a lot of morphological research is related to processes near river bifurcations. This research is carried out by several institutes all focusing on their core expertise being either oriented on geology, present-day processes or modelling. More and more this is done in close collaboration resulting in a number of projects comprising processes in the past, present and future. The state of the art of knowledge on present-day processes near a river bifurcation in the Rhine will be presented. These results will be discussed in view of the ultimate aim of being able to model morphodynamics in the study area with sufficient detail.

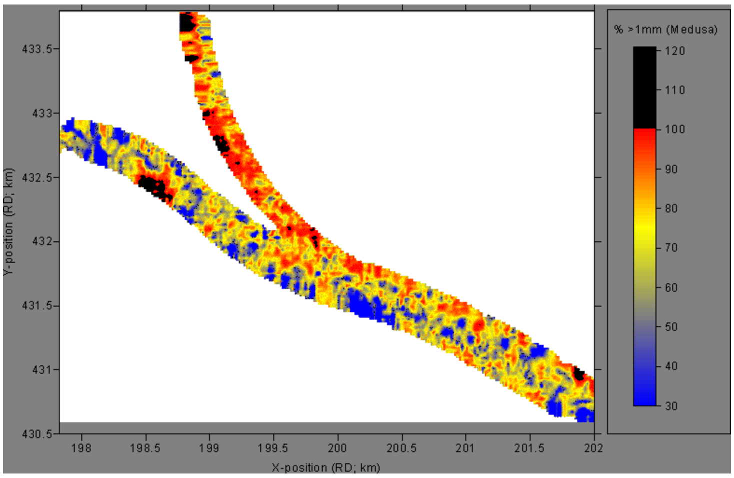


Figure 1: The percentage by weight > 1 mm of the sediments in the upper 30 cm of the bed near the river bifurcation at Pannerdensche Kop according to the Medusa measurements on the combined radio-active decay of $^{238}U + ^{232}Th$.

A 2D morphological model is needed, including 2D variation in grain size and bed roughness for calculating spatial variation in hydrodynamics and sediment transport and subsequent spatial variation in bed level over a certain time span. Besides, a formulation for sediment transport in sand-gravel bed rivers has to be based or validated on field measurements in the study area. For model calibration and validation the sediment transport ratio between the branches has to be quantified and a long-term dataset on bed and water level has to be available.

Over the last years a lot of effort has been put into understanding and quantifying temporal and spatial variability of sediment characteristics and morphological processes in the study area (Figures 1 and 2). The grain size of the upper layer of the bed has been mapped using a new technique based on the natural radio-activity of sediments. The grain size of the subsoil, including the so-called active transport layer, is now being mapped based on borings and seismic profiles. A few campaigns have been carried out focused on the suspended and bed load sediment transport and the development of dune patterns during floods such that the spatial variation in sediment transport and dune characteristics is known quite well. Validation of formulations in the literature for bed roughness in the presence of dunes has been carried out based on measured dune characteristics and grain size, and simultaneous measurements on current velocity and water level gradient.

Along with these processes within the study area at a relatively small time and spatial scale, the study area is subject to more or less autonomous developments and processes on a scale of the entire river system over several decades. At present these autonomous developments in the Dutch Rhine are mostly related to bed degradation due to a variety of causes both upstream and downstream of the study area. In future decades the impact of climate change resulting in higher floods in this area may become another significant autonomous process that affects the study area. When investing in research for modelling morphodynamics of river bifurcations, these investments should be aimed at both detailed process-oriented studies including spatial variability near the bifurcation and autonomous processes on a much larger scale.

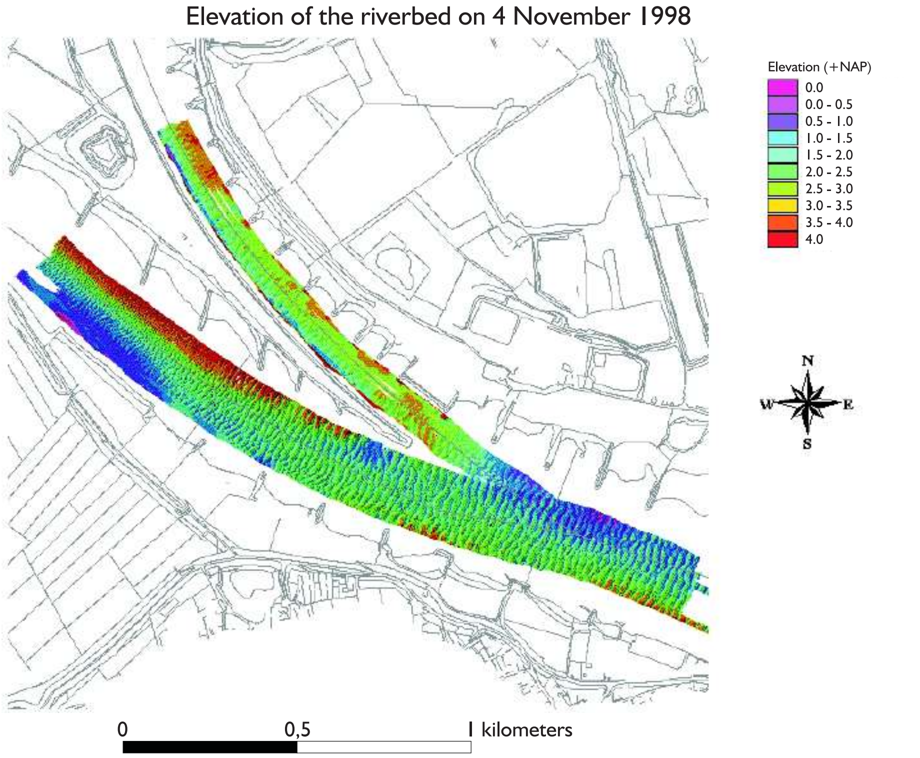


Figure 2: Dune patterns on the bed of the Bovenrijn, Waal and the Pannerdensch Kanaal near the river bifurcation during the 1998 flood, mapped by means of a multi-beam echo sounder, showing the plan form of these dunes.

Analyses of dune characteristics and development around a bifurcation in the Rhine from detailed echo-soundings

A.W.E.Wilbers
Department of Physical Geography, Utrecht University, P.O. Box 80115,
3508 TC Utrecht.
e-mail: a.wilbers@geog.uu.nl

The Dutch National Institute for Inland Water Management and Waste Water Treatment (RIZA) executed a series of successive measurements of bedforms around the bifurcation of the Rhine near the Dutch-German border, during the relative high flood wave of November 1998 (Figure 1). Measurements were performed using multi- and singlebeam echosounders and covered the complete width of the river between the groynes.

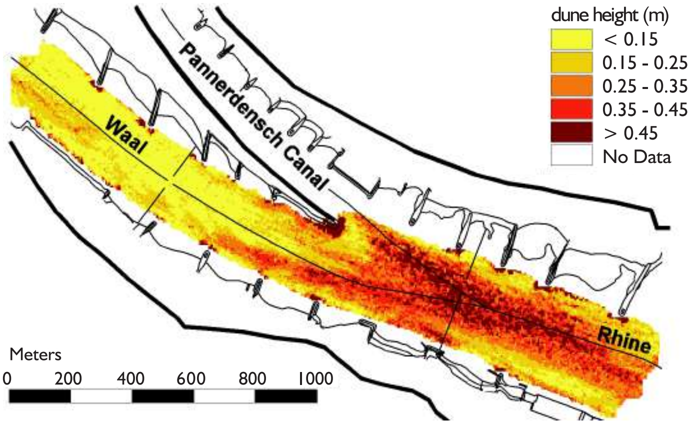


Figure 1: Dune development in the Rhine branch.

Average bedform characteristics were calculated for each branch of the bifurcation separately. The results show that at peak discharge the dunes were on average 22 m long and 1 m high in the Rhine, 11 m long and 0.5 m high in the Waal and 21 m long and 0.65 m high in the Pannerdensch Canal. At rising stage the dunes grew in length and height (Figure 2). During the falling stage the length of the dunes still increased while at the same time their height became smaller. After a few days, new (secondary, smaller) dunes appeared superimposed on the long (relict) dunes of the passed flood wave (Figure 2).

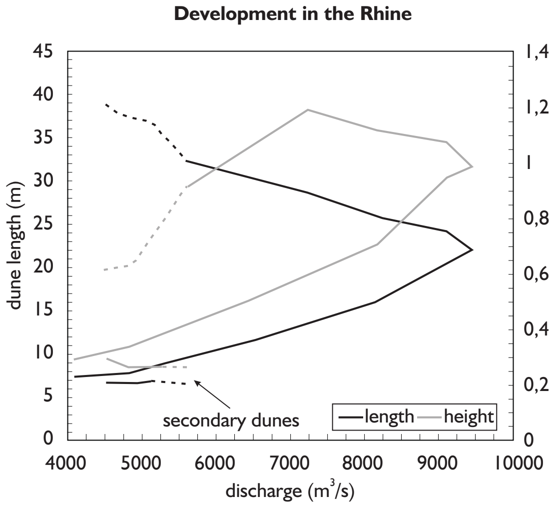


Figure 2: Dune height at the bifurcation of the Rhine mapped from echo-soundings. Flow direction from right to left.

From flume experiments in the past, several researchers suggested that dune height and length depend on water depth, shear stress and grain size. This was checked with the present data record. Because no direct information on bed shear stresses is available the flow velocity was used as an alternative.

During the flood the average water depth changed between about 8 and 12 m. This coincided with the changes in dune size as is shown in figure 2. The water depth around the bifurcation also differed up to 6 m between the deepest and shallowest parts. This difference however, did not coincide with a large change in dune size over the width of the river. This means that the water depth does not directly influence dune development around the bifurcation.

The same kind of conclusion can be drawn about the grain size of the bed material. For example, the grain size in much of the Rhine is practically the same as in the Waal. However, there is always a large difference between the dune sizes from the Rhine and the Waal.

Flow velocity in the Rhine was measured in the left half of the river, in the middle and in the right half. During the flood these velocities varied much in time from about 1.4 m/s to almost 2.0 m/s and little over the width of the river between 1.8 and 1.9 m/s on 2 November, as was also the case for the size of the dunes. Therefore, flow velocity appears to have some relation with dune development. A better correlation will probably appear if accurate data on bed shear stress would be available.

For a certain location most of the change in dune dimensions in time may therefore be explained from a feedback scheme as presented in figure 3. For example: as discharge increases over a bed with small dunes, average velocity will increase and so will shear stress and bedload transport. This increase in bedload transport will cause an increase in dune height and dune length, implying an increase of the hydraulic roughness. However, the latter increase will lag behind the change in flow velocity because it takes time to move the necessary material to build a higher dune.

A hitherto not considered aspect of dune shape and dimension that might be responsible for a different dune evolution is a spatial unsteadiness of the flow. For example: when the flow expands in plan view between two locations the shear stress and bedload transport per unit width of the bed will decrease. As a consequence the dune migration will slow down, which must result in either the coalescence of successive dunes, possibly resulting in higher dunes or a reduction in dune wavelength. This effect will be a subject for further analysis.

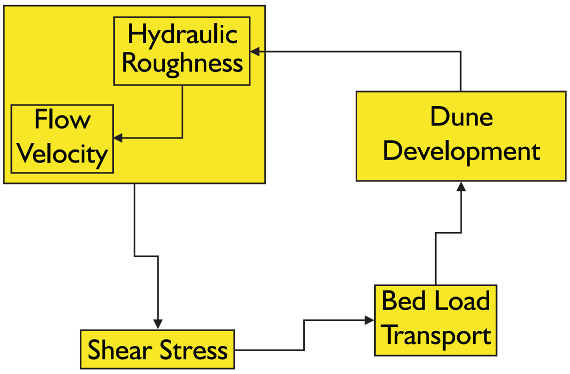


Figure 3: Feedback scheme for dune development.

A 3D grain size model for the subsoil at bifurcation "Pannerdensche Kop"

S.H.L.L. Gruijters
Netherlands Institute for Applied Geosciences TNO, Geo-Mapping South-Netherlands,
P.O. Box 35, 5670 AA Nuenen.
tel. 040-2 348 826 / 06-20 491 494.
e-mail: s.gruijters@nitg.tno.nl

Introduction

A thorough geological knowledge of the subsurface of the riverbed is an absolute prerequisite for morphological computations and analysis of field data. For instance for the numerical models that quantify morphological processes in a river (e.g. SOBEK and Delft2D) it is crucial to have knowledge about the spatial distribution of the various grain sizes of the bed material. Important parameters in this respect are the median grain size (D_{50}) and the sorting coefficient (calculated as $0.5*(D_{16}/D_{50}+D_{50}/D_{84})$. To map the spatial distribution of these values as accurately as possible, TNO-NITG performed drillings and seismic surveys at the river bifurcation "Pannerdensche Kop" for the River Department of the Dutch Institute for Inland Water Management and Waste Water Treatment (RIZA). TNO-NITG vouches for the integration and geological interpretation of the research data into a three dimensional database (grid size 25*25*0.2m). The project runs from August 2000 to November 2001, and covers parts of the Upper Rhine (about 2 km), the Waal (about 2 km) and the Pannerdensch Kanaal (about 2 km) at the Pannerdensche Kop bifurcation.

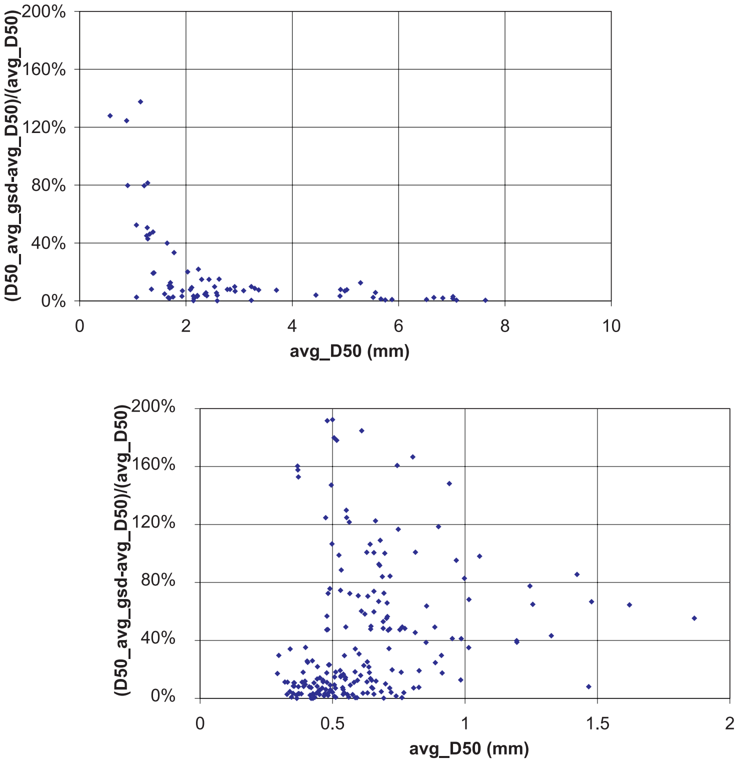


Figure 1: Comparison between avg_D_{50} and D_{50}_avg_gsd for active layer (top) and non-active layer (bottom).

Field measurements and interpretation

TNO-NITG performed 102 vibro-corings. A vibro-corer uses a vibration unit to drill a steel casing with a PVC liner, four meters deep into the riverbed within 20 seconds. Approximately 2000 samples were taken from these borings from which 545 samples were selected to determine the grain size distribution (Fugro Ingenieursbureau BV). In addition, seismic recordings were taken along almost 35 km of river, using both the X-star chirper (TNO-NITG) and the seistec Boomer (GeoMega). RIZA performed additional measurements on the elevation of the riverbed (Meetdienst DON), the lithological composition of the shallow subsurface (Medusa) and an additional seismic technique (Innomar). Once the measurements had been completed, the department of Geo-Infrastructure at TNO-NITG interpreted the data. The core samples were classified, both lithologically and stratigraphically, and combined with the seismic sections. Besides a number of geological strata, the base of the "active layer" was determined. This layer consists of rather coarse material (mainly gravel) that, at high river discharge, forms river dunes. The layers beneath this active layer have not recently (within the last few decades) taken part in sediment transportation and are summarized as "non-active layer".

Interpolation to a three dimensional model in Access

RIZA was interested in a 3D model (grid size 25*25*0.2 m) of the median grain size at the Pannerdensche Kop. However, the median grain size cannot be used in the interpolation itself because it is not additive. This is caused by the non-linear determination of this parameter from a single grain size distribution. To determine the relevance of the incorrectness of using the D_{50} in the interpolation procedure the following analysis was carried out. First a grain size distribution was randomly selected from the available 545 grain size distributions. After this, three neighbouring grain size distributions from the same layer (active or non-active) were selected. First the D_{50} was calculated for each grain size distribution. These four D_{50} values were used to calculate the average D_{50}: avg_D_{50} = ¼*ΣD_{50i}. Secondly, the average grain size distribution was calculated from the separate measured fractions in each selected grain size distribution. From this average grain size distribution the D_{50} was calculated: D_{50}_avg_gsd. This procedure was repeated about 260 times. Figure 1 shows the difference between both methods in the active layer and the non-active layer. The y-axis shows the difference between both methods, relative to D_{50}_avg_gsd. It is obvious that the mean grain size is largely overestimated when the first method is used. Therefore it was decided to interpolate every measured fraction resulting in a database with a full description of the grain size distribution at each cell.

The distinction between the active layer and the underlying layers is very relevant for the interpolation of the grain size distribution. The spatial variation in the active layer is directly related to the current riverbed. The spatial variation in the "non-active layer is related to river processes in the past (up to more than several hundreds of years) and therefore not influenced by the current riverbed. Because of this the interpolation of the grain size distribution has been carried out in both layers separately. For the interpolation a three-dimensional Kriging technique was used. For the active layer the same variogram was used for all 18 fractions of the grain size distribution. However, because of great differences in grain size, different variograms were calculated for the Waal, the Pannerdensche Kop and the Upper Rhine. For the non-active layer 18 variograms were calculated, one for each fraction. For this layer no distinction between the three river branches was made. The interpolated grain size distributions were transferred into an Access database.

Conclusions

Both in the vibro-corings and in the seismic sections the distinction between the active layer and the non-active layer was clearly found.
The interactive, digital interpretation of the seismic surveys combined with the vibro-cores and a good understanding of the geological history of the region resulted in a very useful layer model of the first 4 meters below the current riverbed. This project demonstrates the great potential of seismic techniques and geological knowledge to enhance the understanding of the subsoil in riverbeds.
To construct a three-dimensional model of the median grain size (D_{50}) the interpolation of the full grain size distribution is necessary. The transformation of this three dimensional model into an Access database makes it easy to extract data from the model at user-defined, horizontal or vertical cross sections (Figure 2). Using these tools different data sets can be extracted, which can be used as direct input for morphological models.

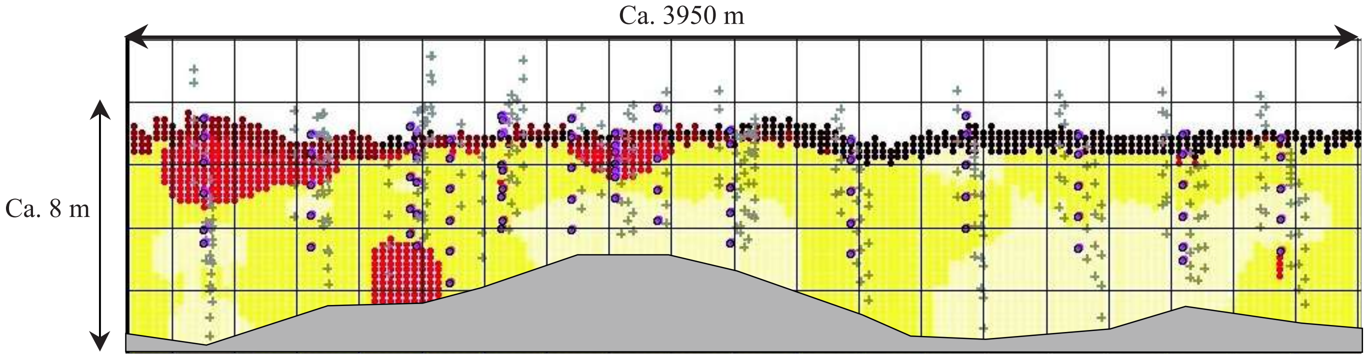


Figure 2: Example of a cross section through the 3D database with gravel (red) and sand (yellow) deposits. At the dots a measured grain size distribution is present, the crosses indicate the grain size distribution measured in other cross sections. The grey color indicates the zone where no data are available.

The effects of groyne shape on river flow

A joint project of Rijkswaterstaat-DWW/DON, WL | Delft Hydraulics, Royal Haskoning (Svasek) and Delft University of Technology

W.S.J. Uijttewaal
Fluid Mechanics Section, Faculty of Civil Engineering and Geosciences, Delft University of Technology, P.O. Box 5048, 2600 GA Delft.
tel. +31-(0)15-2781371.

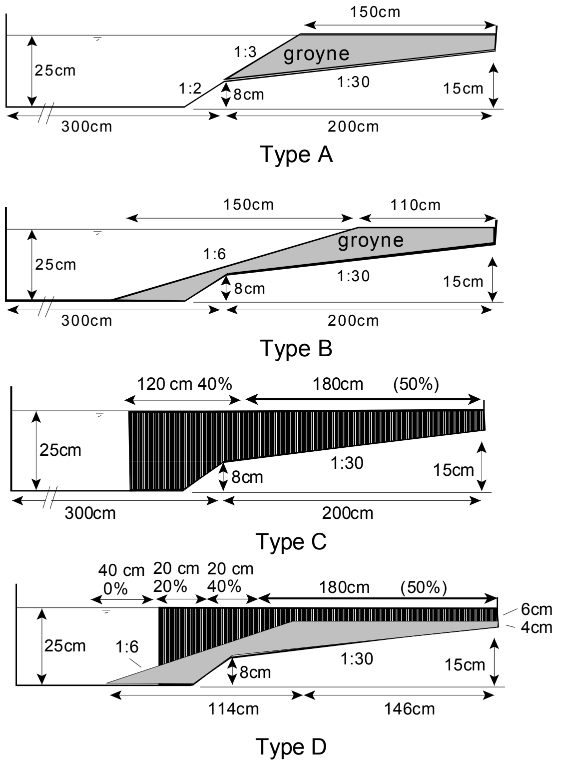
Introduction

The greater parts of the Dutch and German rivers are equipped with groynes. The primary function of a groyne is to keep the main navigation channel at proper depth and location. Through the artificial narrowing of the main channel the groynes contribute to the total resistance of the river. At higher discharges and associated water levels this extra resistance should ideally disappear as to allow for the large discharge. In between the groynes dead zones are formed that exchange mass and momentum with the main flow through the mixing zone and through the navigation-induced water motion. In these exchange flows sediment is transported and morphology of the groyne field adapts itself to flow, which generally results in a pronounced scour hole just downstream of the groyne head, sometimes even undermining the groyne construction. For a newly designed groyne the following requirements are formulated:

- The primary function of a groyne should be maintained, i.e. mean flow velocities in the main channel should not be affected by the new groynes.
- The formation of scour holes should be avoided or at least diminish.
- The strong currents and large velocity gradients around a groyne head, generated either by navigation or mean flow, should be weakened.
- The contribution to the resistance at high water level should decrease.
- A numerical model should be developed that is capable of predicting flow around a groyne of various shapes at various submerged and non-submerged conditions.

New designs for groynes are tested in a scaled physical model as well as in a numerical model.
Apart from practical needs, a thorough understanding of the hydrodynamics of the groyne field flow will contribute to optimisation of groyne design and numerical modelling of shallow flows in general.

In order to test newly designed groynes and to improve our understanding of hydrodynamics of the groyne field flow a series of experiments has been carried out.



type A: impermeable with head slope 1:3,
type B: impermeable with head slope 1:6,
type C: permeable, pile sheet,
type D: hybrid impermeable part and pile sheet .

Figure 1: Cross-sectional views of groyne designs.

Laboratory experiments

Four different groyne types (Fig. 1) are implemented in a physical scale model of a schematised river reach, scaled 1:40. Using a mean water level and groyne height of 0.25 m, and a flow velocity in the main channel of 0.35 m/s, the Froude number is 0.2 and corresponds with a prototype velocity of 2 m/s for standard conditions. The Reynolds number is then approximately 60.000. Inside a groyne field of 4.5 m length this number is still sufficiently large (10.000). It is further assumed that all surfaces are hydraulically smooth. Water levels of 0.25 m (non submerged), 0.30 m (5 cm submerged) and 0.35 m (10 cm submerged) are chosen.
Measures have been taken in order to provide an optimised inflow of water, i.e. the inflow conditions are adapted to the expected profile far downstream such that beyond the first two groyne fields the flow can be considered as fully developed.
Velocities are measured at various locations with emphasis on the shear layer and the area around the groyne, using Particle Tracking Velocimetry (PTV), Laser Doppler Anemometry (LDA), and electromagnetic techniques. A few examples of measured (PTV) turbulence intensities for three cases are shown in figure 2.

Numerical simulations

The groyne field flows of the impermeable groynes have been modelled numerically using two independent approaches, i.e. Depth averaged Large Eddy Simulation (HLES) with a sophisticated sub-grid model, developed by WL | Delft Hydraulics, and a 3D-LES finite element code with a standard Smagorinski sub-grid model, developed by Royal Haskoning (Svasek). Both perform equally well on the non-submerged, non-permeable cases, as demonstrated in figure 3.The recirculation zones and turbulence intensities are predicted satisfactorily. For the submerged cases however, large discrepancies with the experiments are found for which a further data-analysis and in-depth comparison is required.

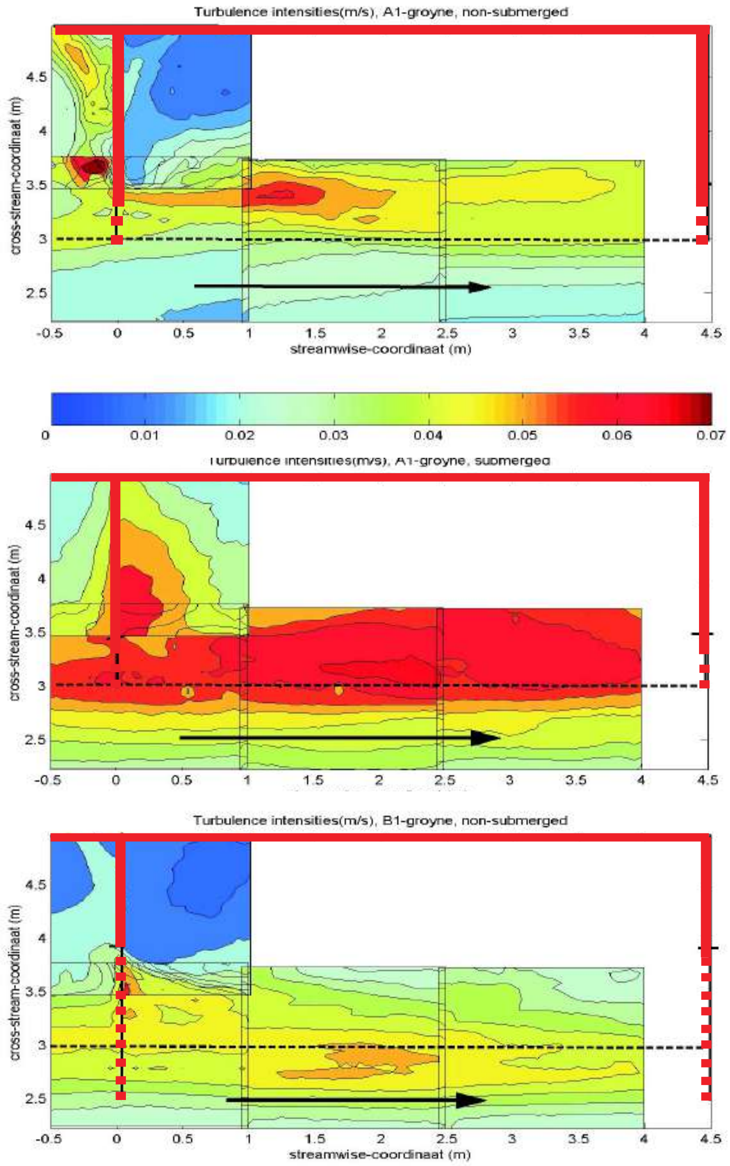


Figure 2: A comparison of turbulence intensities obtained in the experiments for groyne type A non-submerged (top), type A, submerged (middle), type B, non-submerged (bottom).

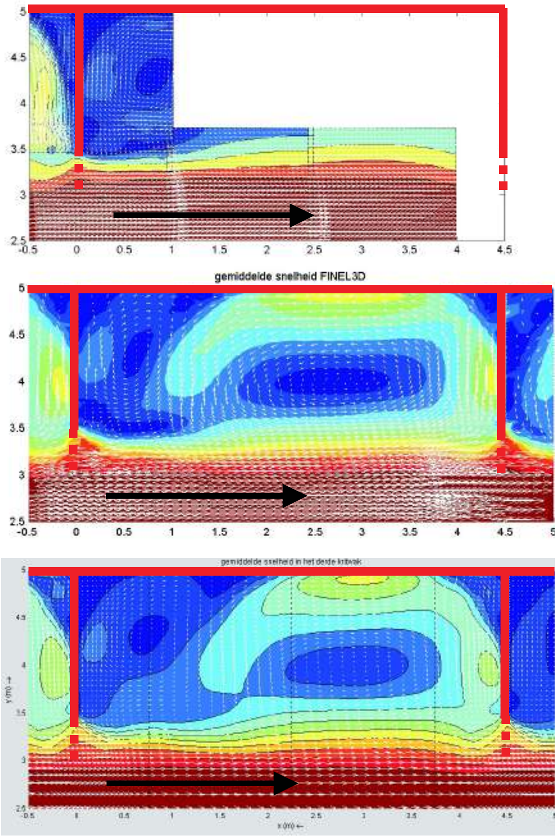


Figure 3: A comparison between mean velocity fields for groyne type A, non-submerged: experiment (top), calculated 3D-LES (middle) and 2D-HLES (bottom).

Field measurements

In order to evaluate the effects of the groynes in a full-scale prototype it is proposed to use a measurement technique that provides information about the flow structures and the dynamics of the whole groyne field area. A first exploration has been performed to demonstrate the feasibility of a technique that uses a large number of cheap and simple floats in combination with image-recording and the PTV analysis technique.

Conclusions

Although the experiments are still going on, the presented results already provide us with useful information regarding the overall flow pattern, the shear layer and the turbulence properties. It is clear from the experiments that relatively small adaptations to the design of a groyne can have great consequences for the turbulence properties at the river-groyne-field interface and thus for the morphology of the bed.

Parts of the large data set already have proven their value for verification of numerical models. It is concluded that the state of the art numerical models are capable of coping with the complex properties of the flow in a groyne field for the non-submerged case, but that additional work has to be done to understand the deviations in the submerged case.

The evolution of coherent structures in a shallow mixing layer

B.C. van Prooijen and W.S.J. Uijttewaal
Fluid Mechanics Section, Faculty of Civil Engineering and Geosciences, Delft University of Technology, P.O. Box 5048, 2600 GA Delft.

Introduction

Rivers, in particular lowland rivers, belong to the class of wide open channel flows. The aspect ratio (depth/width) is in the order of 5% or less. At several places in rivers, shallow mixing layers can arise, i.e. transverse shear layers between contiguous flows of different velocity. Characteristic for these shallow shear flows is the anisotropy of the turbulent motion. The no-slip condition at the bottom results in a turbulent wall flow, with a characteristic length scale of the order of the water depth. The length scale of the transverse shear layer can however be orders of magnitudes larger than the water depth. In this study an attempt is made to understand the dynamics of the large scale motion under influence of the small scale turbulence. First the mean velocity field of a shallow mixing layer is modeled using a self-similarity assumption. Second, the evolution of the coherent structure is determined from a linear stability analysis, making use of the mean flow field. The results are validated with laboratory experiments.

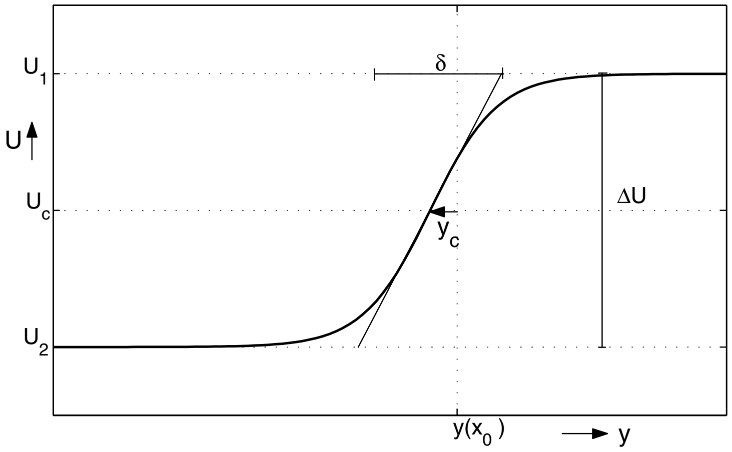


Figure 1: Sketch of the transverse profile of the mean streamwise velocity *U(x,y)*.

Mean flow field

A quasi-1D-model is developed, based on the self-similarity of the transverse profile of the mean streamwise velocity. The velocity field is then just depending on the downstream coordinate x:

$$U(x,y)=U_c(x)+\frac{\Delta U(x)}{2}\tanh\left(\frac{y-y_c(x)}{\frac{1}{2}\delta(x)}\right)$$

Expressions are derived for the downstream development of the velocity in the center of the mixing layer (U_c), the velocity difference (ΔU), the growth rate of the mixing layer width (δ) and the shift of the center of the mixing layer to the low velocity side (y_c):

$$U_c(x)=U_c(x_0)$$

$$\Delta U(x)=\Delta U(x_0)\exp\left(-\frac{2c_f}{H}x\right)$$

$$\delta(x)=\alpha\frac{\Delta U(x_0)}{U_c}\frac{H}{2c_f}\left(1-\exp\left(-\frac{2c_f}{H}x\right)\right)+\delta(x_0)$$

$$\int_0^{\frac{y_c(x)}{2}} HU(x,y)dy=H\frac{W}{2}U_1(x_0)$$

with *H* as the water depth, c_f as the bottom friction coefficient, and *W* as the width of the flow domain. The entrainment coefficient α=0.085 is obtained from unbounded mixing layer experiments. The influence of the shallowness on the widening of the mixing layer is therefore mainly caused by the decreasing velocity difference in downstream direction. Note that in the far field the Reynolds stress produced near the bottom will play a role in the widening, in that case α is not a constant. A comparison with the flow field of a measured shallow mixing layer flow demonstrates the validity of the above described model.

Large scale motion

The shallow-water stability equations can be derived from depth averaged Navier-Stokes equations as the modified Orr-Sommerfeld equation:

$$(U-\frac{\omega}{k})(v''-k^2)-vU''=i\frac{c_f U}{kh}(-k^2v+2\frac{U'}{U}v'+2v'')+i\frac{\nu_t}{k}(v''''-2k^2v''-k^4v)$$

The dissipative terms on the right hand side represent the respective influence of the bottom friction and the Reynolds stress produced by the small scale turbulence. Solving the eigenvalue problem for a mean velocity profile, the growth rates can be determined for each wavenumber. As the whole velocity field is known, the growth rates at each position downstream can be determined. Integrating these growth rates in downstream direction for each wavenumber *k* results in the energy density at a certain position downstream, for a given initial energy density distribution. The peak wave number and peak intensity are well predicted (Figure 3).

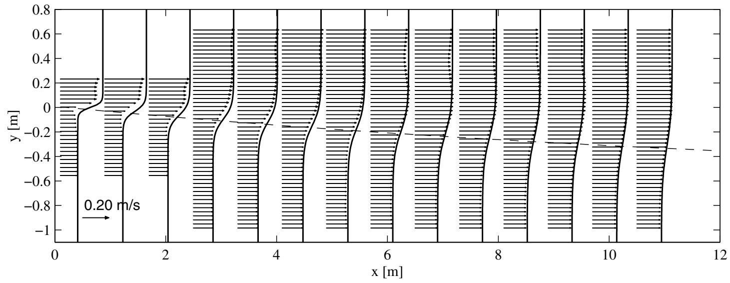


Figure 2: The velocity profiles of the mean streamwise velocity. The arrows represent the measured flow field and the solid lines the computed one.

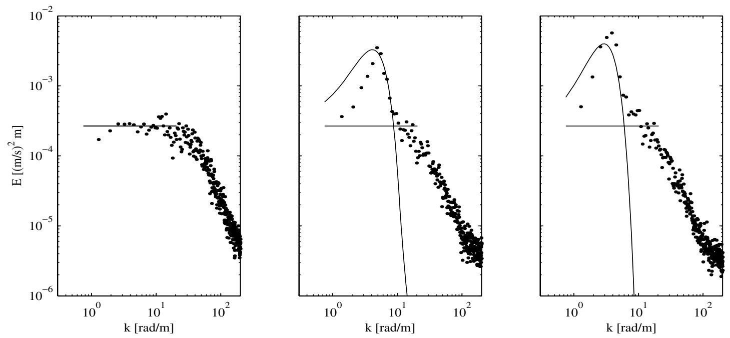


Figure 3: Measured (.) and computed (-) energy density spectra for the 67 mm-case, at different downstream positions: x=0 m, 4.5 m and 10 m.

The peak in the spectra reflects the dominant mode. The associated length scale differs from the length scale of the most unstable mode, obtained from the wavenumber of the maximum growth rate. The different length scales are plotted in figure 4. This analysis shows that the history of the flow has to be taken into account for the development of the typical length scale of the large scale motion.

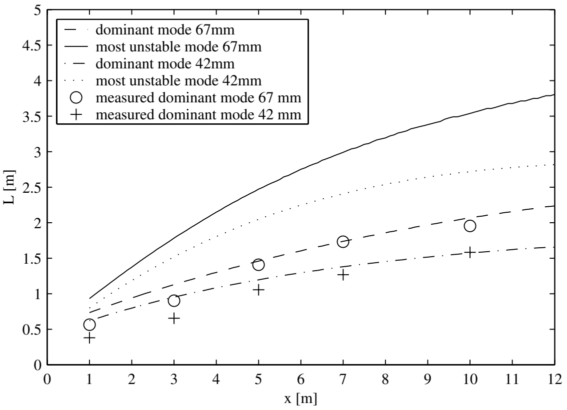


Figure 4: Length scale development of the computed most unstable and dominant mode and the measured dominant mode for the 42 mm-case and the 67 mm-case.

Conclusions

- The mean flow field can be described by a simple model, with the entrainment coefficient α as the only empirical parameter.
- The downstream evolution of the length scale and energy density of the dominant mode is well predicted, using a linear theory.
- In determining the local turbulence characteristics, the advection of the large scale structures has to be accounted for.

El Niño and the Pilcomayo River (Bolivia)

Relations between El Niño, discharge, sediment transport, metal pollution and Sábalo (Prochilodus lineatus)

A.J.P. Smolders[1,3], G. van der Velde[2] and J.G.M. Roelofs[1]

[1]Department of Aquatic Ecology and Environmental Biology, [2]Department of Animal Ecology and Ecophysiology, Section Aquatic Animal Ecology, University of Nijmegen, 6525 ED Nijmegen.

[3]Ambio Chaco, Villa Montes, Bolivia.

e-mail: fonss@sci.kun.nl

The South-American Pilcomayo River (Figure 1) is a tributary to the large 'La Plata' system and has a basin area of approximately 98,000 km^2 . The river arises in the Bolivian Andes (Cordillera Oriental, at approx. 5000 m above sea level) and cuts down through the Andes, until it reaches the Chaco plain near the town of Villa Montes (approx. 400 m above sea level). The Andean part of the river has a length of approx. 500 km and a mean fall of 10 per mill. The river then flows southward through the Chaco, where it forms the frontier between Argentina and Paraguay before it joins the Paraguay River just north of the town of Asunción (Figure 1). This lower stretch of the river has a total length of almost 1000 km and a very low mean fall of only 0.2 per mill.

An important concern during the 1990's was the considerable decrease in the Sábalo catch in the river. The Sábalo (Prochilodus lineatus, Prochilodontidae) is a migratory, detritivorous fish which feeds in the flood plains of the lower Chaco (Figure 1). At the end of the rainy season, the adult fish start their upstream migration to the Andean parts of the river in order to spawn at the onset of the next rainy season. Most fishery activities are located in the narrow canyon north of the town of Villa Montes, where the fish migrate into the Andean part of the river and have to face strong water currents, which hamper their progress. Fish traps built along the shoreline made fishery very efficient. Since 1999, the number of Sábalos migrating upstream has recovered considerably.

Erosion and sedimentation

The sediment load of the Pilcomayo River is amongst the highest in the world (24 g l^{-1} in the wet summer months). The main cause of the strong erosion is the susceptibility of the local geological formations to erosion because of their small particle size. The sedimentation of this material provokes siltation as well as diversion of the riverbed. During the last centuries, the river discharged into a depression called Estero Patiño, located 250 km upstream from the Paraguay River (Figure 1). This depression gradually filled up with sediment until it was more or less completely filled up in the mid 1940's. Then the river started to fill up the lower reach of its own river channel, resulting in a gradual retreat of the river. The point where the river "disappears" has been moving upstream rapidly ever since. It is predicted that the river will change its course radically when it reaches one of the two so-called critical points, which are now located nearby the current point of convulsion (Figure 1). Contamination of the sediments with polluted mine waste from the Potosí mines is largely prevented by the fact that the heavy erosion causes a thorough mixing of the pollutants with uncontaminated suspended matter.

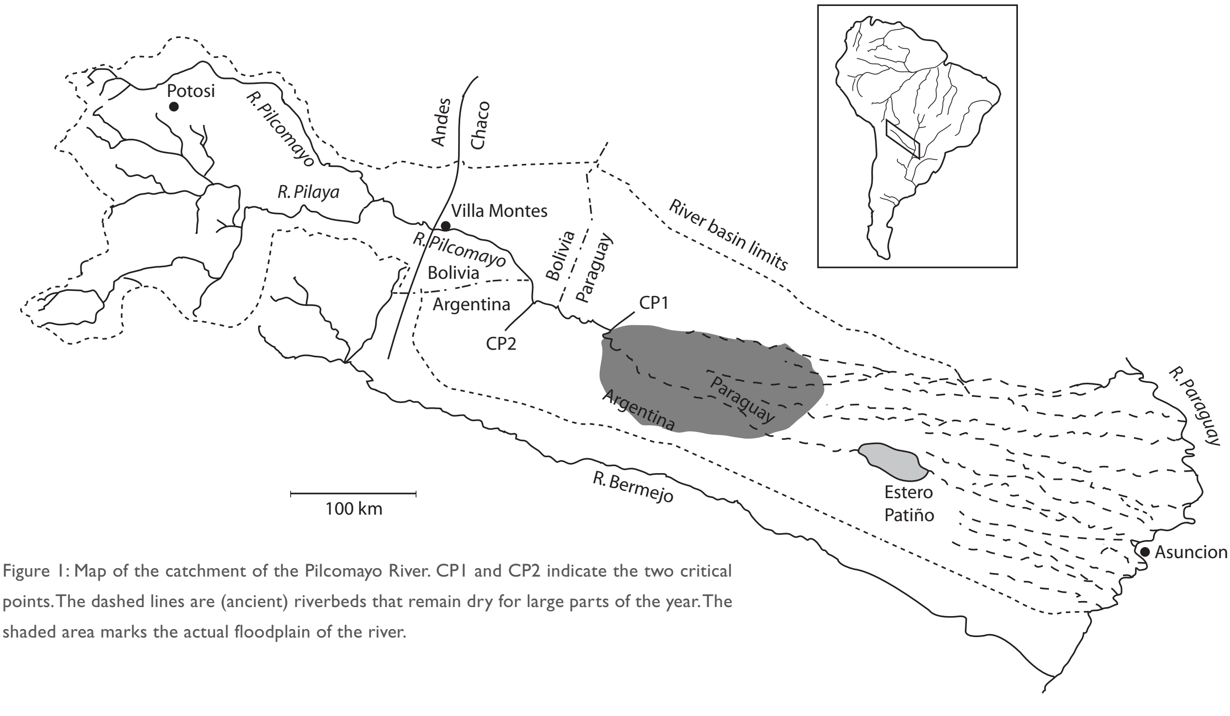


Figure 1: Map of the catchment of the Pilcomayo River. CP1 and CP2 indicate the two critical points. The dashed lines are (ancient) riverbeds that remain dry for large parts of the year. The shaded area marks the actual floodplain of the river.

Variations in river discharge and Sábalo catches

Apart from high sediment loads, the Pilcomayo River is also characterised by strong inter-annual variations in the river discharge. In the nineties, five consecutive years with relatively low or very low mean river discharges coincided with a strong decline in the fish catches in Villa Montes. River discharges can have a strong influence on fish production by their effects on the inundated surface area and thus on the availability of potential feeding grounds. Indeed we were able to relate the amount of Sábalo caught in the Pilcomayo River in a particular year. As the majority of the migrating Sábalo in the Pilcomayo are two or three years old, the strongest correlation was found between catches and the mean river discharge for the three preceding years.

At least over the last twenty years the discharge of the Pilcomayo seems to be determined by the large-scale climatic "El Niño" Southern Oscillation (ENSO) system. The SOI is a measure of the difference between the standardised sea level pressures at Tahiti and Darwin (Australia), negative values indicating "El Niño" years. The two worst "El Nino" years of the last twenty years, 1982/1983 and 1997/1998, were characterised by very low mean river discharges in the Pilcomayo. The low river discharges in the first half of the nineties also coincided with a five-year period in which the SOI was consistently low. Some consider this period as the longest "El Niño" event on record.

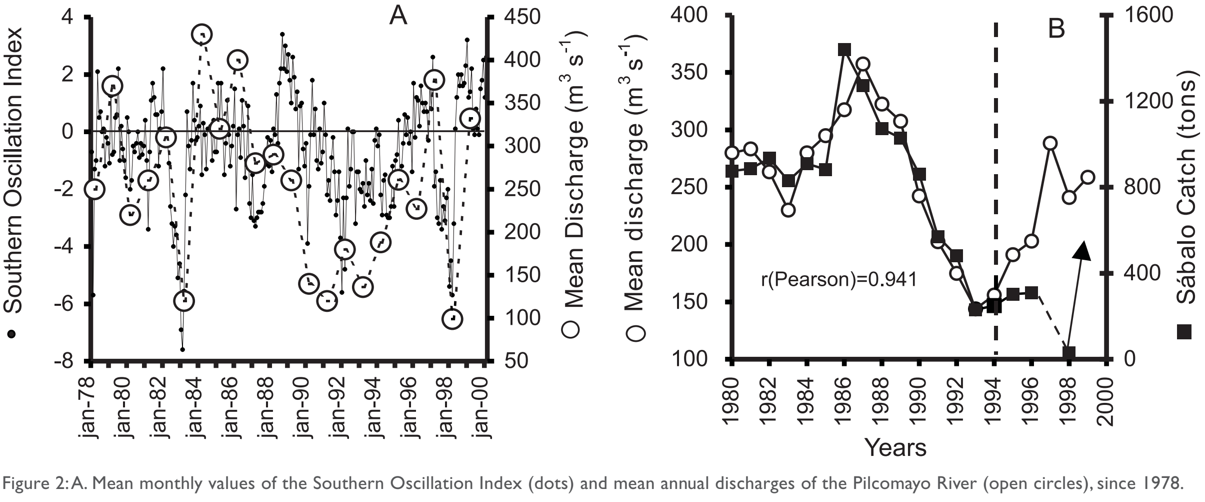


Figure 2: A. Mean monthly values of the Southern Oscillation Index (dots) and mean annual discharges of the Pilcomayo River (open circles), since 1978. The values were calculated for the hydrological year, which runs from October of the previous year until September of the current year.

B. Sábalo catches in tons (filled squares) and mean discharges of the Pilcomayo River over the current year and the three preceding years.

Resuspension by benthivorous fish as a determinant of algal biomass in shallow floodplain lakes

F.C.J.M. Roozen[1], F. Bransen[1], G. van Geest[1], B. Ibelings[2], R. Roijackers[1] and M. Scheffer[1]
[1]Wageningen University and Research Centre, Department of Aquatic Ecology and
Water Quality Management Group, P.O. Box 8080, 6700 DD Wageningen.
[2]Institute for Inland Water Management and Waste Water Treatment, P.O. Box 17,
8200 AA Lelystad.
e-mail: Frank.Roozen@aqec.wkao.wau.nl

Abstract

In the summer of 1999, 100 lakes have been sampled in the floodplains of the River Rhine in the Netherlands (Figure 1). All lakes have an average depth of less than 6 meter, a clay sediment, and 90 percent of the lakes are smaller than 10 ha. The lakes are influenced to various extent by the adjacent river through winter inundation. Analysis shows a positive correlation (Pearson coeff. 0.58, $p < 0.001$) between the chlorophyll-a concentration and the amount of inorganic suspended solids. This suggests that phytoplankton concentration and composition in these lakes is strongly influenced by resuspension. Resuspension by wind is unlikely in most lakes because of their relatively small size. Benthivorous fish, especially Abramis brama - which are abundant inhabitants of these systems - are hypothesised to be the major cause of resuspension, promoting algal biomass through direct resuspension and enhancement of nutrient concentration.

Introduction

Effects of benthivorous fish on phytoplankton is usually considered to be largely due to nutrients released from the sediments and excreted by fish. In addition, fish reduce the top-down control of algae through repression of zooplankton.

The direct effect of bioturbation on phytoplankton has not been so extensively examined. However, Schelske et al. (1995) found that wind-induced resuspension of meroplankton, primarily planktonic diatoms that settle to the benthic environment, accounts for a large component of the temporal variation in phytoplankton biomass in lake Apopka (Florida, US). Carrick et al. (1993) found comparable results during periods of strong wind. Experiments confirmed that direct inoculation of meroplanktonic diatoms into surface waters can account for a doubling in phytoplankton and diatom biomass (Carrick et al., 1993).

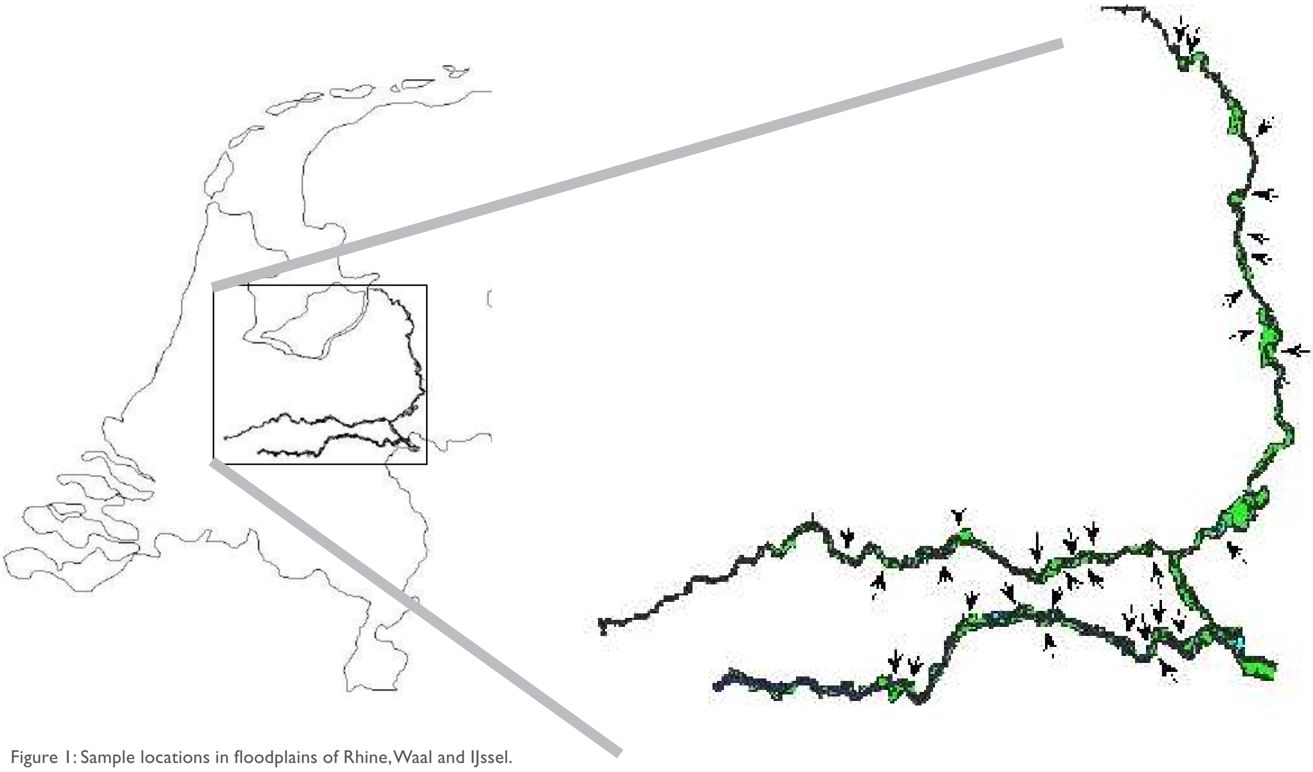


Figure 1: Sample locations in floodplains of Rhine, Waal and IJssel.

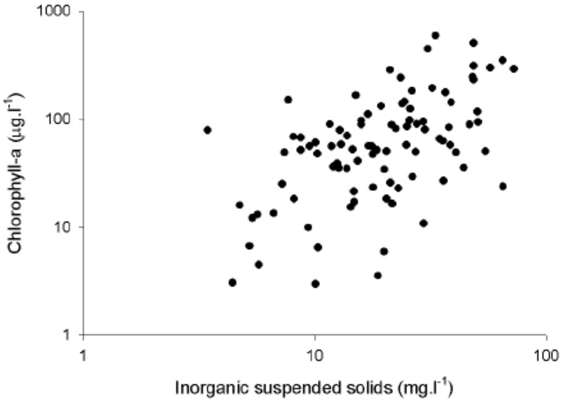


Figure 2: Chlorophyll-a concentration versus amount of inorganic suspended solids.

Multi-lake Survey

We sampled 100 lakes in Dutch floodplains in the summer of 1999, and found a strong positive correlation between the chlorophyll-a concentration and the amount of inorganic suspended solids (Figure 2, Pearson coeff. 0.58, $p < 0.001$). This suggests that resuspension is a major determinant of phytoplankton biomass in these lakes.
Almost all of these lakes are small (median 1.1 ha) and more or less surrounded by vegetation or trees. Therefore, frequent resuspension by wind is unlikely in most of the lakes, as checked with a wave resuspension model of Westphal.

This leaves resuspension by fish as a likely driving force. Indeed, more than 90% of the fish biomass in floodplain lakes consists of the benthivorous Abramis brama (Grift, 2001). Surprisingly, total-P is not correlated to inorganic suspended solids (Pearson coeff. 0.16, $p > 0.10$). Thus, nutrient regeneration seems not to be the main mechanism involved.

Hypothesis

Therefore, we hypothesise that physical resuspension of settled phytoplankton cells or spores by benthivorous fish is an important mechanism in determining the phytoplankton biomass and composition in floodplain lakes. Subsequently two enclosure experiments in different floodplain lakes have been carried out to test this hypothesis.

References

Carrick, H.J., F.J. Aldridge, and C.L. Schelske, 1993. Wind influences phytoplankton biomass and composition in a shallow, productive lake. Limnology and Oceanography 38, p. 1179-1192.

Grift, R.E., 2001. How fish benefit from floodplain restoration along the lower River Rhine. Ph.D. Thesis, Wageningen University.

Schelske, C.L., H.J. Carrick, and F.J. Aldridge, 1995. Can wind-induced resuspension of meroplankton affect phytoplankton dynamics. J. of N. Am. Benth. Soc. 14, p. 616-630.

Processes determining sediment-associated heavy metal pollution on the lowland river floodplains of the Dutch Rhine-Meuse delta

I. Thonon, H. Middelkoop and M. van der Perk
The Netherlands Centre for Geo-Ecological Research (ICG),
Department of Physical Geography, Faculty of Geographical Sciences, Utrecht University,
P.O. Box 80.115, 3508 TC Utrecht.
E-mail: i.thonon@geog.uu.nl

Introduction

Due to pollution of the Rivers Rhine and Meuse over many years, considerable amounts of heavy metals have accumulated in the overbank sediments of the embanked floodplains of their lower reaches, which are mainly situated in the Netherlands. Both from a scientific and a policy point of view it is essential to know which processes and factors actually determine the distribution patterns of heavy metals on the Dutch floodplains. Taken the recent and future river restoration plans into consideration, knowledge about the factors that determine the fate of sediment-associated pollutants can aid in a better and more efficient sanitation of the floodplains, thereby saving time and costs.

Up to date, only a few studies have been conducted that have analysed and integrated all different processes acting on sedimentation and heavy metal distribution. The goal of this project is therefore to provide a conceptual framework in which all relevant environmental factors that influence the spatial dispersion of heavy metals on the Rhine and Meuse floodplains are integrated. This is a first but essential step towards a model that simulates sedimentation, distribution and fate of heavy metals on Dutch embanked floodplains at two different spatial (single floodplain and delta level) and temporal (event and century) scales. This model will be used to determine the key processes at each scale studied: on which scale does a process become significant and how large is the effect on sediment-associated heavy metal pollution of these processes compared to each other?

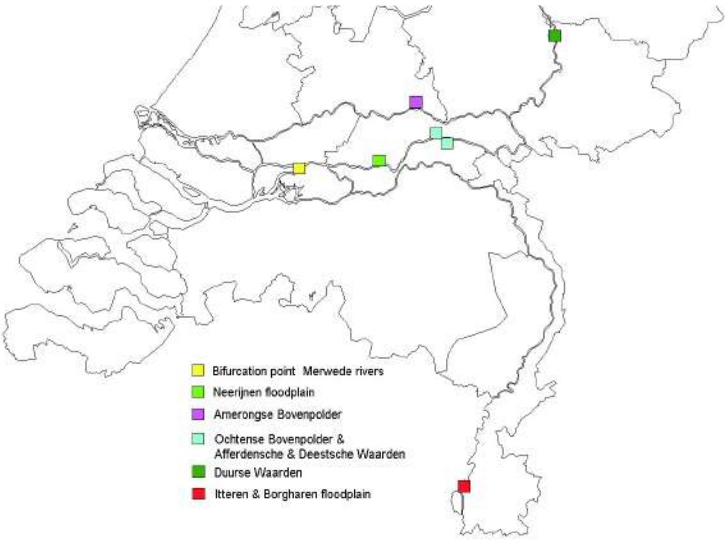
From source to sink: a chain of processes

Water, sediment and pollutants originate in the upstream parts of the river basin. Their quantity in the river depends on various factors and processes, among which are soil erosion (sediment delivery), snowmelt and rainfall that are led to the river by overland flow or groundwater flow (water delivery), and socio-economic exponents such as industrial development and traffic (delivery of pollutants). River discharge, sediment load, and metal concentrations entering the river delta are considered as input variables for a model that simulates the distribution of sediments and pollutants within the delta.

The river channel transports the water with its pollution and sediment load to the delta. In case of high discharge events, out-of-channel flow occurs. The channel plan form and the character of the channel-floodplain boundary influence the velocity pattern of the out-of-channel flow. The hydrodynamic laws that play a role within this respect are included in hydrodynamic models. These models are used to generate the basic hydrodynamic input data (water levels and stream vectors) for the sedimentation model at the event scale.

When the water leaves the channel, it enters the floodplain area. Lowland floodplains are to a large extent covered with vegetation and topographical discontinuities such as embankments and brick factories. Surface topography, hydraulic roughness of vegetation and obstacles within the floodplain strongly influence overbank flow patterns and therefore the distribution of sediment-associated heavy metals and sedimentation rates. However, still little progress has been made in the determination of the effective roughness of floodplain vegetation and its role in overbank flow and deposition processes. It is therefore necessary to gain more insight in the role of vegetation in hydrodynamics, for example with the aid of modern remote sensing techniques such as laser altimetry.

Another key process with respect to sediment deposition on floodplains is flocculation, i.e. the coagulation of individual primary organic and siliclastic particles in the water flow. The fact that flocks tend to exhibit totally different physical and chemical characteristics than individual particles is nowadays widely accepted. Yet, incorporation of this fact in both pollution and sedimentation models is not often done



since measurements on the flocculation process in riverine environments are usually lacking. It is intended to carry out in situ measurements on the effective grain sizes of sediment during overbank flooding that can fill this data gap and give insight in the stability, size and settling velocity of freshwater flocks in a floodplain environment.

Eventually, the sediment will settle out of the water column onto the floodplain. Event-based sedimentation quantities are measured using sediment traps, thereby providing ultimate grain sizes and heavy metal concentrations. These point data will be interpolated with geostatistical techniques to derive a two-dimensional view of sedimentation amounts. In combination with long-term sedimentation quantities, which are measured with sediment cores, a (quasi-) three-dimensional record of past and present heavy metal deposition will emerge, which can be used in model calibration and validation.

Soil processes start to act on polluted sediments directly after deposition. One of the more important soil processes is bioturbation, i.e. mixing of the soil matrix by biological processes. The record of past changes in sedimentation and pollution rate, i.e. the heavy metal profile in a sediment core, is disturbed by this bioturbation. Therefore, the influence of bioturbation on the heavy metal profile needs to be assessed, such that the disturbance can be filtered out from the observed profile to get the initial pollution profile back. This profile can be used in model calibration. Information on the effect of bioturbation has to be provided largely by other studies, as published information that deals with this process is hardly available and existing mixing models are generally too simplistic.

Biochemical soil processes are the last ones determining the fate of the heavy metal pollutants. These processes act on the heavy metal speciation. For example, vegetation roots emit acids that can lead to a local lowering of pH and change the binding agent for heavy metals. This can lead to solution of heavy metals, through which they disappear out of the studied system.

Discussion and conclusions

To enable the development of a model that integrates the entire chain of relevant processes determining sediment-associated heavy metal pollution, several gaps in knowledge and empirical data need to be filled. Since it is unlikely that mentioned gaps can be filled within the present research collaboration with other research activities is desired.

It is expected that a quasi 3D model will give valuable insight in the relations between the different processes and will render a quantification of their individual effects on heavy metal pollution patterns on different temporal and spatial scales. Moreover, it can be a valuable tool within a policy environment to assess the effect of (e.g., climatic or human-induced) changes in floodplain areas on pollution patterns.

Impact of floodplain wetlands on nutrient retention in the river Rhine

H. Olde Venterink[1], G. van der Lee[2], L.W.G. Higler[3] and J.E. Vermaat[1,4]
[1]IHE, Wetland Ecosystems, P.O. Box 3015, 2601 DA Delft.
[2]WL | Delft Hydraulics, Rotterdamseweg 185, 2600 MH Delft.
[3]Alterra, Ecology and Environment, P.O. Box 47, 6700 AA Wageningen.
[4]present address: Vrije Universiteit, Institute for Environmental Studies,
De Boelelaan 1115, 1081 HV Amsterdam.

Introduction

Large areas of floodplains along European rivers are no longer active, in a sense that canalisation and construction of dikes have prevented the floodplains from flooding. Additionally, large areas within the floodplains have been cultivated into agricultural grasslands. These changes in river morphology and floodplain land-use may have reduced the rivers natural capacity to remove nutrients from the water, and may have contributed to eutrophication of rivers and coastal marine waters. Recreation of active floodplains along rivers, or restoration of natural wetlands within the floodplains, may therefore not only enhance the value of rivers for flood protection or biodiversity, but may additionally increase the rivers natural capacity to remove nutrients from the water. This removal of nutrients from the water–called nutrient retention–is performed through processes as sedimentation and denitrification. The main objectives of this study were (i) to evaluate whether an increase of the active floodplain area may increase nutrient retention in the river, and (ii) to evaluate whether rehabilitation of natural floodplain wetlands (i.e. transformation of agricultural grasslands into semi-natural grasslands, reedbeds, woodlands or ponds) may increase nutrient retention.

Floodplain area vs. nutrient retention

We evaluated the importance of the active floodplain area for nutrient retention in rivers by comparing the rates of the various retention processes between the Rivers Waal and IJssel. Floodplains along the IJssel were more active than floodplains along the Waal; i.e. a much larger part of the rivers discharge had been in contact with floodplains in the River IJssel than in the River Waal. In accordance with our expectations, we found that sedimentation of nitrogen and phosphorus, as well as denitrification rates in the soil, were on average higher in floodplains along the IJssel than in floodplains along the Waal. However, compared to the total annual N load in the river, retention of nitrogen in floodplains was rather insignificant; i.e. it was less than 2% of the total amounts of nitrogen that were annually transported through the Rivers Waal or IJssel. In contrast, the active floodplains along the river IJssel were very important for the retention of phosphorus. Up to 14% of the total annual river load of phosphorus was removed from the water in the River IJssel by processes -particularly sedimentation- in floodplains, whereas only 4% was retained in the less active floodplains along the River Waal. Note that these retention percentages of the total annual loads were achieved during a relatively short period of flooding in winter/spring. The difference in importance for the two nutrients is due to sedimentation being the most important retention mechanism for both nutrients. Because 42% of the phosphorus in water of the Rivers Waal and IJssel was adsorbed to sediment particles instead of only 7% of nitrogen, it is obvious that differences in sedimentation along the two rivers had a much larger effect on the retention of phosphorus than on the retention of nitrogen. Hence, we conclude that an increase of the active floodplain area through floodplain rehabilitation will likely increase phosphorus retention, but will hardly affect nitrogen retention.

Floodplain type vs. nutrient retention

To evaluate whether nutrient retention may be increased by transforming agricultural grasslands into more natural types of floodplain wetlands we performed a series of experiments. We compared sedimentation and soil-denitrification rates in agricultural grasslands with those rates in semi-natural grasslands, reedbeds, woodlands, and ponds. Sedimentation rates of nitrogen and phosphorus were measured during a flood event in February 2001, by means of sediment traps (mats) placed in the five types of floodplain wetlands along the Rivers Waal and IJssel. Apart from very high sedimentation rates of nitrogen and phosphorus in a pond along the Waal (11 g N; 5 g P m^{-2}), sedimentation rates were also significantly higher in reedbeds (4.5 g N; 2 g P m^{-2}) than in the other floodplain types (1.5 g N; 0.7 g P m^{-2}). Denitrification rates in the top soil of the five types of floodplain types were measured in February 2001, by measuring N_2O-production after soil incubation with acetylene. Denitrification rates in the soil were rather low; the highest rates were found in agricultural grasslands (8 mg N m^{-2} d^{-1}). Evaluating the results, we concluded that sedimentation was the most important retention mechanism for both nitrogen and phosphorus, and that nutrient retention in the Rivers Waal and IJssel (or similar European rivers) may considerably increase when agricultural grasslands are transformed into reedbeds or ponds. Transformations into woodlands or semi-natural grasslands will likely not affect nutrient retention. Since sediment trapping efficiency in the Rivers Waal and IJssel was already 50-70% of the total sediment load in the present situation, increases in nutrient retention in these rivers will not be more than 1.5- to 2-fold. Potential effects of increased sedimentation rates will be more significant for phosphorus retention than for nitrogen retention, because in river water phosphorus is largely adsorbed to sediment (42%) where nitrogen hardly is (7%).

In addition, we carried out a laboratory experiment to assess denitrification rates in flood water in agricultural grasslands and reedbeds. Light and oxygen conditions in the experiment were simulated for day, evening and night conditions, according preliminary field measurements. Denitrification rates were measured in water, in water + sediment, in water + periphyton, and in water + sediment + periphyton. Water was collected from the River Waal. Sediment and periphyton were collected from a reedbed and an agricultural grassland along the Waal; periphyton was attached to reed stems or grass, respectively. Denitrification rates were rather low at day and evening conditions, increased significantly during night conditions, but only when sediment or periphyton was added to the water. Calculations of denitrification rates per square meter showed that the contribution of bacteria in periphyton to overall denitrification was rather low compared to that by bacteria in sediment, because of the low denitrification rate of periphyton attached to grass, or due to the limited surface area for periphyton on submerged reed stems. Overall denitrification rates were therefore similar in reedbeds and agricultural grasslands (18 mg N m^{-2} d^{-1}). Hence, transformation of agricultural grasslands into reedbeds will likely not affect nutrient retention through denitrification in flood water. Restoration into systems with larger surface areas for periphyton (e.g. ponds with an abundant submerged vegetation) may, however, increase denitrification rates.

Conclusions

Both an increase in the area of active floodplains, as well as rehabilitation of natural wetlands within floodplains, will likely improve water quality with respect to phosphorus, but will hardly affect water quality with respect to nitrogen. Moreover, nature restoration from agricultural grasslands towards reedbeds and ponds will be more beneficial for river water quality, than restoration towards woodlands or semi-natural grasslands.

Impact of sediment pollution on the carrying capacity of benthic communities in river floodplain systems

H.J. de Lange[1], J. de Jonge[2], P.J. den Besten[2], E.T.H.M. Peeters[1] and J. Oosterbaan[2]
[1]Aquatic Ecology and Water Quality Management Group, Wageningen University,
P.O. Box 8080, 6700 DD Wageningen.
[2]Institute for Inland Water Management and Waste Water Treatment,
P.O. Box 17, 8200 AA Lelystad.
e-mail: marieke.delange@aqec.wkao.wau.nl

Sediments in floodplain lakes of the Rivers Rhine and Meuse in The Netherlands are moderately polluted with trace metals, PAHs and PCBs. Several studies have shown that the composition of the benthic macroinvertebrate community is negatively influenced at even low levels of contamination (Brils et al., 1997; De Jonge et al., 1999; Den Besten et al., 1995, 2000; Reinhold-Dudok van Heel & Den Besten, 1999). According to Peeters et al. (2001), approximately 14% of the variation in the macroinvertebrate community structure of the Rhine-Meuse Delta ecosystem could be explained by contaminants. Considerable toxicological knowledge is gathered on acute effects of individual contaminants. However, limited ecological knowledge is available on the chronic effects of contaminants on the benthic macroinvertebrate community. Furthermore, recent laboratory studies showed that the combined effect of two contaminants may exceed the summed effects of the individual contaminants (e.g. Hanazato and Dobson, 1995), and that the impact of a contaminant also depends on other non-contaminant factors (e.g. Preston et al., 1999). Several studies also demonstrated that contaminants in low concentrations did not lead to mortality but had a negative effect on growth and thus production of benthic macroinvertebrates.

The main focus of the present research project is therefore to determine and quantify the effect of sediment-bound contaminants on the productivity of benthic macroinvertebrates. The central hypothesis in this study is that sediment pollution leads to a shift in species composition accompanied by a lower productivity of the benthic community, resulting in a decrease of the carrying capacity for fish and waterfowl.

A major challenge of this project is to estimate the in situ benthic macroinvertebrate productivity. In spring 2001, 16 sites were selected along a clean-polluted gradient in creeks in the Biesbosch floodplain forest (Figure 1). At these sites, samples were taken in April to characterise surface water (pH, O_2, conductivity, nutrients, Chl-a); sediment (grain size distribution, organic matter content, CNP), sediment contamination (total and bioavailable trace metals, PAHs and PCBs), and benthic macroinvertebrate composition and biomass. Additionally, sediment samples were taken for three laboratory bioassays (with Asellus aquaticus, Ephoron virgo and Chironomus riparius), with survival and growth as endpoints.

Exclosures were used to exclude fish predation, and macroinvertebrate samples were taken again in May inside and outside the exclosures. The results from the macroinvertebrate composition and size distribution of main taxonomic groups from the two sampling dates will be used to estimate the macroinvertebrate production in the presence and absence of fish predation. Univariate and multivariate analyses will be performed to analyse the possible impact of pollution on macroinvertebrate production. Sediment samples and macroinvertebrate community structure and productivity are still being analysed. Results of the laboratory bioassay with Asellus are already available. Survival of Asellus ranged between 60 and 100%. The growth in four weeks showed large differences between the 16 sites (Figure 2), indicating that there is a relation with contamination levels.

These exclosure experiments will be repeated in spring 2002 in other floodplain lakes. Laboratory experiments will be conducted with Asellus aquaticus to derive dose-response relations between sediment contamination and performance of Asellus. The project is completed with intensive literature research and the development of an individual based model for Asellus.

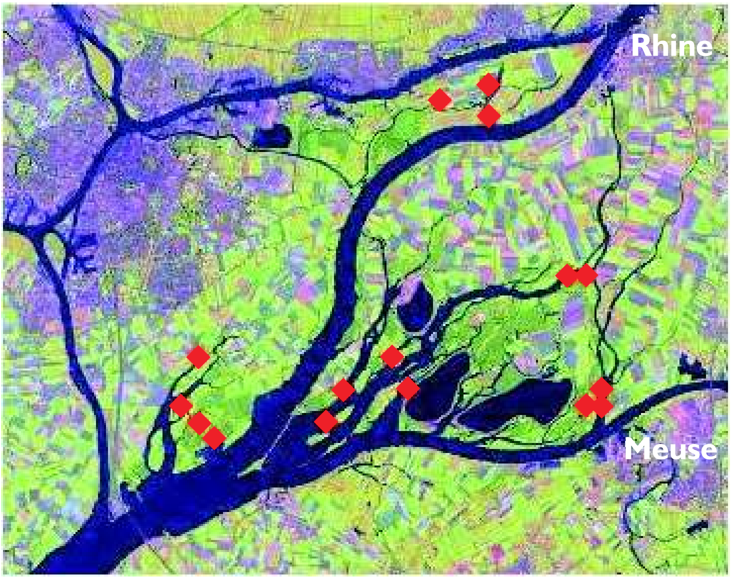


Figure 1: Sites in the Biesbosch area.

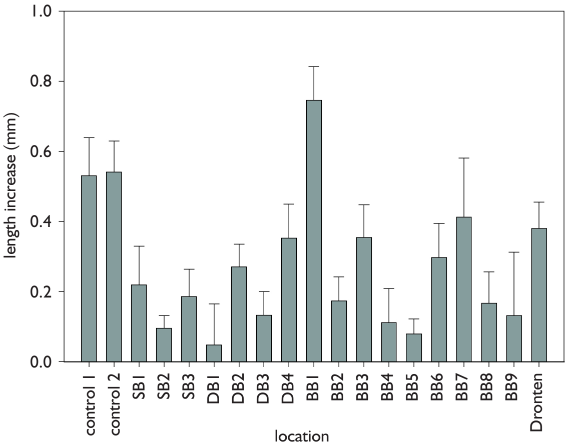


Figure 2: Growth of Asellus ± 1 SE in four weeks.

References

Brils, J.M., J. de Jonge, H.C. Reinhold and P.J. den Besten, 1997. Ecotoxicologisch onderzoek Afferdensche en Deestsche Waarden. RIZA rapport 97.095. 75 p.

De Jonge, J., J.M. Brils, A.J. Hendriks and W.C. Ma, 1999. Ecological and ecotoxicological surveys of moderately contaminated floodplain ecosystems in The Netherlands. Aquatic Ecosystem Health and Management 2, p. 9-18.

Den Besten, P.J., C.A. Schmidt, M. Ohm, M.M. Ruys, J.W. van Berghem and C. van de Guchte, 1995. Sediment quality assessment in the delta of rivers Rhine and Meuse based on field observations, bioassays and food chain implications. Journal of Aquatic Ecosystem Health 4, p. 257-270.

Den Besten, P.J., J.F. Postma, J.W.M. Wegener, H. Keidel, A. Klink, J. Mol and C. van de Guchte, 2000. Biological and chemical monitoring after pilot remediations in the delta of the rivers Rhine and Meuse. Aquatic Ecosystem Health and Management 3, p. 317-334.

Hanazato, T. and S.I. Dodson, 1995. Synergistic effects of low oxygen concentration, predator kairomone, and a pesticide on the cladoceran Daphnia pulex. Limnology and Oceanography 40, p. 700-709.

Peeters, E.T.H.M., A. Dewitte, A.A. Koelmans, J.A. van der Velden, and P.J. den Besten, 2001. Evaluation of bioassays versus contaminant concentrations in explaining the macroinvertebrate community structure in the Rhine-Meuse Delta, The Netherlands. Environmental Toxicology and Chemistry 20, in press.

Preston, B.L., G. Cecchini and T.W. Snell, 1999. Effects of pentachlorophenol on predator avoidance behaviour of the rotifer Branchionus calyciflorus. Aquatic Toxicology 44, p. 201-212.

Reinhold-Dudok van Heel, H.C. and P.J. den Besten, 1999. The relation between macroinvertebrate assemblages in the Rhine-Meuse delta (The Netherlands) and sediment quality. Aquatic Ecosystem Health and Management 2, p. 19-38.

How fish benefit from floodplain restoration along the lower River Rhine

R. Grift
RIVO Netherlands Institute for Fisheries Research, P.O. Box 68, 1970 AB IJmuiden.
tel: +31-255-564702.
e-mail: Rob@rivo.wag-ur.nl

The objectives of this study were to test the beneficial value of newly created secondary channels and reconnected oxbow lakes along the lower River Rhine for fish and to give advice on position, shape and character of future water bodies. These water bodies should contribute to the rebuilding of the population of rheophilic cyprinids that are endangered due to embankment and normalization of the Rhine. The functions these water bodies fulfil during the life cycle of distinct fish species, were inferred from the description of patterns of presence of fish in time and space in 25 floodplain water bodies (secondary channels, oxbows, lakes). In all water bodies, depth, flow velocity and the presence of vegetation determine the fish community present. Secondary channels and reconnected oxbow lakes do have a beneficial value for the riverine fish community. They function as nursery areas for all rheophilic cyprinids (Figure 1; e.g. Barbus barbus, Leuciscus idus and Gobio gobio). Secondary channels probably also function as spawning areas for L. idus and G. gobio but not for certain rheophilic A species (B. barbus, Leuciscus leuciscus) that spawn on gravel since suitable substrate lacks (Figure 1). Eurytopic species (Abramis brama, Rutilus rutilus and Stizostedion lucioperca) use all types of floodplain water body to reproduce (Figure 1). For A. brama, isolated turbid clay-pits form important source areas from which juveniles recruit to the main channel during floods. The dominance of eurytopic species in the lower Rhine is caused by the large area of suitable spawning and nursery areas for these species relative to those of rheophilic species (Figure 2). For limnophilic species (Tinca tinca, Rutilus erythrophthalmus) suitable habitat (vegetated lakes) is also scarce and should be preserved. Within plans on flood protection, floodplain management should focus on increasing the number of secondary channels and on restoring the natural interaction between the river and its floodplains.

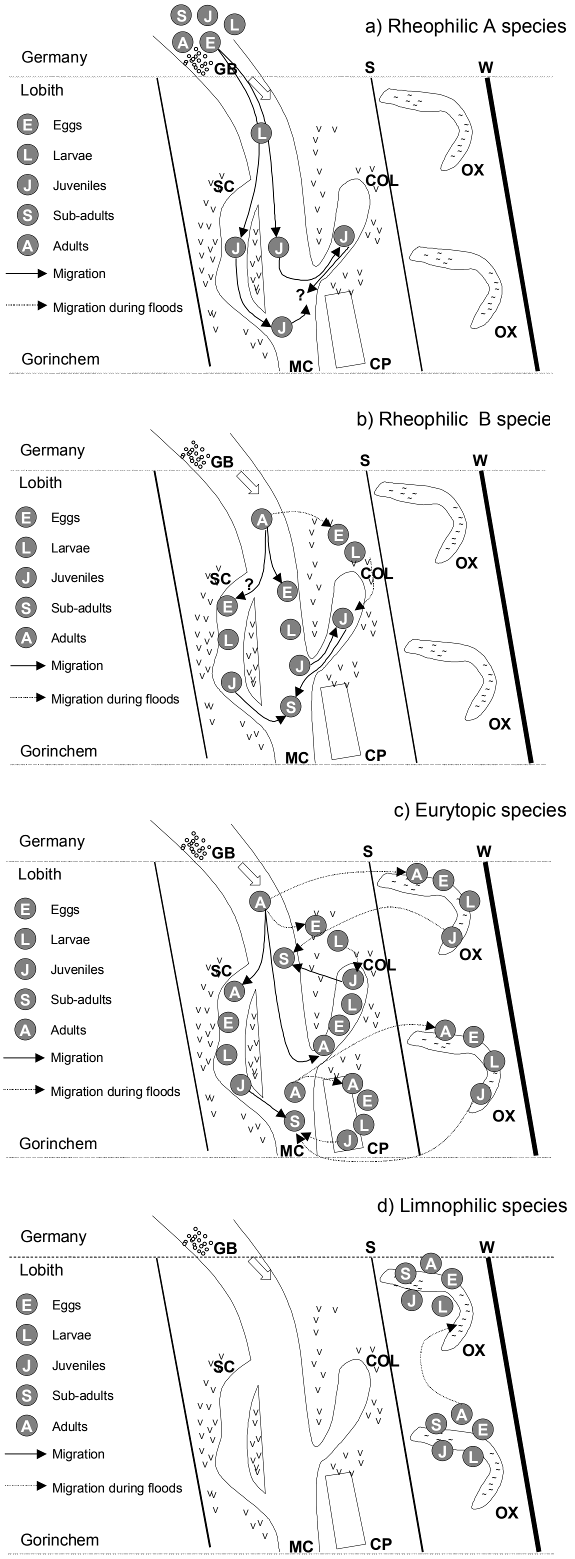


Figure 1: Life-cycles of fish in the lower River Rhine as illustrated for barbel (a), ide (b), bream (c) and tench (d).

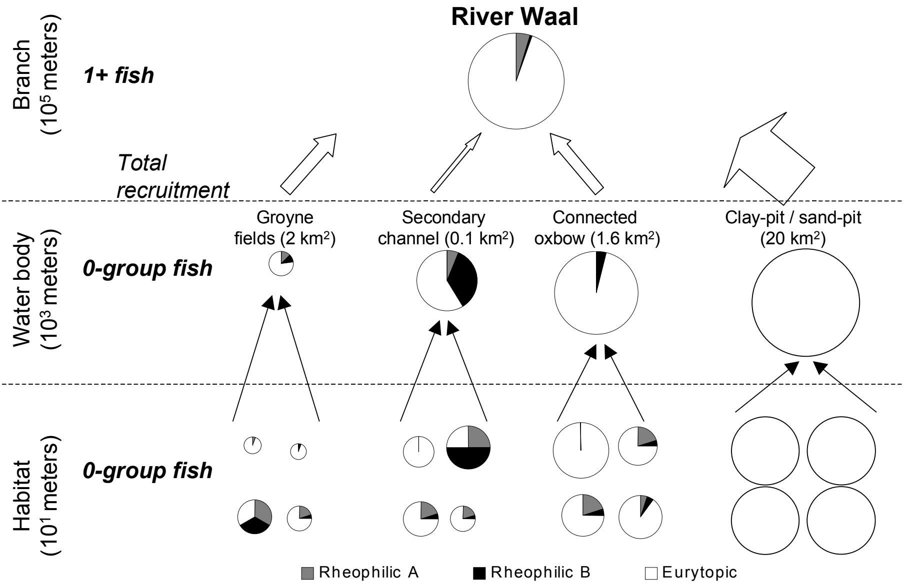


Figure 2: Schematic presentation of the habitats from which fish recruit to the River Waal fish community (1+ fish).

The sizes of the pies indicate fish densities (numbers of fish per square metre of habitat). The upper pie illustrates the species composition in the River Waal, that is determined from the recruitment of 0-group fish from the groyne fields and the different floodplain water bodies (all other pies). Recruitment from the different types of water body depends on the total surface area of the water body, fish density and fish species composition. Fish density and species composition of the 0-group fish assemblage in these water bodies is determined by the assemblage of habitats present in each type of water body. In the secondary channels, for example, a large variability of habitats (the flowing channel, shallow shore zones, etc.) is present and each type of habitat has a specific fish species composition and fish density. On the contrary, in turbit clay-pits, habitat variability is almost zero and in each habitat, fish density is high and species composition is almost equal.

Physical resuspension of algal cells by fish as a mechanism to explain high phytoplankton abundances

F.C.J.M. Roozen[1], H. Vlek[1], E. van der Pauw-Kraan[1], B. Ibelings[2] and M. Scheffer[1]
[1]Wageningen University and Research Centre, Department of Aquatic Ecology and Water Quality Management Group, P.O. Box 8080, 6700 DD Wageningen.
[2]Netherlands Institute of Ecology, Centre for Limnology (NIOO-CL), Rijksstraatweg 6 Nieuwersluis, P.O. Box 1299, 3600 BG Maarssen.
e-mail: Frank.Roozen@aqec.wkao.wau.nl

Abstract

Analyses of 93 floodplain lakes sampled in the summer of 1999 revealed a strong relation between inorganic suspended solids and chlorophyll-a in the lakes, suggesting that a common process may be involved in explaining the variation in both variables (Roozen et al., submitted). Exclusion of wind resuspension as a possible cause suggested an important role of resuspension by benthivorous fish. Here we report on three enclosure experiments in two different floodplain lakes. In a factorial design we varied densities of benthivorous Carp and nutrient additions. Enclosures with carp developed significant higher turbidities and chlorophyll-a concentrations, than enclosures without Carp or enclosures where Carp was prevented from reaching the sediment. Nutrient additions did not lead to higher phytoplankton concentrations, suggesting that physical resuspension of sedimented algal cells, rather than enhancement of nutrient conditions by fish is the dominant mechanism explaining benthivorous fish effects.

Table 1. Design experiment 1

		carp	**net**
1	**control**	**no**	**no**
2	**carp**	**yes**	**no**
3	**carp+net**	**yes**	**yes**

Table 2. Design experiment 2

		carp	**N**	**: P (mg.l^{-1})**
1	**control 0**	**no**	**0**	**: 0**
2	**control 1**	**no**	**1**	**: 0.1**
3	**control 2**	**no**	**3**	**: 0.3**
4	**carp 0**	**yes**	**0**	**: 0**
5	**carp 1**	**yes**	**1**	**: 0.1**
6	**carp 2**	**yes**	**3**	**: 0.3**

Motivation

Analyses of 93 floodplain lakes revealed a strong relation between inorganic suspended solids and chlorophyll-a in the lakes, suggesting that a common process may be involved in explaining the variation in both variables (Roozen et al., submitted).
Exclusion of wind resuspension as a possible cause suggested an important role of resuspension by benthivorous fish.

Experiments

Two factorial designed enclosure experiments have been performed in 2000, in two different floodplain lakes within the same floodplain. The first experiment in May during the clear water phase, varying the presence of Carp and their possibility of foraging in the sediment (Table 1). The second in August in a turbid lake, varying the presence of Carp and nutrient additions (Table 2). Twelve enclosures were incubated with lake water for three days before the start of the experiments. Suspended solids, nutrients, zoo- and phytoplankton, oxygen, pH, temperature and vertical light attenuation have been monitored in a period of 11 days. Also the lake has been monitored.

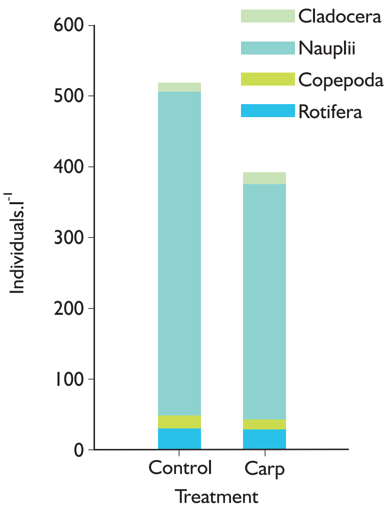
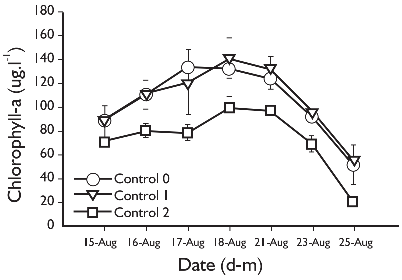
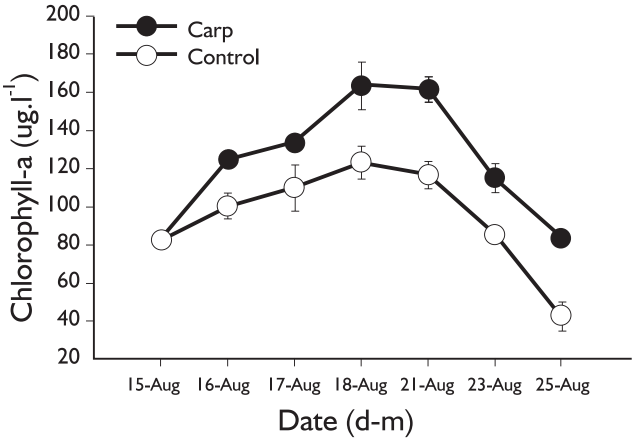


Figure 1: Bar-diagram of the presence (ind.l^{-1}) of the four different zooplankton groups for the control enclosures and the enclosures with carp on the last day of the first experiment.





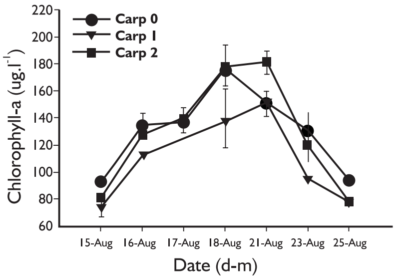


Figure 2: Graphs of chlorophyll-a concentrations (ug.l^{-1}) during the second enclosure experiment. Mean concentrations for treatments with and without carp (left), mean concentrations for each nutrient treatment in the carp enclosures (above-right) and control enclosures (below-right).

Results

Significant higher turbidity in enclosures with carp foraging in the sediment ($p < 0.05$) in the first experiment. Chlorophyll-a increased in these enclosures while the treatments 1 and 3 and the lake did not show this increase. Zooplankton on the last day did not show important differences (Figure 1, only difference in concentration of nauplii). Also significant higher turbidity and chlorophyll-a concentrations in the enclosures with Carp in the second experiment (Figure 2). Table 2 shows no significant differences between the nutrient treatments.

Conclusions

Enclosures with carp foraging in the sediment showed significant higher turbidities and chlorophyll-a concentrations. Nutrient addition did not lead to higher phytoplankton biomass (exp. 2) and zooplankton composition did not differ significantly between the treatments (exp. 1), suggesting that physical resuspension of sedimented algal cells, rather than enhancement of nutrient conditions by fish and zooplanktivory is the dominant mechanism explaining benthivorous fish effects on phytoplankton.

References

Roozen F.C.J.M., G.J. Van Geest, B.W. Ibelings, R. Roijackers, and M. Scheffer, submitted. In-lake processes rather than river dynamics determine turbidity of floodplain lakes along the lower Rhine. Submitted to Freshwater Biology.

The OER-project; Implications for floodplain lake restoration

F.C.J.M. Roozen[1], G. van Geest[1], H. Coops[2], A.D. Buijse[2], B. Ibelings[2], R. Roijackers[1] and M. Scheffer[1]

[1]Wageningen University and Research Center, Department of Environmental Sciences, Aquatic Ecology and Water Quality Management Group, P.O. Box 8080, 6700 DD Wageningen.

[2]RIZA Institute for Inland Water Management and Waste Water Treatment, Dept. Of Ecology, P.O. Box 17, 8200 AA Lelystad.

e-mail: Frank.Roozen@aqec.wkao.wau.nl

The influence of hydrology on the floodplain ecosystem of the Lower Rhine has been changed since embankment with major and minor dikes and channel normalisation in former centuries. Water-level fluctuations have increased, resulting in more extreme and sudden inundations and floodplain accretion has accelerated (Middelkoop, 1997). River rehabilitation of the River Rhine has initially been focussed on water quality improvement, but later on the protection and restoration of river habitat became a major target (Cals et al., 1998). Recent extreme floods in 1993 and 1995 have stressed the importance of integrating physical floodplain restoration with measures to enhance the flood discharge capacity of the riverbed. 'Ruimte voor de rivier" ('Room for rivers') was proposed as a policy to achieve increased discharge capacity. Potential measures in this perspective encompass removing obstacles in the river bed, lowering of floodplains, digging of side-channels, and construction of permanent and temporary floodplain lakes. Besides increasing the flood capacity, new opportunities for aquatic ecosystem development may be created by a lowering of floodplain levels: new side-channels, permanent and temporary water bodies will appear in addition to the existing ones. Existing floodplain water bodies (such as sand and clay pits, side branches, oxbow lakes, etc.) are usually regarded as valuable natural elements although their shape might be far from natural. For instance, the important function of floodplain water bodies as habitat for various fish species during certain life phases has been recognized (Neumann et al., 1996; Schiemer, 1995).

Hydrological connectivity between floodplain lake and river channel and flood pulses are considered as the key factors for understanding the ecology of Floodplain Lakes (Heiler et al., 1995; Schiemer, 1995). The connectivity between river and floodplain lake is a determinant of nutrient and sediment exchange processes and of the potential development of aquatic vegetation. The ecological succession of newly created water bodies in the floodplain therefore will be influenced by initial conditions, such as distance to the river channel, levee height, depth, slope, surface area, location relative to flood currents, and soil type.

Water bodies in floodplains are characterised by temporal fluctuations. Hydrology strongly influences the permanence and structure of biotopes in floodplain lakes, via flooding, seepage of water, precipitation and evaporation of water. The position and elevation of the lake in the floodplain, as well as the "hydrological fingerprint" of the river (Figure 1) affect the incidence of water-level fluctuations. Water quality of a floodplain lake may change rapidly in subsequent hydrological stages of filling, connection, drainage, isolation, and (eventually) desiccation (Akhurst and Breen, 1988; Furch and Junk, 1993; Hein et al., 1996). Water chemistry in lakes in direct connection with the river channel shows close resemblance to the channel, whereas it may diverge in isolated lakes under non-flood conditions due to internal processes.

In 1998, RIZA has started in co-operation with Wageningen University a research project which aims at formulating design and management criteria for floodplain lakes: the OER-project (research to the ecology of floodplain lakes). The impact of steering factors that may be influenced by physical measures in the floodplain (elevation, soil layering, position in the floodplain, connectivity to the main channel) and ecosystem responses will be investigated in a multidisciplinary study. Hydrology and chemistry are two focus points, which will be highly integrated into the two PhD-projects within the OER-project: vegetation dynamics (Gerben van Geest) and plankton and turbidity (Frank Roozen). The main aim of the OER-project is to identify the effect of connectivity

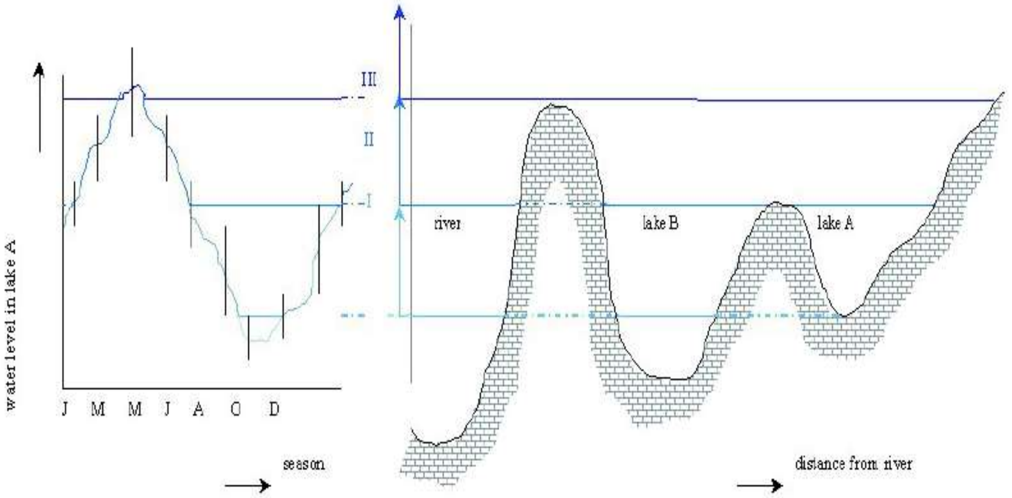


Figure 1: A hypothetical example of a hydrodynamic fingerprint of a floodplain lake A. The curve shows the seasonal water level of the lake, while the horizontal lines indicate the critical water levels for this floodplain lake (from top to bottom), where III lake A is not longer connected to the river, but still with lake B, II lake A becomes totally isolated, lake A dries out. Above critical level III the water level of lake A is influenced by the river, between levels II and III primary by hydrological regulation within the floodplain and below critical level II by seepage, infiltration evaporation precipation.

and morphometry on the (long-term) ecological succession of floodplain lakes of the lower Rhine rivers, and to identify dominant underlying processes.
Ten lakes are monitored intensively from 1998 through 2000 for process studies, while a survey covering 100 lakes gives a broad spatial snapshot. Due to flooding, lakes are disturbed by sediment input, inoculated with plankton and seeds and the fish community is not necessarily attuned to carrying capacity. Additional experimental field and lab experiments are carried out in order to test preliminary hypotheses obtained from the descriptive research.

References

Akhurst, E.G.J., and C.M. Breen, 1988. Ionic content as a factor influencing turbidity in two floodplain lakes after a flood. - Hydrobiologia 160, p.19-32.

Cals, M.J.R., R. Postma, A.D. Buijse, and E.C.L. Marteijn, 1998. Habitat restoration along the River Rhine in the Netherlands: putting ideas into practice? Aquatic Conservation: Marine and Freshwater Ecosystems 8, p. 61-70.

Furch, K., and W.J. Junk, 1993. Seasonal nutrient dynamics in an Amazonian floodplain lake. Archiv fuer Hydrobiologie 128, p. 277-285.

Heiler, G., T. Hein, F. Schiemer, and G. Bornette, 1995. Hydrological connectivity and flood pulses as the control aspects for the integrity of a river- floodplain system. Regulated Rivers Research & Management 11, p. 351-361.

Hein, T., M. Schagerl, G. Heiler, and F. Schiemer, 1996. Chlorophyll-a and hydrochemical dynamics in a backwater system of the Danube, controlled by hydrology. Archiv fuer Hydrobiologie Supplement 113, p. 463-470.

Middelkoop, H., 1997. Embanked floodplains in the Netherlands: Geomorphological evolution over various time scales. Utrecht (Koninklijk Nederlands Aardrijkskundig Genootschap / Faculteit Ruimtelijke Wetenschappen, Universiteit Utrecht). Dissertation 341 p.

Neumann, D., S. Staas, F. Molls, C. Seidenberg-Busse, A. Petermeier, and F. Schiemer, 1995. Restoration of floodplains - possibilities and constraints. Archiv fuer Hydrobiologie Supplementband 101, p. 383-398.

Restoration of dessicated mires in former meanders of the river Meuse: the detrimental effects of a stagnating water layer

E.C.H.E.T. Lucassen, A.J.P. Smolders and J.G.M. Roelofs
Environmental Biology, Department of Ecology, University of Nijmegen, Toernooiveld 1,
6525 ED Nijmegen.

Many alder carr forest in the province of Limburg is situated in former meanders of the river Meuse. Alder carrs are wet mires with characteristic growth of Alnus glutinosa, Caltha palustris, Equisetum fluviatile and Carex elongata. In winter the groundwater input is very high while the groundwater level drops beneath the sediment surface during the summer. During the last decades the quantity and quality of these systems strongly declined as a consequence of lowered groundwater levels resulting from increased agricultural activities. The influence of iron and calcium-rich seepage hereby strongly decreased and plant species characteristic for more dry and acid environments became dominant.

During the last three years efforts have been taken to restore these ecosystems by removing drainage ditches and by damming up water levels. In Kaldenbroek (Gemeente Grubbenvorst) extreme damming of water in 1998 led to permanent stagnation of the water layer and loss of groundwater influence. Within one year this led to the decline of the characteristic species Alnus glutinosa, Caltha palustris and Carex elongata while mass development of Lemna minor and fast growing plant species like Glyceria fluitans, Glyceria maxima occurred (Figure 1). In Dubbroek (gemeente Maasbree) the water level also increased but both a continuous flow of groundwater in combination with a natural annual water cycle were maintained. This led to an enormous increase in area vegetated by Equisetum fluviatile and to a lesser extent by Caltha palustris in the former dessicated parts of the forest. Contrary to Kaldenbroek no mass development of Lemna minor and Glyceria species and no die back of Alnus glutinosa occurred.

During the last decades sulphate concentrations in the groundwater have increased strongly. Increased drought and leakage of nitrate from agricultural lands have led to the oxidation of iron(di)sulphides and leakage of sulphate to the groundwater. Monthly monitoring of Kaldenbroek showed that the change in plant composition was accompanied by increased phosphate and sulphide concentrations in the water layer and increased ammonium, sulphide and methane concentrations in the sediment pore water during the summer. As a consequence of stagnating groundwater, the redox potential in the sediment decreased resulting in decreased nitrification and increased reduction of sulphate and carbon dioxide. Decreased nitrification resulted in increased ammonium concentrations in the sediment pore water stimulating growth of fast growing Glyceria species. Increased reduction of carbon dioxide resulted in increased methane production and sediment buoyancy causing die back of Alnus glutinosa. Increased sulphate reduction caused production of toxic sulphide and mobilisation of phosphate. Mobilisation of phosphate from the sediment led to accumulation of phosphate in the stagnating water layer causing massive growth of Lemna spec. In Dubbroek a continuous flow of ironrich groundwater in combination with the maintenance of a natural annual water cycle prevented a comparable decrease in redox potential of the sediment. Temporary dessication in the summer led to the oxidation of iron(di)sulphides produced during wet periods. The sulphate that is mobilised leaves the system via the flowing water layer while iron is oxidised in the aerobic top layer of the sediment hereby reinforcing the iron content and the redox potential of the sediment. Monthly monitoring showed that sulphate reduction still occurs during summer but the release of phosphate from the sediment to the water layer is limited as it is bound in the iron rich top layer of the sediment or removed from the system via the flowing waterlayer. The importance of a flowing water layer and a natural annual water cycle is confirmed in an enclosure experiment which showed that stagnation of sulphate-rich groundwater also leads to the production of sulphide and phosphate, the decline of water plants and the development of algae in Dubbroek.

Figure 1: Kaldenbroek one (left) and three years (right) after re-wetting measures were taken.

Process-based modelling of landscape and fluvial system response to rapid climate change

Model presentation and application to the Meuse river during the Last Glacial-Interglacial Transition

P.W. Bogaart
Department of Quaternary Geology and Geomorphology, Faculty of Earth and Life Sciences, Vrije Universiteit Amsterdam, De Boelelaan 1085, 1081 HV Amsterdam.
e-mail: bogw@geo.vu.nl

Introduction

Rivers play a crucial role both within the earth-scientific, as well within the socio-economic context. However, rivers are by no means an autonomous phenomenon, but are controlled by a multitude of factors, of which climate and tectonics are the most important. Since global climate change may be expected for the near future, it is thus crucial to assess how rivers – or fluvial systems in general – may respond to these changes. Understanding of how rivers reacted on rapid climate transitions during the geological past may help in this assessment.

The response of landscape processes to climate change is non-linear and highly complex. River channel processes like incision, aggradation and pattern switching are not directly driven by climatic parameters, but are a complex response to (the distribution of) water and sediment input. These latter factors are controlled by a number of factors like soil structure, vegetation, etc.

The Last Glacial-Interglacial Transition (LGIT) offers ample opportunities for the understanding of river response to climate change. It is by far the most well investigated climate change event, and the response of rivers throughout Europe to this event has been reconstructed.

Objective

The main goal of this extended abstract is to show how we tackle the central problem 'what can we meaningful say about fluvial dynamics on the millennial time scale, from a process modelling point of view'.

Scale considerations

Spatial scale. Intrinsic spatial processes like hillslope erosion are calculated on catchment scale, in a spatially averaged fashion. Intrinsic point processes, like transport capacity at a location along the stream network, are only considered near the catchment outlet.

Temporal scale. Relevant processes, like sediment transport or hillslope erosion have fundamental small time scales of storms or at least days. However, palaeoclimate data on this detailed time scale is non-existent, nor is our interest on this small time scale. The solution proposed is to use a daily weather generator, and do all process modelling on the daily time scale and then average to the 100–1000 year scale. The weather generator can be parameterised by palaeo-climatic reconstructions (e.g. summer/winter mean temperature), appended with modern-analogue weather statistics, or AGCM predictions.

Modelling framework

We have developed a modelling framework to investigate the response of fluvial systems to climate change. This framework consists of the following steps:

- Climatic parameters (temperature, precipitation) are derived from AGCM (atmospheric general circulation model) experiments. AGCM output is on a daily timescale. AGCM weather predictions may be generalised or extended by means of a simple weather generator. Hundred years of daily weather has been generated for each time slice of the LGIT.
- A simple process-based rainfall-runoff model has been used to predict daily river discharge timeseries near the catchment outlet. The model is an adaptation of RHINEFLOW; the original model has been converted from 'distributed' to 'lumped', and the time scale has been increased from month or 10-day to daily. Hundred years of daily discharge has been simulated for each time slice.

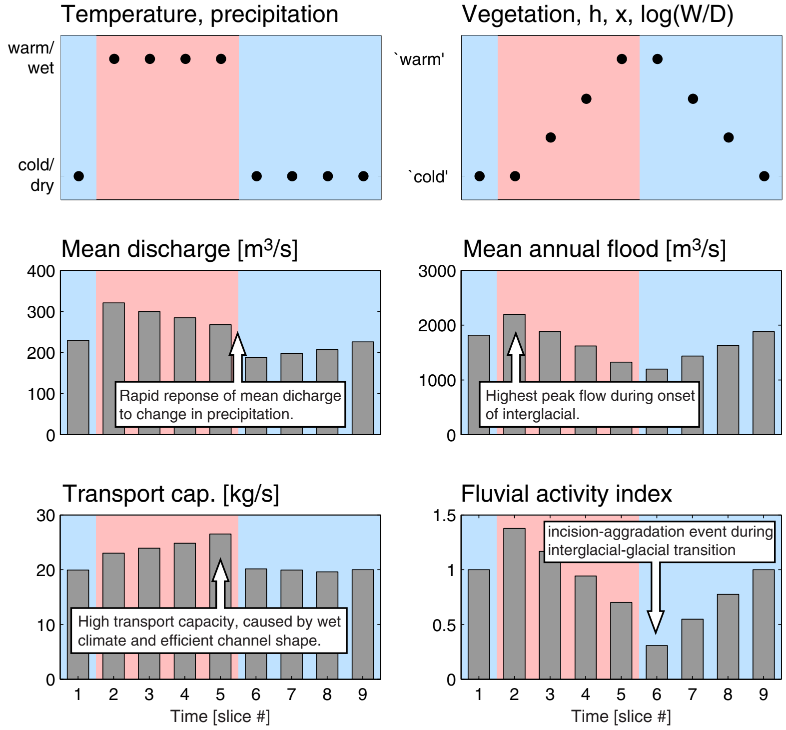


Figure caption

Forcing and response of a hypothetical river, during a full glacial–interglacial–glacial cycle. Main climatic regimes are indicated as blue (glacial, cold) and red (interglacial, warm) background panels.

Climate: temperature and precipitation are assumed to change rapidly. Environment: environmental controls like vegetation cover, soil water holding capacity, quick/delayed runoff separator and channel shape are assumed to respond slowly. The first and last time slices of each period indicate no and full adaptation. Mean discharge: shows the direct effect of more precipitation during interglacials. An overall maximum is reached during the first time slice of the interglacial (#2) because evapotranspiration is low due to the absence of vegetation. Peak discharge: shows a more complex response. The peak discharge under full glacial conditions (#9) is higher than under full interglacial conditions (#4), but lower than during the onset of an interglacial (#2). This maximum is caused by the combination of high precipitation rate on an impermeable surface (permafrost). Transport capacity: shows the major impact of channel shape. During the environmental adaptation to interglacial conditions (#2–5), transport capacity is increasing, despite decreasing mean and peak discharges. This is caused by a shift towards hydraulic more efficient narrow, deep river channels. Fluvial activity index: shows the results of a simplified sediment balance. The interglacial–glacial transition is marked by an incision-aggradation event. These events are also known from the sedimentological record of the Meuse and other NW European lowland rivers.

- MAF (Mean Annual Flood, $Q_{2.33}$) magnitude has been calculated from the daily discharge predictions. MAF is assumed to be equal to bankfull discharge Q_{bf}. From Q_{bf}, channel dimensions (bankfull width, bankfull depth) are calculated using established hydraulic geometry formulae.
- Daily sediment transport capacity is calculated from daily discharge, within this channel. Long-term transport capacity is obtained by averaging over these daily values.
- Daily catchment-scale erosion potential is calculated from daily overland flow rates and erodibility parameters. Long-term erosion potential is obtained by averaging.
- Channel pattern (braided, meandering) is calculated from bankfull discharge sediment characteristics and valley gradients.
- A fluvial activity index (FAI) is calculated as the ratio of sediment production (erosion potential) and sediment transport capacity. An increase in FAI indicates aggradation, and a decrease indicates incision.

Concluding remarks

Results obtained thus far indicate that the modelling framework presented here is able to predict the response of fluvial systems to the major climate changes of the late Quaternary. Observed responses of the Meuse (and other) rivers can be explained by the model, or additional mechanisms. Within-catchment sediment storage, and a proper quantification of the lag-effects of vegetation and soil development deserve closer attention within further research.

A rapid rainfall-runoff model to assess human impacts on the discharge pattern of the Meuse in Limburg

P. Valkering and J. Rotmans
International Centre for Integrative Studies (ICIS), University of Maastricht,
P.O. Box 616, 6200 MD Maastricht.
For more information, see: www.icis.unimaas.nl
or e-mail: p.valkering@icis.unimaas.nl

Goal

To develop a rainfall-runoff model for the Meuse catchment to assess the possible impacts of climate change, land use change, and canalization on the discharge pattern of the Meuse at Borgharen, in an interactive way with stakeholders. A short calculation time is thus required.

Principle

The model concept critically depends on the following basic assumption. The relevant hydrological characteristics of the Meuse catchment influencing the discharge pattern can be subdivided into: 1) characteristics that affect only the monthly averages of the discharge (here called "slow parameters"), and 2) characteristics that affect only the variability of the discharge pattern at timescales shorter than a month and thus the occurrence of peak discharges (here called "fast parameters"). In the first category we include the monthly averages of precipitation and temperature, in the second category we include the variability of precipitation at a time scale ~1 week, land use, and canalization.

In the light of the above assumption we propose a model that consists of two distinct components. On the one hand we intend to include a simple rainfall runoff model that enables the model user to calculate how the monthly averages of the discharge Q_m will change as a result of changes in the "slow parameters". Hereto, we will develop a lumped version of the model MEUSEFLOW, similar to the existing "MEUSEFLOW light" (Van Deursen, 2000). As the second component we intend to include parameterizations of the probability distributions $P(Q_p|Q_m)$, that indicate the probability of occurrence of a certain peak discharge Q_p, for a given average discharge Q_m (see section "Probabilities of extremely high discharges"). The shapes of these probability functions will be calculated with the detailed hydrological model LISFLOOD (De Roo et al., 2001).

Probabilities of extremely high discharges

Conditional peak method (Kwadijk, 1993)

The probability density function $P(Q_p|Q_m)$ is defined as the probability that a peak flood falls within class C_p in a month with average discharge Q_m in class C_m:

$$P(Q_\mathrm{p} \mid Q_\mathrm{m}) \equiv P(Q_\mathrm{p} \in C_\mathrm{p} \mid Q_\mathrm{m} \in C_\mathrm{m}).$$

The probability P is fitted to a log normal distribution F parameterized by the average μ_y and standard deviation σ_y of the log transformed Q_p:

$$P(Q_\mathrm{p} \mid Q_\mathrm{m}) = F(y, \mu_y, \sigma_y),$$

with $y \equiv \ln[Q_p - Q_m]$.

Shifts in the probability density functions $P(Q_p|Q_m)$ Kwadijk (1993) assumes that the probability distributions $P(Q_p|Q_m)$ are constant over time. They can be deduced from historical discharge data by determining the values of the parameters μ_y and σ_y for each discharge class C_m. In our hypothesis, however, we claim that these distributions will change over time as a result of changes in temporal rainfall variability, land use and canalization. We will thus calculate the shapes of probability distributions $P(Q_p|Q_m)$, using LISFLOOD to generate discharge data. This will be done:

- For the present situation by generating discharge data with historic climate data and present day land use and canalization.
- For possible future situations by generating discharge data for different (combinations of) states of climate, land use and canalization according to a number of reference scenarios.

Assumptions

The model set up proposed here critically depends upon the following assumptions:

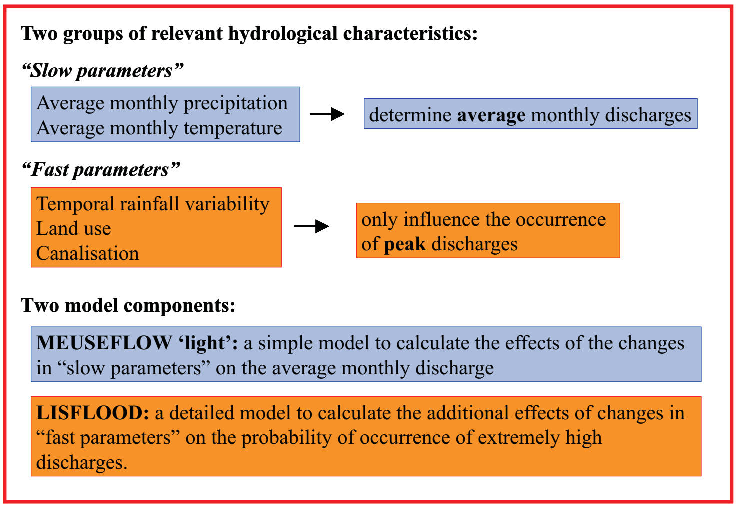
- Changes in average monthly temperature and precipitation affect only the average monthly discharges, and they do not change the shape of the probability functions $P(Q_p|Q_m)$, nor the way the probability functions $P(Q_p|Q_m)$ depend on temporal rainfall variability, land use and canalization.
- Changes in temporal rainfall variability, land use, and canalization affect only the shape of the probability functions $P(Q_p|Q_m)$, and they do not change the average monthly discharge, nor the way the average monthly discharge depends on the average monthly precipitation and temperature.

It is not a priori clear that these assumptions remain valid for all cases, especially for the case of land use. Therefore, these assumptions will be tested by investigating the MEUSEFLOW and LISFLOOD simulation runs.

Reference scenarios

A number of reference scenarios will be developed. This part of the study is at its initial phase, so that we only outline the approach and give a set of references:

- Climate scenarios will be based on results of the ECLAT-2 project (Beersma et al., 2000).
- Land use projections will be derived from existing land use studies for the Rhine basin (Veeneklaas et al., 1994) and a perspective base scenario study for the Rhine and Meuse basins (Van Asselt et al., 2001). The LADEMO model (Menzel, 2000) will be used to construct GIS-based land use scenarios.
- A simple canalization scenario will be based on 1) possible increases in the design discharge and 2) increasing needs for shipping along the Belgian Meuse.



Two groups of relevant hydrological characteristics:

"Slow parameters"

Average monthly precipitation
Average monthly temperature

→ determine **average** monthly discharges

"Fast parameters"

Temporal rainfall variability
Land use
Canalisation

→ only influence the occurrence of **peak** discharges

Two model components:

MEUSEFLOW 'light': a simple model to calculate the effects of the changes in "slow parameters" on the average monthly discharge

LISFLOOD: a detailed model to calculate the additional effects of changes in "fast parameters" on the probability of occurrence of extremely high discharges.

Figure 1: The model principle.

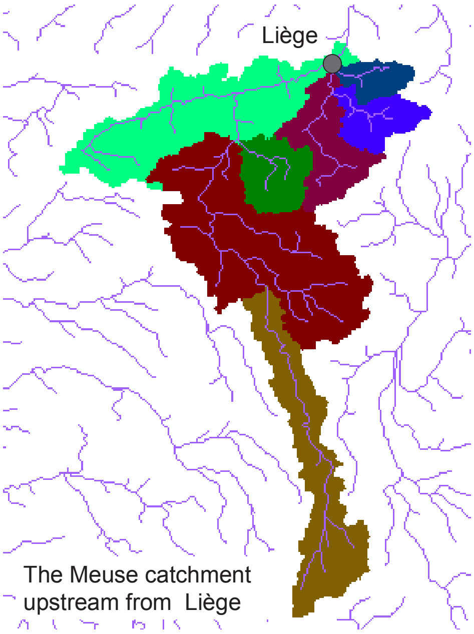


Figure 2: MEUSEFLOW 'light': a lumped water balance model with a monthly time step.

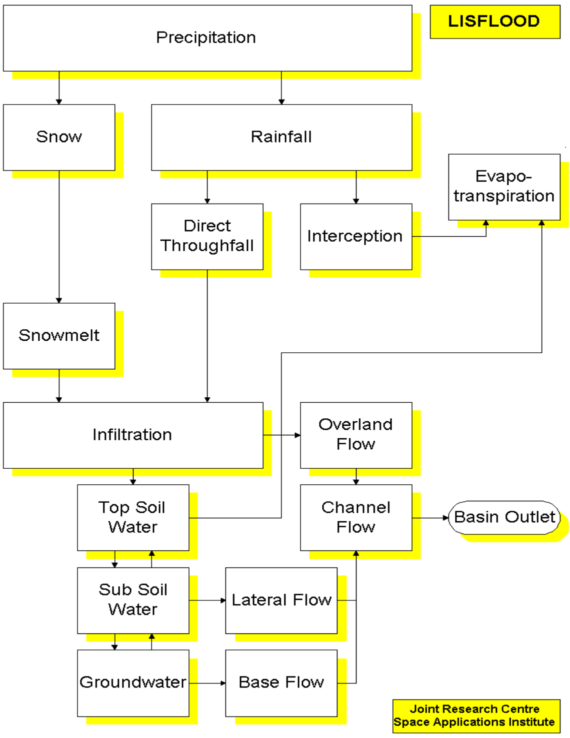


Figure 3: LISFLOOD: a detailed water balance model; spatial resolution ~ 1 km, temporal resolution ~ 1 hour.

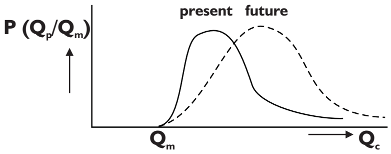


Figure 4: Possible shifts in the probability distributions $P(Q_p|Q_m)$ due to changing temporal rainfall variability, land use or canalization.

Literature

Van Asselt, M.B.A., H. Middelkoop, S. van 't Klooster, W.P.A. van Deursen, M. Haasnoot, J.C.J. Kwadijk, H. Buiteveld, G.P. Können, J. Rotmans, N. Van Gemert and P. Valkering, 2001. Integrated water management strategies for the Rhine and Meuse basins in a changing environment. Final report of the NRP-project O/958273/0.

Beersma, J., M. Agnew, D. Viner, and M. Hulme, (eds.), 2000. Climate scenarios for water-related and coastal impacts. ECLAT-2 Workshop Report No. 3. KNMI, The Netherlands, 10 –12 May 2000. CRU, Norwich, UK.

Van Deursen, W.P.A., 2000. MEUSEFLOW 2.1, Laagwaterstudies Maasstroomgebied. Report to RIZA, October 2000.

Kwadijk, J.C.J., 1993. The impact of climate change on the discharge of the river Rhine. Ph.D. thesis University of Utrecht, department of Physical Geography. KNAG/NGS publication 171.

Menzel, L., M. Blongewicz, 2000. LADEMO – A user supported model for the development of land use scenarios. In: Proceedings of the European Conference on Advances in Flood Research, November 1-3, 2000, Potsdam, Germany. Vol. 1, PIK report No. 65.

De Roo, A., M. Odijk, G. Schmuck, E. Koster, and A. Lucieer, 2001. Assessing the effects of land use changes on floods in the Meuse and Oder catchment. Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere 26, p. 485-640.

Veeneklaas, F.R., L.M. van den Berg, D. Slothouwer, and G.F.P. IJkelenstam, 1994. Rhine basin study: land use projections based on biophysical and socio-economic analysis. Volume 4. Land use: past, present and future. Wageningen (The Netherlands), DLO Winand Staring Centre.

Restoration of the river discharge to the southern Delta: Opportunities to enhance resilience and safety

H. Haas[1] and M. Tosserams[2]
[1]National Institute for Coastal and Marine Management (RIKZ),
P.O. BOX 8039, 4330 EA Middelburg.
[2]Institute for Inland Water Management and Waste Water Treatment (RIZA),
P.O. BOX 17, 8200 AA Lelystad.

Introduction

The Dutch Delta region in Southwest Netherlands originally consisted of interconnected estuaries, interfacing the rivers Rhine, Meuse and Scheldt with the North Sea. The execution of the Delta Project during the period 1960-1986 has changed this area dramatically. This huge project, which was initiated after the storm surge of 1953, resulted in a system of dams and sluices that guarantees protection of the region against flooding from the sea. The Figures show the situation after the completion of the Delta Project. The new infrastructure has fundamentally changed the hydraulic, morphological and ecological characteristics of the region. The open interconnected estuaries with dynamic gradients between riverine and marine systems were transformed into isolated water systems disconnected from the rivers and the sea. This resulted in a loss of estuarine gradients and buffering capacity within these water systems (de Vries et al., 1996). Because of the compartmentalisation the gradients were replaced by discrete boundaries between fresh and salt water systems.

Due to this compartmentalisation the former estuary of the Krammer Volkerak has changed into a eutrophic stagnant fresh water system, lake Volkerak-Zoom (Tosserams et al., 2000), which is partly connected to the regulated river mouth of the Rhine and Meuse. The discharge of the Rhine and Meuse into the Krammer Volkerak is controlled by the Volkerak sluices and, at present, is minimized because of the poor water quality. Besides ecological problems in lake Volkerak-Zoom, the Hollandsch Diep-Haringvliet system faces water quantity problems in times of high river discharges. Recent high water levels in 1993 and 1995 were the trigger for studies how to lower the high water levels in the river Rhine during high river discharge (Integrale Verkenning Benedenrivierengebied).

Objectives

The objectives of this study were:

1. What are the possibilities to increase the exchange of water between the compartments within the southern Delta in order to restore estuarine gradients?
2. What are the socio-economic effects of these measurements?
3. Can an increase of the exchange contribute to a lowering of the high water levels in the mouth of the Rhine-Meuse Delta?

Methods

Because of the complex hydraulic regime of the Delta region a one dimensional hydraulic Delta model was constructed for the Rhine-Meuse Delta including lake Volkerak-Zoom, lake Markiezaat, Oosterschelde and lake Grevelingen (Svasek, 2000a,b). With this model it was possible to explore different discharge strategies to the southern Delta (low, high, extreme and extreme+). The model calculates flow rate, flow velocity, water levels and salinity. The Volkerak sluices represent the 'fresh water valve' between the Hollandsch Diep and Lake Volkerak-Zoom. The four sluices in this complex have a total dimension of 120 m with the threshold on –4.25 m NAP. In the Delta model three additional sluices were implemented:

1. Sluice in the Philipsdam between the Oosterschelde and lake Volkerak with a dimension of 57 m and a threshold on –3 m NAP,
2. Sluice in the Oesterdam between the Oosterschelde and lake Zoom with a dimension of 40 m and a threshold on –3 m NAP,
3. Sluice in the Grevelingendam between lake Volkerak-Zoom and lake Grevelingen,
4. Spillway between lake Markiezaat and lake Zoom with a dimension of 200 m and a threshold on – 5 m NAP.

For lake Volkerak-Zoom (VZM) two different alternatives were explored in this study:

1. RIVER DYNAMICS: no salt intrusion in the VZM, but more fluctuation of the water levels in this water system (min. –0.3 m NAP max. +0.5 m NAP)
2. ESTUARINE DYNAMICS: salt intrusion and salinity gradients in the VZM and tidal fluctuations of about 0.5 – 1 m.

In both alternatives the water in the VZM can rise to higher levels during extreme river discharge. Also storage of river water during storm floods and extreme river discharge (extreme+) is explored.

Main results

- Restoration of the original estuarine gradients and (partial) tide in lake Volkerak-Zoom, as developed in the alternative ESTUARINE DYNAMICS, offers the best opportunity for the sustainable development of this area. With a tidal amplitude of 50 cm about 630 hectare inter-tidal area can be created.
- The indicative model study shows that during extreme discharge of the Rhine (16.000 m^3/s) the average flow rate through the opened Volkerak sluices is about 2000 m^3/s. This is roughly 10% of the river discharge, which is similar to estimations of the discharge in the 'pre dam' period

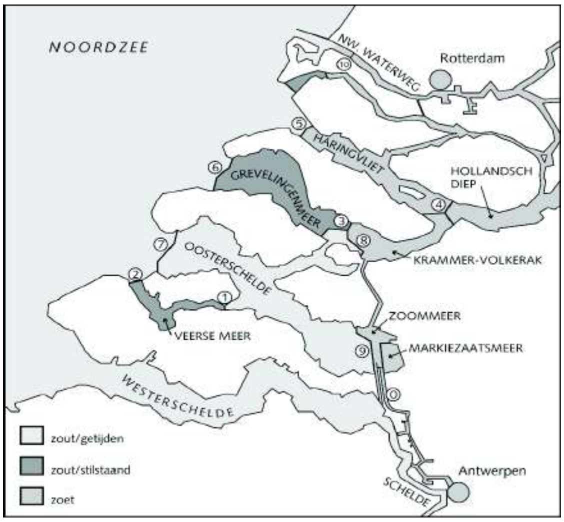
during high discharge (Pieters, 1998). These discharges have a significant effect on water levels in the surrounding area of the Hollandsch Diep-Haringvliet, varying from about 20 cm in the Lek to 50 cm near Moerdijk.

- Under these extreme circumstances the water levels in the lake Volkerak-Zoom can rise to a level of approximately +2,5 m NAP.
- ESTUARINE DYNAMICS leads to a relatively small decline of the tidal range of 5% in the eastern part of the Oosterschelde.
- For preservation of an estuarine gradient a minimum flow rate of 50 m^3/s fresh water is necessary. This is about 5% of the total flow during low discharge of the Rhine (1000 m^3/s).

Recommendations

- The water management in West Brabant strongly depends on a fixed water level (-15 cm to +20 cm NAP) in lake Volkerak-Zoom (VZM). Because of the connection between the VZM and the small rivers in West Brabant water levels above +50 cm NAP result in flooding problems in the city of Breda. An integrated model study, including the watersystem of West Brabant, is therefore necessary.
- The availability of fresh water for agricultural production is at this moment an important socio-economic use of the VZM, alternatives have to be developed.
- The national division of fresh river water is an important issue during low water discharge. The fresh water demand during low discharge can give rise to conflicts between different users and regions, especially in the Haringvliet. A decision support system can be a helpful tool.
- More study is needed to predict the effect of introducing nutrient rich and (in the current situation) polluted river water on the productivity in de Delta.

This study has shown that there are good opportunities to partly restore the estuarine characteristics of the Delta by using the Volkerak sluices as a ‘fresh water valve’ to the southern Delta (Haas and Tosserams, 2001). By doing so enhancement of the resilience of the Delta and safety in the lower reaches of the Rhine and Meuse can go hand in hand. To explore these opportunities and their effects on different users of the water systems a process has started called ‘Integrated Vision for water in the Delta’ (IVD). In 2003, fifty years after the storm surge, this process must lead to a new vision on the Delta of the future. Discussion with all stakeholders and civilians in the area is essential to increase the awareness of potential problems and opportunities in order to create integral solutions for the future.



Literature

Haas, H.A. and M. Tosserams, 2001. Balanceren tussen zoet en zout: ruimte voor veerkracht en veiligheid in de Delta. Rapport RIKZ/2001.18 RIZA/2001.014.

Pieters, T., 1998. Overgangen zoet-zout in de Oosterschelde in het verleden. Een historische analyse op basis van beschikbare literatuur. Bureau Getijdewateren BGW-98.1.

Svasek, 2000a. Verkennende berekeningen Project Blauwe Delta met Oostzwen. Bureau Svasek.

Svasek, 2000b. Aanvullende berekeningen Project Blauwe Delta met het Delta model. Rivier dynamiek en extreme afvoeren. Bureau Svasek.

Tosserams M., E.H.R.R. Lammers, and M. Platteeuw, 2000. Het Volkerak-Zoommeer. De ecologische ontwikkelingen van een afgesloten zeearm. RIZA rapport 2000.024, Lelystad.

De Vries, I., A.C. Smaal, P.H. Nienhuis, and J.C.A. Joordens, 1996. Estuarine management strategies and the predictability of ecosystem changes. Journal of Coastal Conservation 2, p. 139-148.

SOBEK Model of the River Mosel

H.H. Rabbers and D.G. Meijer
Meander Consultancy and Research, Bisonspoor 342A, 3605 JW Maarssen.
internetaddress: www.meander-advies.nl

Background

After the Rivers Rhine and Meuse flooded their banks in 1993 and 1995, the European IRMA programme was established, which stands for INTERREG Rhine-Meuse Actvities. The IRMA programme funds the IRMA-SPONGE Umbrella Programme.

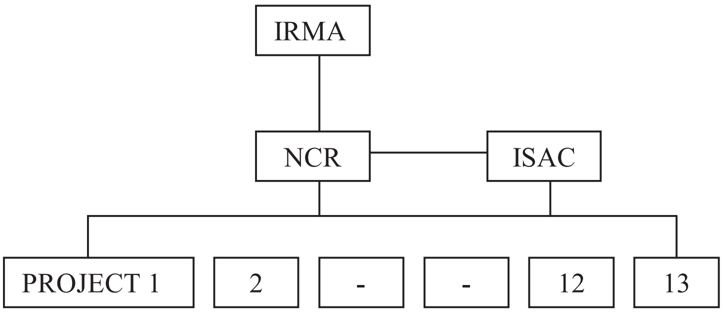


Figure 1: Scheme IRMA-SPONGE.

This programme deals with different aspects of flood risk management in all countries in the Rhine and Meuse River Basins. The Netherlands Centre of River Research (NCR) is leading the programme and an International Scientific Advisory Committee (ISAC) is set up to advise on scope and content of the Umbrella program, and to monitor activities in 13 individual projects. One project (project 12) aims at the improvement of the existing flood forecasting system FloRIJN by extending the forecast horizon at Lobith from 2 to 4 days. Parts of this project are the integration of the model Andernach – Maxau (part of the IRMA-LAHOR project) into the existing model and development of a hydraulic model for the German part of the Mosel. Within this project Meander Consultancy and Research was assigned by NCR to develop and calibrate a SOBEK model of the River Mosel. SOBEK is a 1D modelling system, developed by the Institute for Inland Water Management and Waste Water Treatment of the Ministry of Transport, Public Works and Water Management (RWS / RIZA) and Delft Hydraulics.

Model data

The model reach occupies the most downstream 52 kilometres, from the gauging station Cochem to the confluence of the Mosel and the Rhine.

Figure 2: Model reach of the River Mosel.

In this section three weirs and four major tributaries are present. The cross-sections were generated by the GIS database system BASELINE. The BASELINE tools consist of different tools for administration, query, processing and presentation. It dictates a standardized data structure and forms the basis of the numerical model systems SOBEK (1D) and WAQUA (2D).

Weir regulation

The weir regulation schemes in the Mosel are quite complicated, as each upstream steering level depends on the downstream weir level of the upstream weir (i.e. on the river discharge). Parallel to the weirs, there are hydropower stations, which belong to the electricity company RWE Energie. At low discharges the whole river discharge is used for the power stations. Then the power station is responsible for maintaining the upstream water level. At higher discharges the turbines will discharge their maximum capacity and the surplus is released by the weirs. The responsibility for maintaining the upstream water level is handed over from RWE Energie to the Wasser- und Schiffahrtsambt (WSA).

In the SOBEK model, the dynamic tuning of the weirs was carried out with the help of an advanced system of PID controllers and triggers.

With this the weir regulation can be simulated automatically. In order to simulate this weir regulation adequately in SOBEK, four different controllers were used for each weir.

Figure 3: Weir Fankel in the River Mosel.

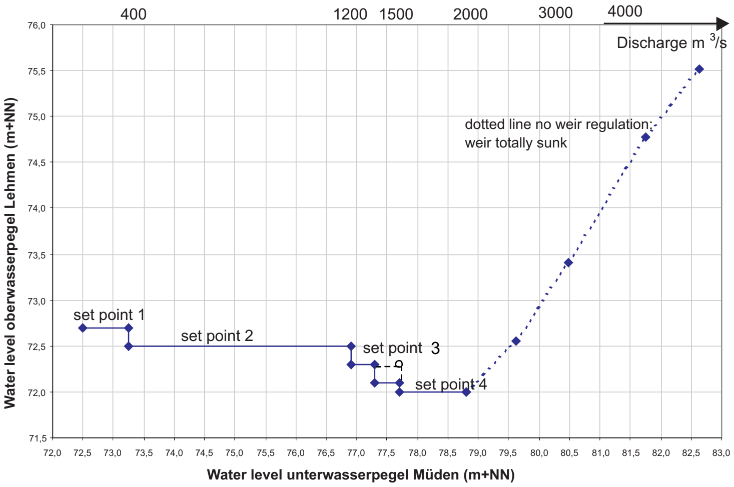


Figure 4: Weir regulation scheme.

Calibration and verification

The hydraulic roughness of the floodplain was determined based on CORINE land cover database data. These data were transformed into representative Nikuradse values.

The calibration of the hydraulic roughness of the main channel and the banks took place based on eight stationary surface profiles. These roughness values are expressed by Strickler coefficients.

In order to check the usability of the Mosel-model in a dynamic flood prediction model, a verification was made with a hypothetical flood wave.

Related projects

Within the framework of the IRMA-LAHoR project, Meander Consultancy and Research also developed SOBEK models of the Rivers Main (project 10011) and Neckar (project 10001) and also some intended river interventions in the River Rhine between Maxau and Lobith have been imported into BASELINE (project 10033). Consultants from Meander Consultancy and Research also visit the Federal Institute for Hydrology in Koblenz (BfG) for SOBEK and BASELINE support and assistance (project 10032).

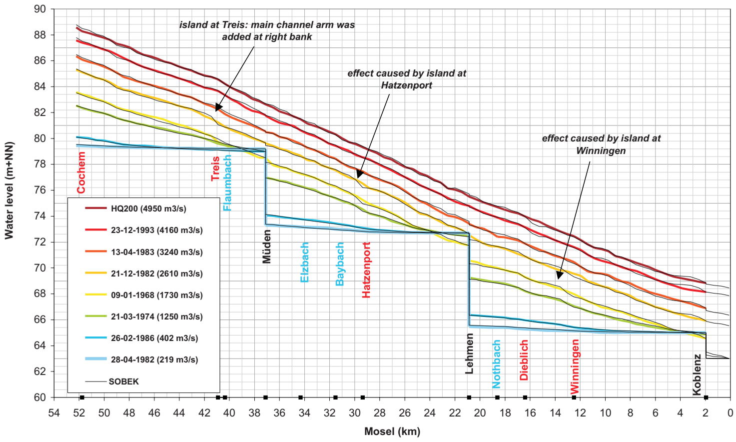


Figure 5: Eight measured and calculated surface profiles.

An automatic calibration method for hydraulic models

M. Visser, M. Duits and W. van der Lee
HKV LIJN IN WATER, P.O. Box 2120, 8203 AC Lelystad.

Usually hydraulic models are calibrated by reducing the differences between calculated and measured flow conditions. These differences are reduced by expert judgement with regard to the effect of various specified hydraulic roughness components on the flow conditions, followed by a recalculation of the flow conditions with adapted hydraulic roughness values. In general, this approach depends mostly on the skills of the expert, while the process is time consuming.

A more systematic approach was developed by Wijbenga et al. (1998) on the basis of a function minimisation using the Simplex Method as proposed by Nelder & Mead (1965). Here, the application of the method will be discussed.

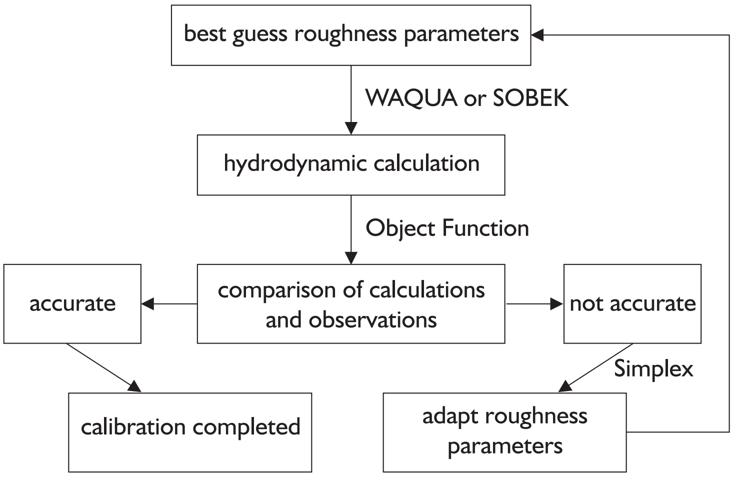


Figure 1: Schematic calibration procedure.

The simplex algorithm is a well-known minimisation algorithm using only function value information. The function to be minimised (object function) represents the (absolute) differences between calculated and measured water levels.

The object function is a function of the roughness parameters that are calibrated. The roughness parameters are optimal when the object function is minimal. To prevent the roughness parameters from taking on unrealistic values, lower and upper bounds for the parameters are defined.

When the number of parameters is small (i.e. fewer than 15) the simplex method is competitive with more complex search algorithms that require many algebraic calculations. The initialisation of the simplex method using n parameters takes only n+1 calculations.

The calibration method is illustrated in figure 1. The input for the hydrodynamic model is a file with roughness parameters. With this input file a calculation is made. The calculated water levels and discharges are compared to the measurements using an object function. The simplex algorithm is then used to minimize the object function and a new set of roughness parameters is obtained. With this new input file a new calculation is started. The process continues until the desired accuracy is obtained.

In the object function the calibration criteria are defined. The choice of the object function is very important. In the object function several choices have to be made. First of all, one has to decide which measurements are to be taken into account (which stations, which time series etc.). Secondly, one has to decide if all the measurements are equally important or if weight functions will be used. Especially when two types of measurements are taken into account (e.g. water levels and discharges) it is very important to decide proper weight functions. Thirdly, one has to decide in which way differences between measurements are quantified (e.g. absolute values, quadratic differences).

Another option is to include a penalty function. This means that the object function consists of two parts: one part that is the sum of the differences between calculations and observations and another (penalty) part. This part is zero when a certain condition is fulfilled and has a positive value when that condition is not fulfilled. The optimisation method will select a low object function, i.e. an object function in which the penalty function is zero and the condition is fulfilled.

In the application of the method to Dutch rivers, a penalty function is often used if water levels and discharges are included in the calibration. As water level measurements are often more accurate than discharge measurements, water level observations are usually included in the object function and discharges in the penalty function. When the calculated discharge lies within a certain value of the observed discharge (or the discharge obtained from a discharge-stage relationship) the penalty function is zero, but when the difference between observed and calculated discharges is too large, a penalty will be added to the object function.
An example of an object function (OF) with penalty function (PF) is given by:

$$OF = \sum_{stations} \sum_{time} \left| h_{calculated} - h_{observed} \right| + PF$$

$$PF = \left[\begin{array}{lll} 0 & if \left| \dfrac{Q_{calculated} - Q_{QH}}{Q_{QH}} \right| & < 0.05 \\ & & \\ 10000 & else & \end{array} \right.$$

where h is water level and Q is discharge. Q_{QH} is the discharge obtained from a discharge-stage relationship.

The calibration method was successfully used to calibrate the WAQUA-models of the Meuse river and the Rhine river and its branches. During both calibrations the roughness of the minor bed (in several sections), cultivated areas and grasses and brushes was modified.

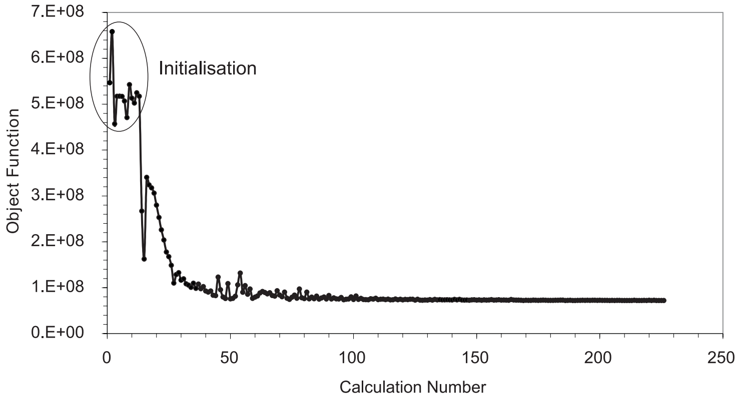


Figure 2: Value of the object function in a test case (SOBEK, 12 parameters used for calibration).

HKV LIJN IN WATER developed an application that can be used to calibrate the main channel roughness in SOBEK-models. This application was used to calibrate the SOBEK-models of the Meuse and the Rhine river and its branches. In this application, the dune length, dune height and sediment grain size are modified (Van der Veen et al., 2001).
In figure 2 it is shown that after the initialisation of the Simplex Method, the object function quickly converged to a stable value.

Although the method works very well there is one significant disadvantage. The Simplex algoritm assumes that the object function is convex. If the object function has more than one minimum it is not guaranteed that the Simplex algorithm will find the desired absolute minimum. Future research will focus on a search for other suitable algorithms that can be used for the calibration of hydrodynamic models like WAQUA and SOBEK.

Acknowledgment

The Dutch Ministry of Transport, Public Works and Water Management has commissioned the underlying studies for this paper.

References

Nelder, J.A., and R. Mead, 1965. A Simplex Method for Function Minimisation. The Computer Journal 7, p. 308-313.
Van der Veen, R., U. Pakes, and L. Schutte, in voorbereiding.
Bouw en calibratie Sobek Rijn, versie 2000.1 t/m 2000.3. RIZA rapport, Rijkswaterstaat/RIZA, Arnhem.
Wijbenga, J.H.A., M.T. Duits, and J.M. van Noortwijk, 1998. Parameter optimisation for two dimensional flow modelling. In: V. Babovic and L.C. Larsen (eds.), 1998. Hydroinformatics '98. A.A.Balkema/Rotterdam/ Brookfield, p. 1037-1042.

A River HAbitat SImulation Model for quantification of ecological effects of low discharge on the Common Meuse

W. Liefveld[1], U. Pakes[1,2] and F. Schulze[3]
[1]Ministry of Transport, Public Works and Water Management, Institute for Inland Water Management and Waste Water Treatment (RIZA), P.O. Box 9072, 6800 ED Arnhem.
[2]present address: Hogeschool Larenstein, Larensteinselaan 26A, Velp.
[3]Witteveen + Bos, P.O. Box 233, 7400 AE Deventer.

Ecological rehabilitation of the Common Meuse

A River HAbitat SImulation Model (RHASIM) was developed, to gain insight into the effects of low discharge on the ecological development of the Common Meuse. The model is based on the Physical HABitat SImulation Model (PHABSIM) from the U.S. It is a flexible method by which the changing habitat conditions can be quantified for target species, representing characteristic habitats, for nearly all disturbances in a river ecosystem. The Common Meuse is a free flowing part of the rain-fed River Meuse with low discharges in summer; a natural phenomenon, influenced, however, by human impact.

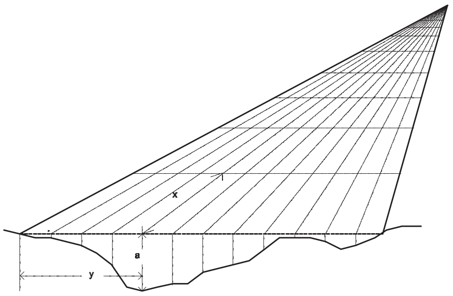


Figure 1: Schematisation of the Common Meuse for application in RHASIM.

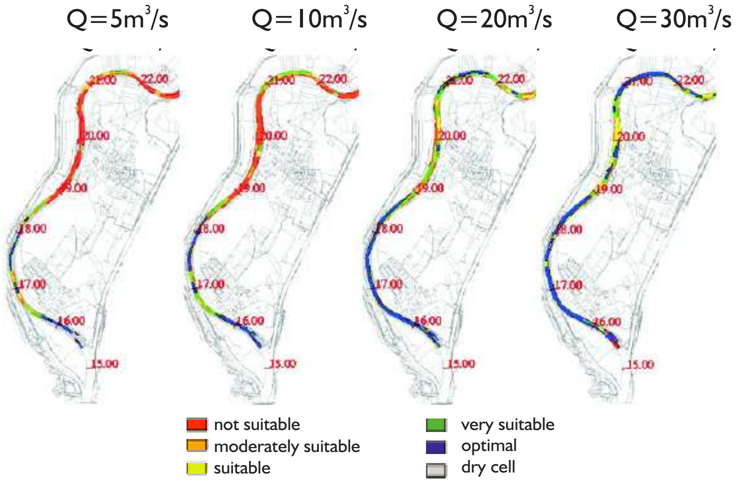


Figure 2: Example of results from RHASIM calculations: habitat suitability per grid cell for adult Chub for the parameter stream velocity at 4 discharges.

Method

In RHASIM the physical habitat is being modelled in relation to river discharge. RHASIM consists of 2 major components;

1) Habitat simulation; calculating ecologically relevant hydro-morphological parameters: water depth, stream velocity, sedimentation, suspended matter and oxygen content. Other relevant environmental factors like, water temperature, phosphate and chloride, are derived from simple statistical relationships with discharge, based on a large dataset of measurements in the River Meuse.

2) Habitat-Suitability-Indices; relating the changes in the physical environment to effects on habitat suitability for target species on a scale from 0 to 1; based on experiments and field data, referred to in international literature.

The river stretch is schematised in grid cells of 10 by 100 m (Figure 1). At a chosen discharge, for every grid cell the value of the different parameters is calculated and translated to one value for habitat suitability for a certain species. The calculations have been carried out for a number of characteristic species.

The results for the different parameters were combined by taking into account only the lowest habitat-suitability per grid-cell and then classified (see Figure 2). The individual habitat-suitability values per grid cell have been translated to total surface area of suitable habitat by:

$$\sum_{i=1}^{5} mi * Ai$$

mi = mean value habitat suitability class
Ai = surface area habitat suitability class

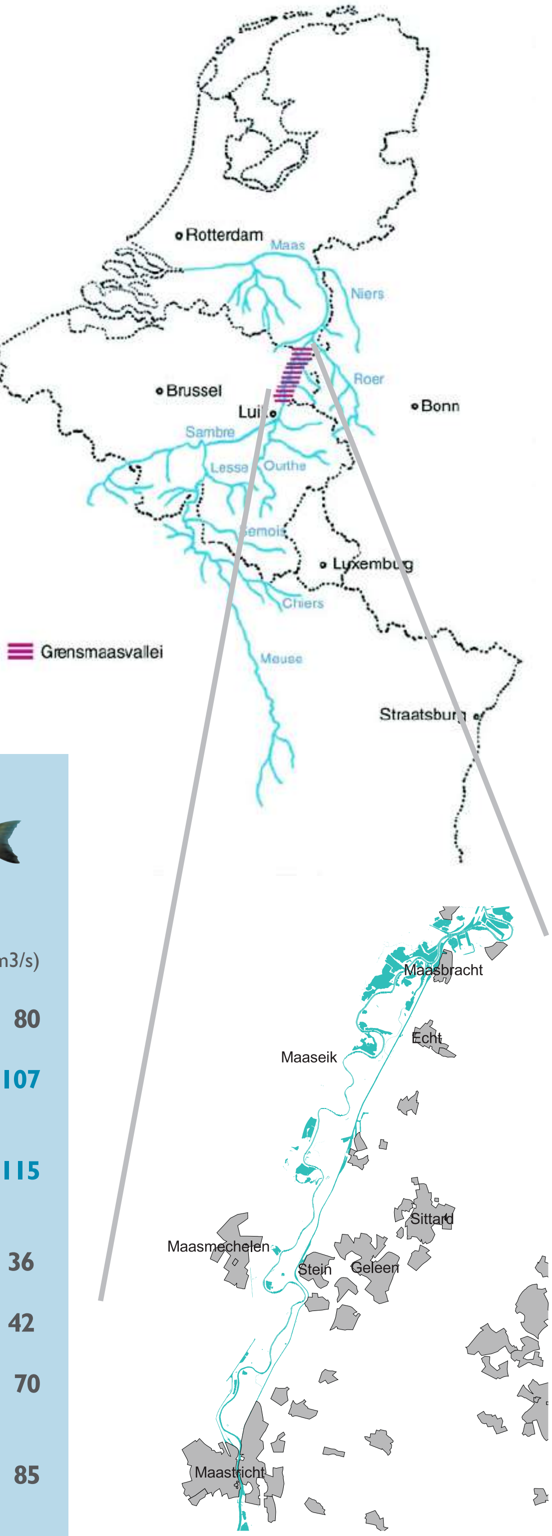
Results

Simulations have been carried out at seven different discharges (from 5 to 80 m^3/sec) for a number of characteristic species and life stages, to determine the effects of low discharge on the ecological development. The integrated results indicate that rheophilic species like Barbel or Chub have a preference for higher discharges to a certain maximum (± 40 m^3/sec) (see table). Early life stages of these species on the other hand prefer lower discharges because they favour shallow parts of the river with low stream velocity that are easily warmed by the sun.

Conclusions

To get an indication of the minimum discharge needed for ecological functioning of the Common Meuse, the surface area required for viable populations of target species has been hold as a threshold. In the present study this was determined for adult life stages of the rheophilic species Barbel and Chub. The results indicate that at discharges below ± 10 m^3/sec the surface area of suitable habitat is too low for a viable population of Chub (table). Because the yearly discharge distribution has not been taken into account, no conclusions can be drawn in relation to the duration of the situation.

Although the model strongly simplifies the actual occurring processes on the Common Meuse, RHASIM enables decision makers to take into account the ecological effects of measures affecting the occurrence and level of low discharges. Water management for the Common Meuse aims at 10 m^3/s as a threshold value for low discharge on the Common Meuse, which seems to be ecologically sufficient.



insufficient surface area for one viable population
sufficient surface area for one viable population
no surface area analysis possible or relevant

	Discharge (m3/s)						
Species	5	10	20	30	40	60	80
Chub – adult *(Leuciscus cephalus)*	76	115	141	143	143	136	107
Barbel – adult *(Barbus barbus)*	106	138	149	148	147	140	115
Barbel – juvenile	104	113	90	68	56	42	36
Chub – juvenile	84	92	81	67	60	50	42
Long Leaf Pondweed *(Potamogeton nodosus)*	29	40	57	68	73	77	70
Mayfly *(Palingenia longicauda)*	20	24	26	31	39	59	85
Total wet surface area	196	255	257	266	266	277	278

Table : Surface area of suitable habitat (ha) for a number of species at different discharges, based on the integrated results of the calculations per parameter in RHASIM. The species and life stages in the upper part of the table are included in the surface area analysis to determine minimum discharge for the Common Meuse.

SPEAR: An audit model for ecological river bank reconstruction planning

R.J.W. de Nooij and H.J.R. Lenders
Department of Environmental Studies, University of Nijmegen, Faculty of Science,
Mathematics and Computing Science/Netherlands Centre for River studies (NCR),
P.O. Box 9010, 6500 GL Nijmegen.

Goal

The SPEAR audit model (SPreadsheet application for the Ecological Audits of River bank reconstruction planning) was developed to enable quantitative ex-ante and ex-post evaluations of the process and reconstruction designs of river bank reconstruction projects aimed at improving the ecological value of these river banks (Lenders and De Nooij, 2001).

Introduction

The ecological significance of natural river banks within river systems is enormous. They are ecotones between the river channel and the adjacent floodplains and serve as transition zones for several ecological processes in the river system. Furthermore, they offer habitats for more or less specialised species and function as longitudinal as well as transversal ecological corridors. At present, the banks of the main river systems in the Netherlands, viz. the rivers Rhine and Meuse, like those in many other countries, are functioning in a far from ecologically sound way. As part of the ecological rehabilitation of river systems in the Netherlands, two major programmes have been developed which aim to improve the ecological functioning of river banks. The "Oeverture" programme for the Dutch branches of the river Rhine was presented in 1993, aiming at ecological development of 538 kilometres of banks along the Rhine. The Programme for Ecologically Sound River Banks for the river Meuse (1994) involved the reconstruction of 360 kilometres of river bank stretches. River management policies in the Netherlands aim to link ecological river bank reconstruction with other large-scale river works such as shipping channel improvement, flood risk reduction, and ecological rehabilitation of entire floodplain areas. Full river bank restoration is therefore hardly ever a realistic option, since the river and its banks have to fulfil other functions as well. To address the various constraints, several types of multifunctional river bank constructions have been developed and tested, both in the Netherlands and abroad (example: see Figure 1). The question arises to what degree ecological considerations are implemented in the planning process and design of the reconstruction of river banks.

Materials and methods

In constructing SPEAR, we adopted the approach described in (Lenders et al., 1999). This method comprises hierarchical and modular assessments, expressed by means of indices, on the basis of criteria concerning all aspects of the planning process that are relevant from an ecological point of view. Three consecutive stages can be distinguished in river bank reconstruction planning: I) Design preparation, II) Design and III) Preparation for execution and aftercare. Assessment criteria for the Design preparation stage were directly derived from the guidelines drawn up by the Dutch Institute for Inland Water Management and Waste Water Treatment, RIZA (Peters et al., 1992). This stage comprises all steps necessary to draw up a well-designed blueprint for ecologically sound river banks. The criteria for the two subsequent stages were derived from a literature search and from interviews with national experts in the field of river bank reconstruction. The Design stage involves the drawing up of the river bank reconstruction blueprints, while the Execution and aftercare stage involves the formulation of technical guidelines for materials to be used, of execution and management directives, and of evaluation and monitoring schemes. In total, 180 aspects of river bank reconstruction are evaluated and represented by 30 indices. Aggregated indices that give insight into the quality of: 1) the planning process (Final Process Index) and 2) the actual design (Final Content Index) and 3) the reconstruction plan as a whole (Final Index) were calculated. SPEAR was applied to ten ecological river bank reconstruction projects along branches of the rivers Rhine and Meuse in the Netherlands (for an example of a river bank stretch, see Figure 2).

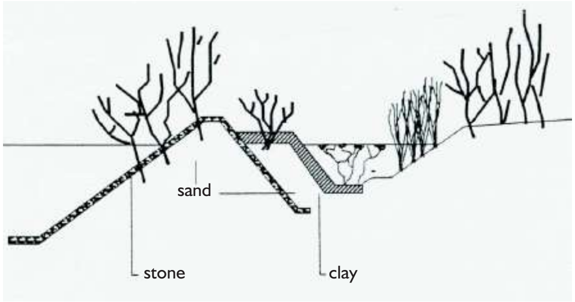


Figure 1: Marsh construction.

Results

The outcomes of the SPEAR model applications for each individual project and module are listed in the Table below. It was found that two of the ten river bank reconstruction projects examined were rated as good in terms of the Final Indices (FI), four were rated as sufficient and four as insufficient (insufficient <55, sufficient 55-80, good >80). The average assessment of the ten projects examined was rated as sufficient. In terms of the scores for the Final Process Indices (FPI), only two projects were rated as insufficient and two were scored as good.The average score for FPI was sufficient.With regard to the Final Content Indices (FCI) six projects were scored as insufficient and two as good. The average score for FCI, however, was still sufficient.

Discussion and conclusions

Applying SPEAR to ten river bank reconstruction projects along the rivers Rhine and Meuse in the Netherlands demonstrated that the model met the objective very well. Further analysis showed that there are strong correlations between the planning process - especially the inventory of the present biotic and abiotic conditions, the inventory of societal demands and preferences, and the drawing up of a target image - and the expected ecological benefits after execution. As SPEAR is not a location-specific model, it can be applied with relative ease in other river basins as well. Evaluations offer opportunities for optimisation of such projects. Since the near-floodings of the rivers Rhine and Meuse in 1993 and 1995, river engineering has been focussing on flood risk reduction rather than on ecological rehabilitation.Although ecological river bank reconstruction and, for that matter, ecological rehabilitation as a whole, may profit from this development, it is obvious that ecology is no longer the only main issue of river management anymore. It is strongly recommended that instruments like SPEAR are applied as a guideline for implementation of ecological aspects throughout the planning process concerning flood risk reduction projects.

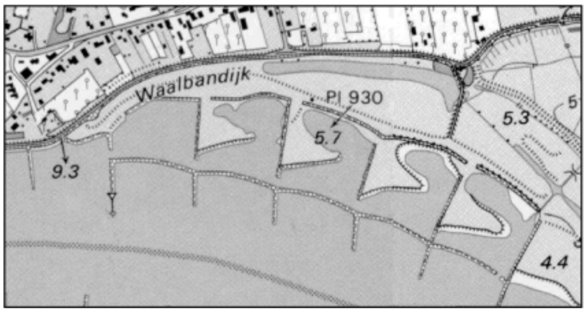


Figure 2:Waal bank near Opijnen, an early ecological project.

References

Lenders, H.J.R., M.A.J. Huijbregts, B.G.W. Aarts and C.A.M. van Turnhout, 1999.Assessing the degree of preservation of landscape, natural and cultural historical values in river dike reinforcement planning in the Netherlands. Regulated Rivers: Research and Management 15, p. 325-337.

Lenders, H.J.R. and R.J.W. de Nooij, 2001. SPEAR:An ecological audit model for ecological river bank reconstruction planning. European Water Management. European water Management 4 (5), p. 37-49.

Peters, J.S., M.H.C. van den Hark and C. Bakker, 1991. Ecologische advisering natuurvriendelijke oevers: een methodische leidraad. RIZA Notanr. 91.086, Lelystad.

Table: The River Bank Reconstruction projects selected for assessment, with some characteristics.

Nr.	Project	Situation	Length (in metres)	Year of design	FI	FPI	FCI
1	Opijnen	Waal	1,000	1993	48.0	53.9	45.3
2	Loevestein	Waal	850	1993	53.7	61.8	50.5
3	Duursche Waarden	IJssel	2,300	1994	67.5	65.4	66.6
4	Ossenwaard	IJssel	1,200	1995	64.5	65.1	64.0
5	Blauwe Kamer	Nederrijn	1,800	1993	46.7	52.9	44.9
6	Amerongse Bovenpolder	Nederrijn	1,150	1997	58.7	72.3	53.1
7	Grote Bol	Lek	1,650	1994	56.1	74.0	51.6
8	Bosscherwaarden	Lek	3,200	1995	53.0	58.4	51.7
9	Batenburg	Meuse	3,600	1996	83.0	84.9	82.7
10	Ossenkamp	Meuse	1,000	1998	88.5	91.3	87.4
Mean (N=10)					62.0	68.0	59.8

FI = Final Index, FPI = Final Process Index, FCI = Final Content Index

Do Alternate Stable States Occur in Natural Ecosystems? Evidence From an Estuarine tidal flat

J. van de Koppel[1] and P. Herman[2]
[1]IHE Delft, P.O. Box 3015, 2601 DA Delft.
[2]NIOO-CEMO, P.O. Box 140, 4400 AC Yerseke.

Diatoms and silt

Diatoms increase sediment cohesion by excreting extracellular polysaccharides (EPS). As a result, high densities of diatoms significantly alter the frequency and magnitude of erosion events. Frequent and severe erosion will selectively remove clay and silt particles from the sediment. Hence, by reducing erosive stress, diatoms promote the silt content of the sediment. Diatom growth, in turn, benefits form a high silt content. Silt provides a more stable substrate for growth relative to sand. Furthermore, silt is rich in nutrients that are important for diatom growth.

Model analysis

We made a model of the interaction between diatoms and silt content of the sediment. We investigated the consequences of a positive feedback mechanism in which high densities promote the silt content of the sediment, which in turn promotes diatom growth. This interaction may lead to alternate stable states. Depending on external conditions, the system either evolves towards a state with a high diatom and high silt content, or to a state with low diatom and low silt levels. At low water flow rates, only the first state occurs, whereas the latter is predominant at high water flow rates. However, at intermediate water flow rates, the system may flip between the two states, leading to an inherently unpredictable relation between shear stress and silt content (Figure 1).

Empirical observations

Alternate stable states may reflect in pattern formation on tidal flats. Patches with a high density of diatoms and high silt content are alternated by patches with virtually bare and sandy sediment, while patches with an intermediate diatom and silt content are relatively rare.

We related our model predictions to data on the physical and biological properties of sediments of the Molenplaat tidal flat. In accordance with our model, the silt content of sediment with high bottom shear stress showed a clear and significant bimodal distribution, which may reflect the existence of alternate stable states (Figure 2B). At low bottom shear stress, silt content was better explained by a unimodal distribution, as is predicted by our model (Figure 2A). Patterns in chlorophyll content were less clear. Nevertheless, chlorophyll content was best explained by a bimodal distribution at high bottom shear stress, and in two of the three periods at low bottom shear stress.

In an experimental study, we showed that the growth rate of diatoms increases with the silt content of the sediment. Net growth of diatoms, as measured by the chlorophyll content of the sediment, was significantly higher on silt than on sandy sediment after nine days of incubation, supporting our model analysis.
Alternative explanations for the occurrence of bimodal patterns were addressed. These failed to explain the observations, however. Our study indicates that the positive feedback between enhanced production of

diatoms and reduced erosion of sediment significantly affects the dynamics of intertidal mudflat systems.

Ecomorphology project

Model investigations are currently extended into spatial aspects of the above-mentioned positive feedback, as a part of the Delft Cluster Ecomorphology project. Application of positive feedback models to management issues typical to estuarine systems is limited by lack of consideration of spatial aspects of the system in the models. We plan to investigate the consequences of spatial heterogeneity and spatial interactions in simple models of plant-sediment or diatom-silt feedbacks. Inclusion of spatially-explicit ecological processes into positive feedback models will improve our understanding of a range of phenomena occurring in estuarine systems, such as salt marsh development and tidal flat dynamics.

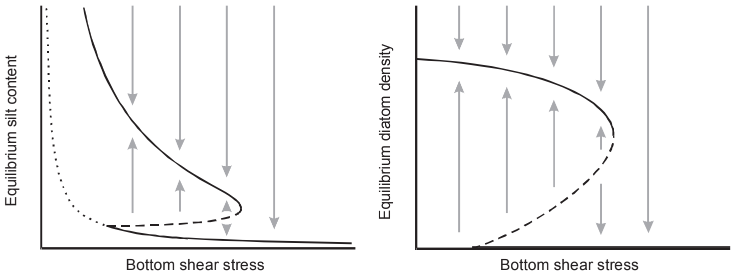


Figure 1: Equilibrium silt content and diatom density as a function of bottom shear stress τ (which increases with the flow rate of the water). The dashed line depicts unstable equilibria. Two stable states are found at intermediate bottom shear stress. The dotted line represents the relation between silt content and bottom shear stress in a system without diatoms.

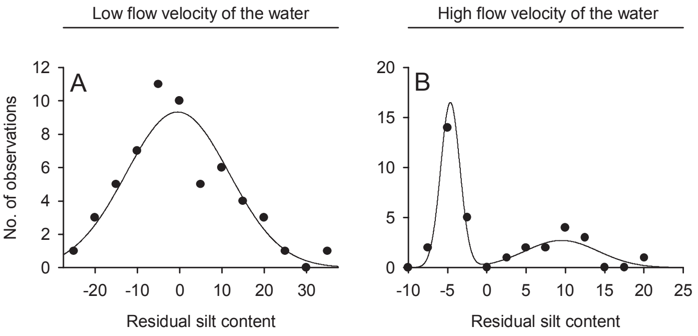


Figure 2: Distribution of the residual silt fraction and chlorophyll content after removal of the negative trend in the data (see text for explanation). Left and right figures represent the data at $\tau_{max} < 1$ and $\tau_{max} > 1$ respectively. Curves represent the fitted probability distribution. Bimodal distribution is given when it explained significantly better than the normal distribution.

Modelling Nutrient Fluxes into Lake Peipsi / Chudskoe (Russia / Estonia)

D. Mourad and M. van der Perk
Centre for Geo-Ecological Research, Faculty of Geographical Sciences,
Utrecht University P.O. Box 80.115, 3508 TC Utrecht.
e-mail: d.mourad@geog.uu.nl

Within the MANTRA-East project*, issues regarding water management on the existing and future borders of the European Union are investigated. The lake Peipsi catchment (Estonia, Latvia and Russia) has been selected as a pilot area.
For the analysis of nutrient fluxes at the river basin scale, large-scale models are used and further developed.

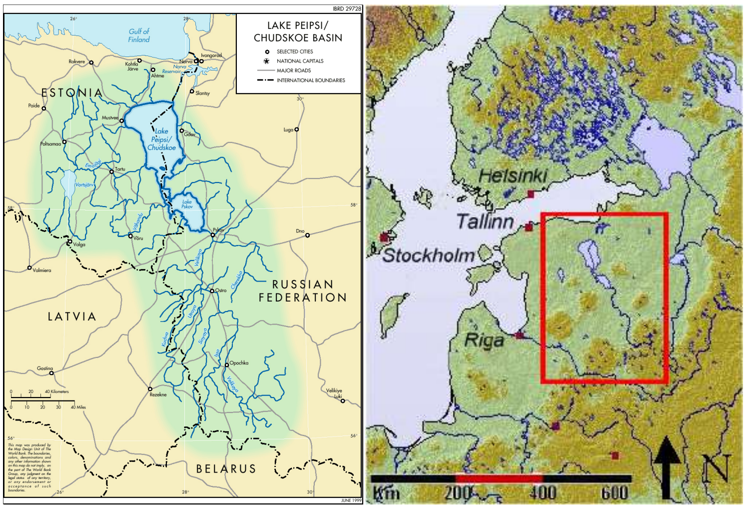


Figure 1 and 2: Location of the lake Peipsi catchment (source: The World Bank (1), BOING Baltic environmental atlas (2)).

Study area: the Peipsi / Chudskoe basin

Lake Peipsi / Chudskoe (Figures 1 and 2) is situated on the border of Estonia and Russia and is the fourth largest lake of Europe, with a surface of 3550 km^2 and a length of about 150 km. Water depth never exceeds 15 m. The lake is drained by the Narva river (annual mean discharge: 380 m^3/s). Main tributaries of the lake are the Velikaya (Russia) and the Emajogi (Estonia). The catchment surface totals 47.800 km^2 and is divided between Russia (56 %), Estonia (34 %) and Latvia (8 %). It is characterized by various Quaternary deposits. Forest and agricultural land is the main land use (Figure 3). Population is sparse, except for some larger cities (Tartu, Pskov).

Modelling nutrient transport: PolFlow

For modelling nutrient transport the spatially distributed GIS-based PolFlow model (De Wit, 1999) is used. The model was already successfully applied to the Rhine, Elbe and Po basins before.
PolFlow has been implemented in the PCRaster dynamic modelling language. Figure 4 shows an outline of PolFlow.

Input for PolFlow

All model inputs are collected at a spatial resolution of 1 km^2.

Catchment parameters:
- long term average specific runoff
- groundwater recharge index and residence time
- hydrogeological characteristics
- slope gradient and Local Drainage Direction (from DEM and river network, Figures 5 and 6)
- land use (Figure 3)
- soil type

Emission parameters
indirect:
- organic manure production
- fertilizer consumption
- atmospheric deposition
- natural background
- wash-off from built-up areas

direct:
- industrial point sources
- public sewage systems

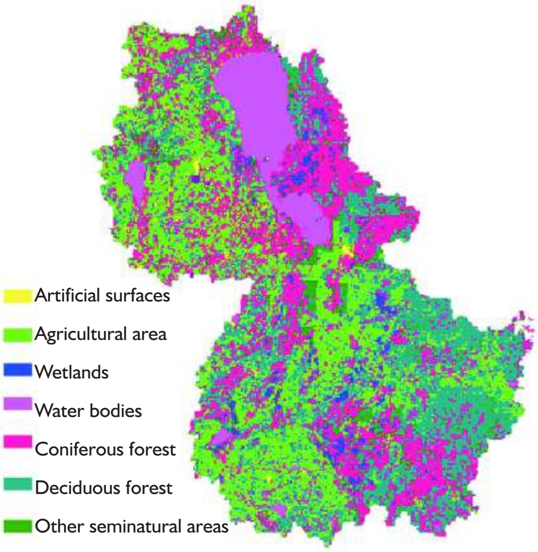


Figure 3: Land use map (BALANS data).

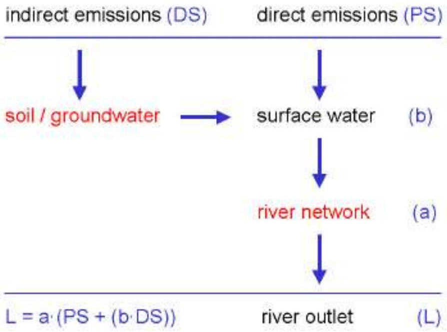


Figure 4: Outline of PolFlow and the basic equation. The factors a and b will be calibrated and validated using measurement data.

The end of communism: Changing emissions

Previous studies (De Wit, 1999; Stålnacke et al., 2001) showed that in European rivers, nutrient load is strongly influenced by diffuse sources, especially agricultural fertilizer use.

After the fall of the Soviet Union in 1991, fertilizer application decreased rapidly (Figures 7 and 8).

The effects of those socio-economic changes on the long-term nutrient load of the rivers in the Peipsi basin are unknown. The PolFlow model allows to assess the effects of those changes and possible management strategies on the nutrient fluxes within the lake Peipsi basin.

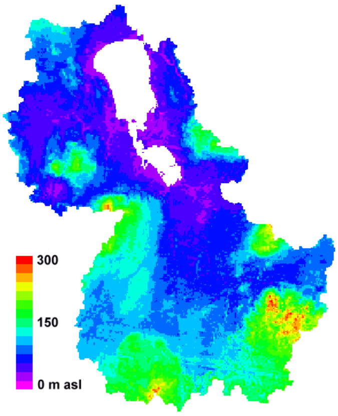


Figure 5: Digital Elevation Model.

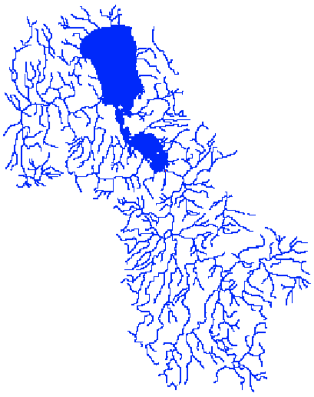
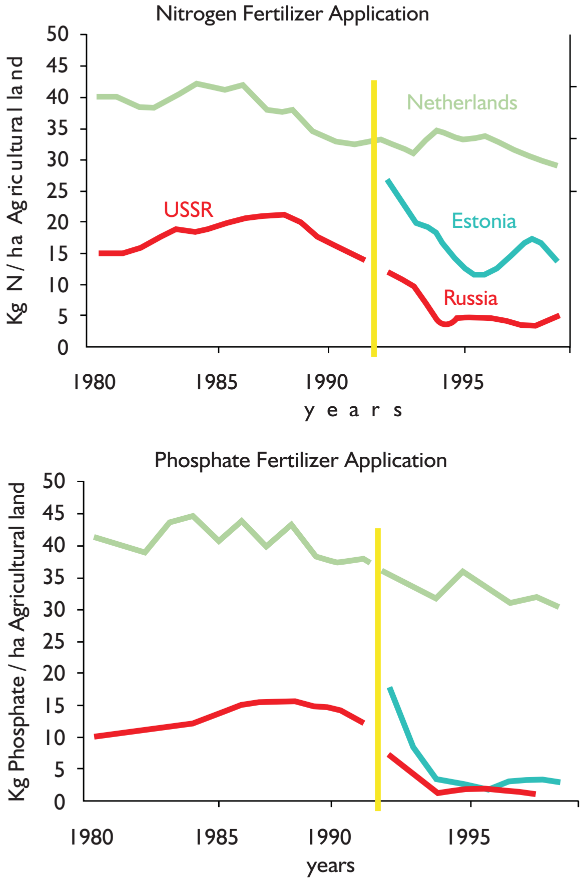


Figure 6: River network.



Figures 7 and 8: Development of fertilizer application in Estonia, Russia and the Netherlands. The yellow line represents the end of communism (source: FAO).

Literature

De Wit, M., 1999. Nutrient fluxes in the Rhine and Elbe basins. Thesis Utrecht University. Netherlands Geographical Studies 259, KNAG/ FRW Universiteit Utrecht, 163 p.

Stålnacke, P., U. Sults, A. Vasiliev, B. Skakalsky, A. Botina, G. Roll, K. Pachel, and T. Maltsman, 2001. Nutrient Loads to Lake Peipsi. Jordforsk Report No. 4/01.

*Integrated Strategies for the Management of Transboundary Waters on the Eastern European Fringe - The pilot study of Lake Peipsi and its drainage basin.

MANTRA-East is funded within the EU Fifth Framework Programme 1998 - 2002, there are 10 participating institutes in Norway, Sweden, Estonia, Russia and the Netherlands

Stochastic modelling of river morphodynamics

H. van der Klis
Delft University of Technology, Subfaculty of Civil Engineering, c/o WL | Delft Hydraulics,
P.O. Box 177, 2600 MH Delft.
e-mail: Hanneke.vdKlis@wldelft.nl

Introduction

Interventions in rivers cause a morphological response in the form of erosion and sedimentation that may affect functions of the rivers such as safety against flooding, navigability and the provision of natural habitats. Any river engineering intervention or nature rehabilitation project thus requires a prediction of the morphological changes. These predictions involve numerous uncertainties, for example,

1. **uncertainties in the model structure, due to a lack of knowledge of the morphological processes, or to discarding phenomena that are thought to be of minor influence;**
2. **uncertainties in boundary conditions, due to limited availability of measured data and to inherent uncertainties in the time-evolution of the conditions at the upstream boundary;**
3. **uncertainties in initial conditions and model parameters, due to a limited availability of site-specific measured data.**

The last decades have resulted in great advances in the development of morphological prediction models. However, despite the uncertain factors, these models are mostly deterministic. This means that the model output represents only one realisation of a stochastic process, and thus one choice out of a range of possible occurrences. Strictly speaking, this should not be called a prediction.

In the present study we investigate methods to estimate the influence of the various uncertainties on the reliability of the model outcome. In this, we pay most attention to the influence of the uncertain future river discharge.

Illustration

To illustrate the results of a stochastic prediction, we used a one-dimensional case study of a constriction within the main channel of a straight river reach. By applying the Monte Carlo method, we estimated the influence of a number of uncertainties in the model input. The Monte Carlo method basically performs a large number of deterministic simulations (typically a couple of hundreds) with randomly selected input. The uncertainties we considered are those in the future river discharge, in the hydraulic roughness of the main channel, and in the grain size of the bed material. Although these are not necessarily all the important uncertainties, the results show that the deviation in the morphological effects can be significant (Figure 1). Also note that the impact of the random discharge is relatively large.
Here, we presented the results in terms of a 90%-confidence interval. In general, the output of a stochastic model is the probability distribution of the predicted morphological effect, or any information that can be obtained from this distribution.

Stochastic modelling

In general, we see three difficulties for the stochastic modelling of river morphodynamic processes, namely,

- the non-linearity of the processes,
- the time and space dependence of the results, and
- the time consuming numerical calculations involved.

The frequently applied Monte Carlo method is suitable in the light of the first two difficulties. However, since it requires a large number of numerical simulations, the computation time in case of morphological calculations is often far too large.

More experience with stochastic modelling has been obtained within other research areas, such as hydrology, weather forecasting, and groundwater modelling. Roughly spoken, the methods applied are of the following types:

- Monte Carlo methods - efficient sampling techniques have been developed (e.g. Latin Hypercube sampling)
- First order approximation methods - based on linearisation of the model (e.g. First Order Reliability Method (FORM))
- Methods to solve Stochastic Differential Equations
- Meta modelling - where complex models are substituted by simpler representative models.

We compared the straightforward Monte Carlo method with FORM, as this last method takes little computation time in its usual applications, such as the probabilistic construction of river works. Again, we used the case study of the constricted river reach. Since we have not yet succeeded in applying FORM to the uncertain time-dependent future river discharge, the comparison is based on the uncertainty in the grain size only. It appeared that FORM is not suitable straightaway for the prediction of the complete distribution function of morphological effects (Figure 2). The inaccurate results, especially downstream of the constricted reach, are due to the non-linear relation between the grain size and the bed level effect. This relation is highly influenced by the time-varying river discharge, inducing bed waves travelling through the system.

Further research

We will try to apply FORM in a more effective way, based on local instead of global linearisation of the process. This will lead to more simulations, and thus a larger computation time. We want to investigate whether accurate results can be obtained within an acceptable computation time.

It appeared that the statistical description of the time-dependent river discharge requires special attention. The discharge has a variety of random aspects, such as the magnitude and duration of the discharge peaks, the time of occurrence of those peaks, the variability of the low discharges, or the chronology of the peaks. We investigate what characteristics are relevant to the morphological changes and should therefore be included in the statistical description of the river discharge.

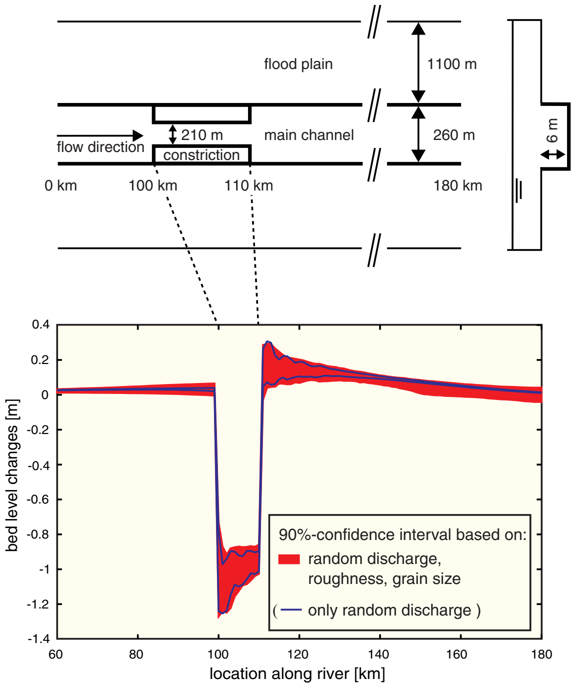


Figure 1: Results of a Monte Carlo simulation with uncertain river discharge, hydraulic roughness and grain size.

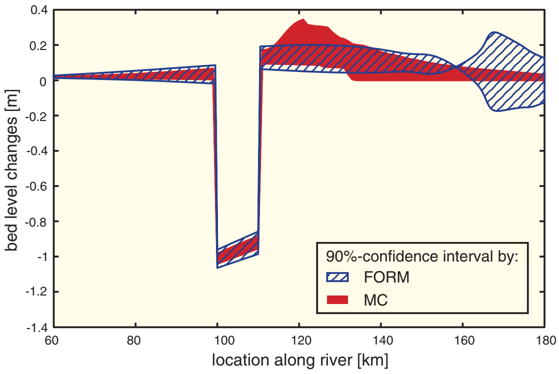


Figure 2: Comparison of Monte Carlo and FORM with uncertain grain size.

Stochastic modelling of river morphology: an analysis of bathymetric data

S. van Vuren
Delft University of Technology, P.O. Box 5048, 2600 GA Delft.
tel. +31 15 278 4735, fax +31 15 278 5124
e-mail: B.G.vanVuren@ct.tudelft.nl

Introduction

The river response to engineering measures and river basin management policies receives much attention. Both natural changes and human interference influence the river system and lead to an immediate hydrodynamic response (water motion) and a delayed morphological response (the induced gradual changes in the bed topography). These responses may affect the functions of the river, like safe discharge of water, ice and sediment; safe and efficient navigation; land-use in floodplains; water supply; ecology and recreation.

In river management the understanding of long-term and large-scale river morphodynamics, over a time span of decades to a century and stretches of tens to hundreds of kilometres, becomes more important, in particular in densely populated areas. The effects of, for example, large engineering works or climate changes may become more apparent on such scales. However, our knowledge of the behaviour of the river on these time and spatial scales is restricted compared to that on the smaller scales (years-kilometres).

River engineers generally apply a variety of tools in river impact assessment projects to determine the morphological responses. These tools include among others numerical models. These models approximate 'reality'. In the modelling process uncertainties are introduced. Quantification of uncertainties in river morphological computations and expressing ranges of possible future states is desired to obtain a better understanding of what might happen.

Ph.D. research

The focus of my Ph.D. research is the development of a model approach to quantitatively describe uncertainties in long-term and large-scale morphological response to:

- the natural dynamical behaviour of the river, and
- the rivers' response to changes (natural changes, e.g. climate change and human interference).

This model approach must give insight in the time-evolution of uncertainty bounds of the morphological change.

Uncertainties in the computations of morphological responses are introduced during the model schematisation and the specification of the model input. The Ph.D. research is built up in two phases. The first phase consists of an analysis of bathymetric data. This analysis is meant to obtain insight in the bed level variability observed in the river Rhine. The second phase is the application of probabilistic and stochastic methods to morphological impact studies. Several case studies are defined and incorporated in my research. The project aims at the specification of the statistical characteristics of the morphological response. The relative contribution of the different sources of uncertainty to the uncertainty in the morphological computation will be investigated with an uncertainty analysis. Results and conclusions from this research phase will be compared with those from the data analysis. Here, I focus on the data analysis I performed on the bathymetric database of the Dutch branches of the River Rhine.

Data Analysis

Data over large distances and long time spans is required when analysing the morphological river system behaviour at the scale of hundreds of kilometres over decades. An extended bathymetric database of the Dutch branches of the River Rhine is available. The Institute for Inland Water Management and Wastewater Treatment (RIZA) in the Netherlands maintains the bathymetric database. We have the database at our disposal for this data analysis.

We use the bathymetric database to obtain insight in dynamic bed level variability and to analyse whether this variability is spatial-dependent or can be considered as a characteristic of the specific river branch.

Before we remark upon bed level response rates (degradation and aggradation patterns) and bed level variability we have to understand the factors determining the data characteristics. The bathymetric data is affected by:

Structural changes in the system

Due to obtrusive alteration in the environment of the 'measured' system, non-homogeneity can be introduced into the data series. Causes of non-homogeneity can be either natural (extreme hydraulic events) or man-made (river regulation works, river bend cut off, canalisation works).

Structural changes may affect the temporal variation of the river system, like the degradation and aggradation patterns.

Incidental changes in the system

Dredging activities are incidental changes in the river system, which can introduce non-homogeneities in the data.

Post processing techniques, the measurement frequency and technology

For example, modernisation of measuring equipment can cause inconsistency to appear in a data series. Inconsistency is a change in the amount of systematic error associated with the recorded data. It can arise from the use of different instruments and methods of observations. Each instrument and method introduces its own errors and uncertainties.

Examples of how these factors affect the bed level variability are found in the Dutch bathymetric database.

The impact of the construction of the canalisation works in the River Lower-Rhine and Lek (weir near

Hagestein in 1958 at kmr 947, weir near Amerongen in 1966 at kmr 922 and weir near Driel in 1970 at kmr 891) can be noticed from the record bathymetric data. The bed level response rate (rise or fall) and the bed level variability (Figure 1) are affected.

In the last century many dredging activities have been carried out. These dredging activities are not registered accurately. The registered amount of dredged sediment in the period between 1975 and 1979 in the downstream part of the IJssel is 2.070.000 m^3. This is high in comparison with the averaged dredged sediment of 350.000 m^3 in the other 5-year periods between 1950 and 1999. The impact of these intensive dredging activities is apparently noticed in the time record of the bed level at the downstream part of the IJssel (Figure 2). From 1950 onwards at annual base bed level soundings are performed in the River Rhine. Perpendicular to the river axis at rays with a mutual distance of 100 or 125 meter in longitudinal direction, the soundings are performed between the groyne heads in the cross-sections of the main channel. In fact the data are annual instant recordings. After the winter season the soundings took place in the months April through November. This implies that the time interval between successive soundings at a particular location may vary between 0.33 and 1.67 year. It implies that the sampling has a seasonal bias. The data at which the bed level soundings are taken are not registered in the database.

Based on the annual soundings for each ray the bed level is averaged over the cross-section. Data administration through the last century was not always that accurate. This induced that the several data sets are available. The ray-averaged values were based on different procedures. Most of the unprocessed data is lost. In the time series of all measured cross-sections in the River Waal and the Upper-Rhine a systematic discontinuity is observed. In 1985 a bed level fall over an average depth of 0.25 meter is observed in both river branches (Figure 3). This degradation is unrealistic and is assumed to be the result of changes in the post processing of the bathymetric data.

We have to correct for these impacts to analyse the bed level variability. The bathymetric record of the river system cannot statistically be considered as a whole after human interference, changes in post processing or changes in measurement technology, unless we correct the records for these changes (and so for the non-homogeneity, inconsistency and non- stationary behaviour they introduce).

In further research I focus on this point. I will perform statistical analysis on the corrected bathymetric data. Per river cross-section at mutual distances of 1 kilometre the significant rise or fall of the riverbed and the bed level variability will be statistically estimated. With respect to my Ph.D. research project the resulting bed level variability will be used as a reference. It gives an impression of the bed level variability (in space and in time) with respect to the large-scale and long-term morphological behaviour in the Rhine river system. However, we have to realise that the bathymetric data is one single realisation of the bed level response. It reflects one possible state that could have occurred. The uncertainty bounds resulting from the application of probabilistic and stochastic methods must be outside the range of the observed bed level variability.

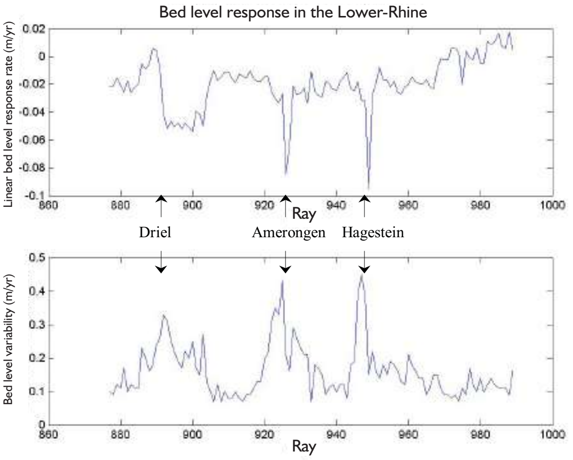


Figure 1: Bed level response in the Lower-Rhine.

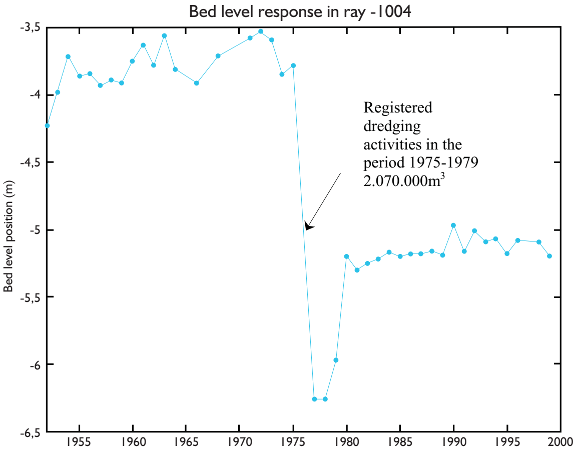


Figure 2: Bed level response in the downstream part of the IJssel.

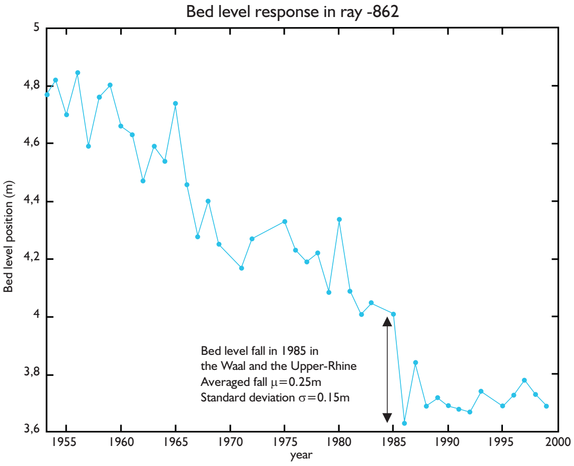


Figure 3: Bed level fall in 1985 in the Waal and the Upper-Rhine. The averaged fall is 0.25 m with a standard deviation of 0.15 m.

Impact of uncertain parameters in Flood Extent Estimation

M.Werner[1,2]
[1]Delft University of Technology, Delft, P.O. Box 5048, 2600 GA, Delft.
[2]WL | Delft Hydraulics, P.O. box 177, 2600 MH Delft.
tel +31-15-2784771, fax +31-15-2787700.
e-mail: M.Werner@ct.tudelft.nl

A central element of flood risk assessment is the estimation of the inundated area due to a given (design) event. To this end a model capable of predicting spatially distributed estimates of water depth and possibly velocity is required (Bates et al., 1999). Although Bates et al. (1999) apply a 2D finite element model to predict these variables, they note that model calibration is the dominant factor affecting model sensitivity, as opposed to other factors such as grid resolution and accuracy.

Calibration of models for predicting floods extent limits due to extreme flood events is unfortunately not as straightforward as it may seem. The problem is that there is typically very little data available for calibration and verification (Aronica et al. 1998). Particularly for flood events of high return periods measurements are scarce and often even unavailable due to events with a magnitude in the order of design events never having occurred. Once calibrated on the limited data available, the models are typically applied to these (design) events of larger magnitude, assuming that the behaviour of the system can be extrapolated from that observed for the lower calibration events.

In this paper the impact of limited data on parameter uncertainties as well as the effect of these uncertainties in extrapolation is investigated. To estimate the extent of flooding due to a discharge event, stages are first calculated through application of a 1D hydrodynamic flow modelling code, SOBEK, and interpolated through application of a GIS based flood mapping routine to obtain flood extent maps (Werner, 2001). Rather than assume a single optimal parameter set to be found through calibration, the Generalised Unlikelihood Uncertainty Estimation method (Beven and Binley, 1992) is applied in parameter estimation. Monte Carlo simulation is used to generate randomly sampled parameter sets from parameter prior distributions, and based on each parameter set the model is run and compared to the observed data using the Nash-Sutcliffe efficiency. Model runs with an efficiency of over 80% are considered behavioural and thus retained, whereas those with lower efficiencies are discarded from the analysis. Using the thus retained behavioural parameter sets, predictive uncertainties for events other than the calibration event can be estimated. The method is applied to a 17 km stretch of the Saar River in Germany, where the downstream end at Mettlach is held at a controlled level through a weir and a gauge is located at the upstream end at Fremersdorf. Three events of medium magnitude (Events 1,3 & 4) as well as one event of extreme magnitude (Event 2) are used to evaluate predictive uncertainties for water levels at Fremersdorf and inundated area for Event 2 (Figure 1a). Floodplain and main channel roughness are the parameters considered in calibration. In Event 2A, all four events are used to estimate parameter posterior distributions, while in Event 2B only the data of Event 2 is used. Finally Event 2C uses only Events 1,3 & 4 to estimate parameter posterior distributions. Figure 1b shows that the distributions for predicted water levels at Fremersdorf are low, particularly when the information in Event 2 is not used (Event 2C). This is reflected in 90% uncertainty bounds of the inundated area (Figure 2 and Table).

Table : Inundated Areas of various depths.

	Event 2A		Event 2B		Event 2C	
	Lower	Upper	Lower	Upper	Lower	Upper
Depth > 4m	53.5	53.6	53.5	148.1	53.5	53.5
Depth > 2m	101.9	163.0	101.7	526.2	102.0	154.4
Depth > 0m	391.9	444.0	390.2	645.5	392.6	442.1

Results show that parameter uncertainties have significant influence on predicted extent of flooding. It is also clear that estimated extent of flooding might be underestimated for design events with magnitudes higher than the events used in calibration. This affirms the dangers of extrapolation of model behaviour to events of higher magnitude than those used in calibration, as noted also by Uhlenbrook et al. (1999) in conceptual rainfall-runoff modelling. It is important to note that even for models assumed to be physically based models such as that used here these dangers are still apparent.

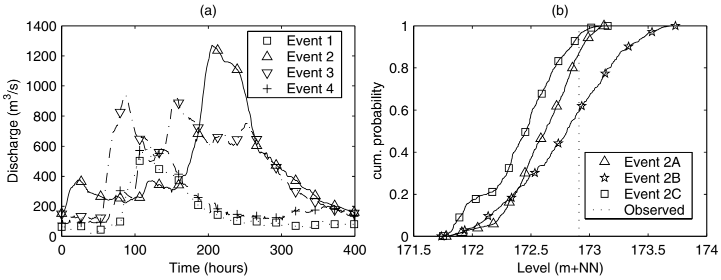


Figure 1: Observed discharges (a) and posterior distribution of peak level (b) at Fremersdorf.

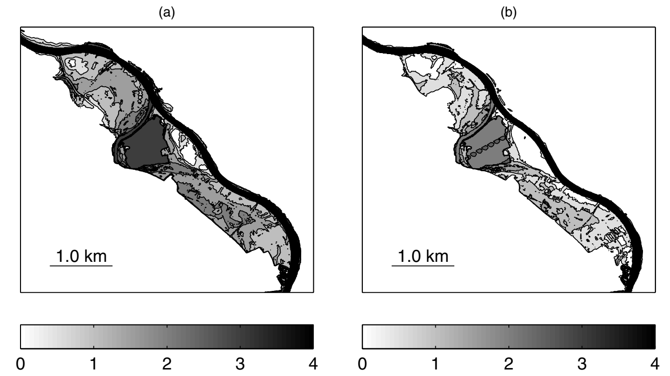


Figure 2: Upper (a) and lower (b) bounds of the 90% confidence interval of flood depth maps for Event 2C.

Acknowledgement

This work has been carried out partly using methods developed in the EUROTAS project funded by the EC (Contract No. ENV4-CT97-0535). The Bundesanstalt für Gewasserkunde in Koblenz, Germany is thanked for kind permission to use the data.

References

Aronica, G., B. Hankin, and K. Beven, 1998. Uncertainty and equifinality in calibrating distributed roughness coefficients in a flood propagation model with limited data. Advances in Water Resources 22. No. 4, 349-365.

Bates, P.D., M. Horrit and J.M. Hervouet, 1999. Investigating Two Dimensional, Finite Element Predictions of Floodplain Inundation using Fractal generated Topography. In P.D. Bates and S.N. Lane (eds.), High Resolution Flow Modelling in Hydrology and Geomorphology, John Wiley & Sons, p181-201.

Beven, K. and A. Binley, 1992. The future of distributed models: Model calibration and uncertainty prediction. Hydrological Processes, 6, 279-298.

Werner, M.G.F, 2001. Impact of grid size in GIS based flood extent mapping using a 1D flow model. Accepted for publication, Hydrology and Earth System Sciences.

Uhlenbrook, S., J. Siebert, C. Leibendgut and A. Rodhe, 1999. Prediciton uncertainty of conceptual rainfall-runoff models caused by problems in identifying model parameters and structure. Hydrological Sciences Journal 44. No. 5, 779-797.

An impact assessment tool for participatory evaluation of dam and reservoir locations

G.A. Vonk and P.P. Schot
Environmental Sciences, Utrecht University, P.O. Box 80.115, 3508 TC Utrecht.
e-mail: p.schot@geog.uu.nl

Large dams and the associated reservoirs can have negative impacts on citizens and ecology at the location where they are created, as well as downstream of these dams, because they change river water and sediment discharge patterns. On the other hand, dams and reservoirs can also have positive effects because they provide the opportunity to generate electricity and supply water during dry seasons or to dry areas. One of the great challenges of river basin management is to utilize the advantages and to prevent the disadvantages of dams and reservoirs as much as possible. Who benefits from the advantages or suffers from the disadvantages often depends on where one is situated in the catchment. For this reason participation of stakeholders in the whole catchment is desirable in river basin management, in order to attain optimal locations and dimensions of dams and reservoirs. Impact assessment tools may assist in determination of negative effects of dams and reservoirs. To become useful in participatory processes, these tools need to be able to deal with many different stakeholders' demands and they should provide results that are comprehensible for both experts and non-experts.

A study has been conducted of which the aim was to develop an impact assessment tool for dams and reservoirs, suitable for use in participatory dam and reservoir planning studies. This aim has been reached. A tool has been developed within the graphical PCRaster GIS environment which is able to assess the suitability of a location for dam and reservoir development, taking into account the demands of one or many stakeholders. The tool consists of three modules that all provide information to evaluate the suitability of a location by simulation of:

- the effects of a dam on river discharge at any location downstream of the dam;
- the effects of a change in river discharge (due to the dam) on the amount of inundated floodplain area of a lake downstream of a dam;
- the suitability of a location to meet stakeholders' demands with respect to (amongst others) abstracted domestic and irrigation water, electricity generation, reservoir level fluctuations and river discharge dynamics downstream.

The impact assessment tool is used in combination with a surface water model based on the algorithm of Kwadijk and Van Deursen (1993).

The developed tool has four advantages which make it suitable for application in participatory dam and reservoir location evaluation processes:

1. The tool is able to deal with many different stakeholders' demands. It can be used by individual stakeholders to evaluate alternative dam locations that meet their own demands and those of other stakeholders better than a proposed location.
2. Integrated solutions may be developed by simultaneously taking into account the demands of many different groups such as:
   - navigation stakeholders, demanding a minimum amount of water in the riverbed downstream of the dam for navigation;
   - nature conservation stakeholders, demanding as little change as possible of natural river discharge dynamics in ecologically valuable areas downstream;
   - agricultural stakeholders, demanding water for irrigation purposes during the dry season;
   - municipalities, demanding water for domestic purposes from the reservoir and electricity;
   - river valley inhabitants, demanding that their properties are not inundated by the reservoir;

- recreation stakeholders, demanding little fluctuation of the reservoir level so that beaches remain accessible throughout the year and water recreation can take place safely;
- industry, demanding process water from the reservoir.

3. Results are presented on maps and graphs which make them easily comprehensible for both expert and non-expert stakeholders, involved in participatory processes.
4. The tool requires only a relatively small amount of input data, which can be particularly useful for application to river basins outside the developed world where data is often scarce.

The tool has been applied to two case-areas: the catchment of Mustafa Kemalpasa brook in Northwestern Turkey and the Orinoco river basin in Venezuela and Colombia. The table and figures 1 and 2 show an example of a dam and reservoir location evaluation for the catchment of Mustafa Kemalpasa brook. The table shows assumed stakeholders demands converted to tool boundary conditions. Figure 1 shows simulated river discharge just downstream of the planned dam before and after dam construction, abstracted domestic and irrigation water and generated electricity resulting from dam development according to the stakeholders' demands in the table. Figure 2 shows a 3-dimensional plot of the catchment of Mustafa Kemalpasa brook, with the river network and a dam and reservoir projected on a location, that was found suitable to meet the assumed demands.

Results obtained in both cases suggested the tools function correctly as variables changed in the directions expected. However, up till now it has not been possible to apply all the features of the tools and to verify them satisfactorily. The fact that the tools have not been verified sufficiently is the main disadvantage of the tools at this stage.

Nevertheless, it is anticipated that the developed tools are potentially a valuable addition to the existing toolboxes for participatory river basin management, since no tool for dam and reservoir location evaluation purposes has been found yet which is as flexible as the developed tool in dealing with stakeholders' demands as which requires so little input data.

References

Kwadijk, J. and W. van Deursen, 1993. RHINEFLOW: an integrated GIS water balance model for the Rhine. In: Kovar K. and H. Nachtnebel, 1993. Application of Geographic Information Systems in hydrology and water resources management. IAHS Publication 235, IAHS Press, Wallingford, United Kingdom.

Table : Example stakeholders' demands converted to tool boundaries.

demands in terms of tool boundary conditions	value
allowed relative water level fluctuation	30%
allowed maximum level above talweg	250m
minimum required irrigation water	3.0 m^3/s
minimum required domestic water	1.1 m^3/s
yield for electricity generation	remaining possible yield

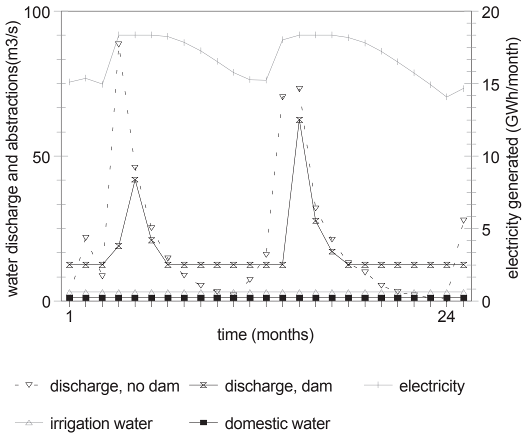


Figure 1: Simulated river discharge just downstream of the planned dam location before and after dam construction, abstracted domestic and irrigation water and generated electricity.

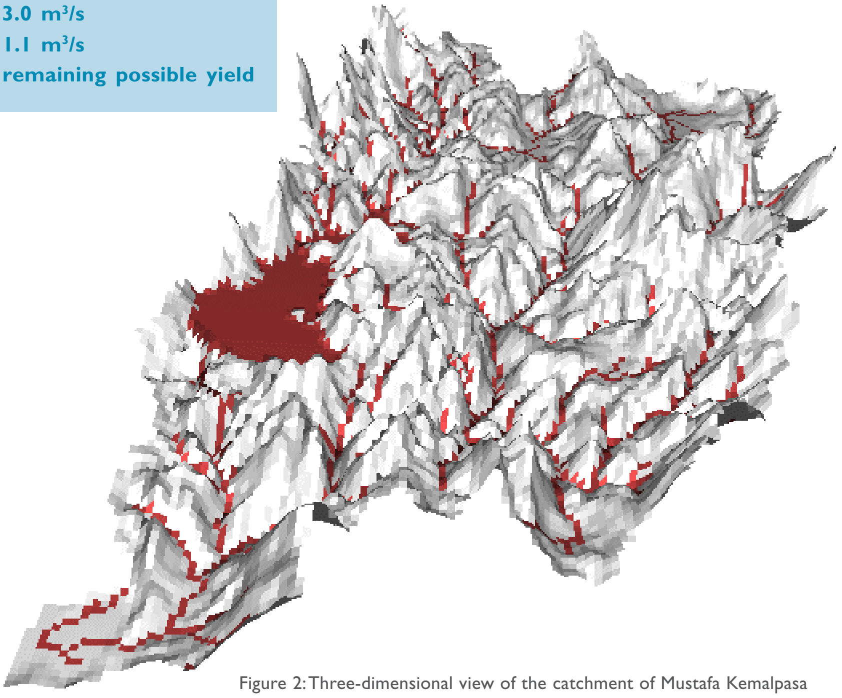


Figure 2: Three-dimensional view of the catchment of Mustafa Kemalpasa brook with the dam and reservoir that meets stakeholders' demands projected on it (large red flat surface on the left = reservoir).

Balancing Water and Social Challenges In Southern Africa

J. Heyink Leestemaker
Shared River Initiative on the Incomati River, Eduardo Mondlane University, Maputo,
Mozambique. Present address: Heemraadssingel 56, 3021 DC Rotterdam.
For the complete report, please contact: J.heyinkleestemaker@stadsadviseur.nl

Irrigation from the rivers enables Southern Africa to be a surplus producer of sugar. South Africa is a global competitive exporter of sugar, Swaziland is amongst the lowest-cost producers and Mozambique intends to recover and reverse its position as net exporter of sugar by the year 2005.

The research addresses the following questions:

1. **Under the given water scarcity, which options are there for 'levelling the playing field' between South Africa, Swaziland and Mozambique while improving the employment options for the increasing population? Should the sugarcane industry be reorganised, what reallocations of water should take place and how can water conservation and demand management help to solve the water scarcity?**

2. **While looking at the water demand of the different crops produced in the river basin, which land use patterns give the best social, economic and financial returns in relation to the (water) costs?**

Background

Some background on population and employment: The communities sharing the Incomati river basin add up to 2,294,542 people and are estimated to grow towards 3 million people in 2010. About 82 % lives in South Africa, 6.6% in Swaziland and 11.2% in Mozambique. The population growth rate is causing a doubling in twenty-five years.
Under employment is a major issue in the area and makes job creation a social and political objective. Irrigated sugar cane production provides about 0.5 jobs per ha in the Incomati river basin, whereas irrigation farming as such provides 1.5 jobs/ha.

Sugarcane remains the dominant agro-industry and is earmarked to increase its area and production levels. Sugarcane production provides opportunities for (self) employment at a low risk-level and is considered as a job creator at a relatively low capital outlay. Whereas banana is the most profitable crop in the region, sugarcane gives a secure return to investments within one or two years, and the best values after eight to nine years, but at a high water price.

The production of sugarcane has advantages for smallholders such as a guaranteed market and therefore a secured return of the loans to the bank and technical, managerial and marketing support provided by the Sugar Mill.

South Africa, Mozambique and Swaziland are therefore increasing sugarcane production in the Incomati river basin as part of their social development strategy, arguing that once a farmer makes a success of cane farming, it will enable him or her to start diversifying towards higher value crops such as mangoes, bananas and citrus. Water, however, remains the limiting production factor.

South Africa

The TSB-experts in Transvaal consider the best option for sugarcane production to increase the efficiency of water and electricity use. Avoiding over-irrigation in the wintertime will help a great deal. A combined approach to careful monitoring of the water levels, fertilisers and pesticides enables TSB to stay in business even without former subsidies and fixed prices as part of government protection.

The improved methods include a daily measuring of water levels at the sugar cane roots, computerized monitoring of the water levels and irrigating the exact amount of water needed, at the time needed, with a drip irrigation system at the roots. The installation costs of such an improved irrigation scheme is calculated at 14,000 Rd/ha and needs a skilled computer data analysis.

Mozambique

The sugar industry in Mozambique has peaked in 1972 with a production of 325,051 tonnes, the production after this has been reduced to 13,224 tonnes in 1992, and the sector was at 5 % of its capacity with 23,000 tonnes in 1997. The sector suffers from outdated technologies, war damage and improper utilisation of water, raw materials and chemicals in production. After a long discussion as to whether sugar production could be the right answer to Mozambique's problem, the government decided to support the sugar industry with an import tax protection of almost 20 %. A rehabilitation process with an investment program of 100 million US dollars started in 1998. Regional sugarcane producers such as Tongaat-Hulett and Illovo bought major shares in Xinavane and Maragra Sugar mills and support the workforce with training and management. In the Incomati river basin, the sugar production offers 7,623 jobs to the workers of Maragra and Xinavane. Many more Mozambicans work legally or illegally at sugarcane plantations in Swaziland and South Africa.

In the lowlands of the Incomati, water becomes scarce in the dry season, just when the sugar cane needs most irrigation. The Corrumane Dam was built to keep up the flow in the river to support the sugarcane plantations. It is to be seen whether the water flow will be sufficient when the sugar plantations and the mills are working at their full capacity. For the year 2005, INA calculates that, after the recovering from the floods of early 2000, Maragra will produce 82,900 tonnes and Xinavane 125,000 tonnes per year. The Mozambican domestic demand for sugar is limited to 7 kg/p/year, which is very low, even for the SADC average of 19 kg/p/year.

Short term option: 2000-2010

The water efficiency can be improved by better scheduling and changing all methods to drip irrigation. Investments needed for this improvement can be estimated at approximately US$ 100 million. The benefits will be an estimated 50 percent increased efficiency in water use.

Long term option: 2010-2050

Changing land use patterns: Irrigation water from the Incomati River can better be used for high value and less thirsty crops such as citrus and vegetables. Improved access and land availability in the northern part of Mozambique, the southern part of Tanzania, Angola and Zambia could provide long term possibilities for adjusting land use to the available water in the SADC-region.

Integrated water management strategies for the Rhine and Meuse basins in a changing environment

M.B.A. van Asselt[1], H. Middelkoop[2], S.A. van 't Klooster[1], W.P.A. van Deursen[3], M. Haasnoot[4,5], J.C.J. Kwadijk[5], H. Buiteveld[4], G.P. Können[6], P. Valkering[1], and J. Rotmans[1]

[1]International Centre for Integrative Studies (ICIS), University of Maastricht,
P.O. Box 616, 6200 MD Maastricht.
[2]Department of Physical Geography, Faculty of Geographical Sciences,
Utrecht University, P.O. Box 80.115, 3508 TC Utrecht.
[3]Carthago Consultancy Rotterdam, Oostzeedijk beneden 23A,
3062 VK Rotterdam.
[4]National Institute for Inland Water Management and Waste Water Treatment (RIZA),
P.O. Box 9072, 6800 ED Arnhem.
[5]WL | Delft Hydraulics, P.O. Box 177, 2600 MH Delft.
[6]Royal Netherlands Meteorological Institute (KNMI), P.O. Box 201, 3730 AE De Bilt.

Abstract

Water management of the Rhine and Meuse is surrounded by major uncertainties. The central question is then: given the uncertainties, what is the best water management strategy? This raises the need for integrated scenarios that consider possible futures in a coherent and consistent way. In the present NRP project a scenario study was carried out in which physical modelling has been combined with socio-cultural theory. Existing climate, land use and socio-economic scenarios, as well as water management strategies have been structured using the Perspectives method. This resulted in integrated scenarios for water management, each representing a different view on the future, together with the according water management style. These were put in a scenario matrix with combinations of world views and management styles, both where these match and mis-match. Using a suite of existing modelling tools the implications of each scenario for the water systems were evaluated. Finally, a comparison of different water management styles under different possible futures was made, showing the risk, cost and benefits of different strategies.

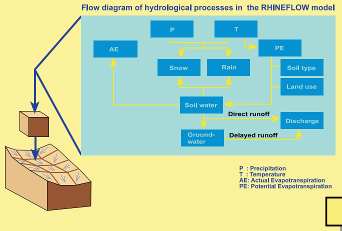
The problem

Water management for the Rhine and Meuse faces large uncertainties.
→Given the uncertainties, which water management strategy should be followed?
→How can we define integrated scenarios for future water management?
→How can we evaluate these scenarios?

Physical concepts

Hydrological models:
hydrological implications of changes in land use, climate and water management measures

Water balance models for the Rhine and Meuse basins:
- RHINEFLOW
- MEUSEFLOW

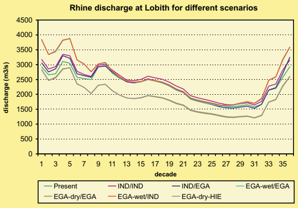

Flow diagram of hydrological processes in the RHINEFLOW model

P : Precipitation
T : Temperature
AE: Actual Evapotranspiration
PE: Potential Evapotranspiration

Water balance model for the IJsselmeer:
- BEKKEN-WIN

National ground water models:
- NAGROM-MONA-MOZART-DM

Impact models and DSS:
implications of hydrological changes for water-related functions: safety, nature, agriculture, recreation, navigation, landscape values


Rhine discharge at Lobith for different scenarios

The approach

- Combining Cultural perspectives and Physical modelling of water systems
- Development of Perspective-based scenarios
- Evaluation of water management strategies

Implementation

1. Development of scenarios

a. Inventory of knowledge sources and estimates of the future
- Literature review
- Interviews
- Expert-meeting
- Stakeholder workshop

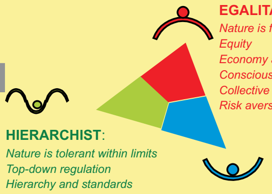
b. Analysis and structuring using Perspectives resulting in
- Water-specific world views and management styles
- Perspective-based integrated scenarios with
  - climate change
  - land use changes
  - socio-economic developments
  - water management measures
- Story lines of future developments

2. Implementation in models through
- Schematisation
- Input variables
- Model parameters

3. Model runs - scenario evaluation on
- Hydrological changes
- Implications for water-related functions
- Cost / benefits
- Flexibility
- Resilience

Socio-cultural concepts

Cultural Perspectives under uncertainty:
- different views on the world lead to
- different management styles



EGALITARIAN:
Nature is fragile
Equity
Economy as means
Conscious consumption
Collective interest
Risk aversive

HIERARCHIST:
Nature is tolerant within limits
Top-down regulation
Hierarchy and standards
Risk avoiding
Authority through expertise and experience

INDIVIDUALIST:
Nature is robust
Economic growth
Anti-regulation
Market-oriented
Adaptation
Risk = challenge

A Perspective combines:
- World view: description of how the world functions
- Management style: set of preferred policy options

Combinations of world views and management types make up a matrix of scenarios

World view

Management style	Egalitarian	Hierarchist	Individualist
Egalitarian	utopia	*dystopia*	*dystopia*
Hierarchist	*dystopia*	utopia	*dystopia*
Individualist	*dystopia*	*dystopia*	utopia

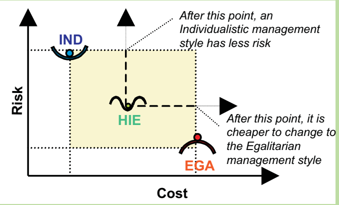
Perspective-based water management styles

EGALITARIAN	HIERARCHIST	INDIVIDUALIST
Water guides	Water follows	Water follows
Sustainability	Win-win strategy	Cost-benefit analysis
Resilience	Control, standards	Water = economic good
Prevention	Top-down regulation	Anti-regulation

Evaluation of Perspective-based management styles

Comparison of management styles
- Analysis of Utopias and Dystopias for each style
- Implications for functions
- Cost / Benefits
- Risks
- Robustness

Recommendations for water management strategies for the Rhine and Meuse basins



After this point, an Individualistic management style has less risk

After this point, it is cheaper to change to the Egalitarian management style

Conclusions

Water management strategies can be described in terms of three Cultural Perspectives:

Egalitarian management style:
- safe, resilient water systems
- expensive and space demanding
- low economic gains
- most robust

Hierarchist management style:
- win-win situations may become loss-loss
- (too) long planning and implementation time
- expensive
- less robust

Individualist management style:
- high risk in case of dystopia
- high economic gains
- low resilience, least robust

None of the strategies is superior in all circumstances.

Current water management in the Netherlands has Hierarchist characteristics.

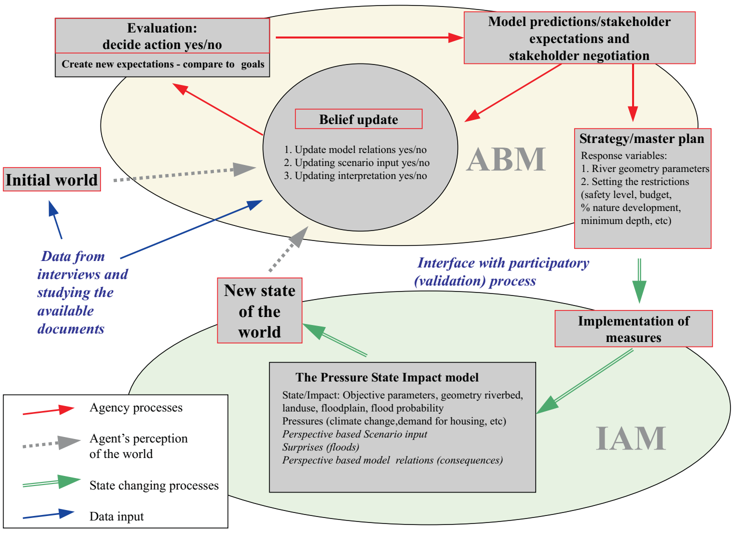
Combining Social and Physical sciences provides a broader view on scenario studies.

From stakeholders to agents - An analysis of social behaviour of actors within a negotiation process upon a water management project

J. Krywkow[1,2], P. Valkering[1], A. van der Veen[2] and J. Rotmans[1]
[1]International Centre for Integrative Studies (ICIS), University of Maastricht,
P.O. Box 616, 6200 MD Maastricht.
[2]Department for Civil Engineering and Management, University of Twente,
P.O. Box 217, 7500 AE Enschede.

Introduction

The European project FIRMA (Freshwater Integrated Resource Management with Agents) aims to improve water resource planning by combining agent-based modelling* and integrated assessment to describe physical, hydrological, social and economic aspects of water resource management in an integrated way. A new type of IA models will be developed in which stakeholders, like planners, decision makers, consumers, suppliers and nature organisation are explicitly represented using agent-based, social simulation techniques. An innovative method used by the FIRMA project is the incorporation of stakeholder participation for model development to improve the quality of the model, to raise the interest of stakeholders and to increase their confidence in the model results (Downing et al., 2000).



The case study

In this paper we describe the Maaswerken project as one specific case study of the FIRMA project. Maaswerken is one of the largest water-related infrastructure projects in the Netherlands. The planning of the two sub-projects 'Grensmaas' and 'Zandmaas/Maasroute' is a long-term and complex procedure involving three main issues: flood control, improvement of the navigation route and nature development. This will be achieved by a combination of deepening and widening of the summer bed, lowering of the floodplains and side gullies, altering embankments, and upgrading of the navigation infrastructure. A successful solution can only be expected by applying an integrated approach that also factors in the side effects of the planned measures plus the impacts on affected people.

Methodology

The integrated approach mentioned above involves a (physical) integrated assessment model (IAM), an agent-based model (ABM), the involvement of stakeholders in the modelling process and a conceptual framework to couple the two models.

The Participatory Integrated Assessment comprises four main tasks within the FIRMA approach:

1. eliciting mental models of organisations and institutions, collecting additional information as input for the agent-based model, and problem analysis (interviews and dialog methods),
2. communicating and developing the model with the stakeholders (interviews and dialog methods),
3. validating the model structure and simulation results with the stakeholders (focus groups),
4. identifying system problems and learning new strategies for system management (focus groups and interviews).

An analysis of the most relevant actors and their interaction within the target system is required to create an interface between the participative process and the agent-based model. In the case of the Maaswerken project the ensemble of actors consists, primarily, of a number of governmental and non-governmental institutions.

The agent-based model applied here is based upon a complex or cognitive agent approach developed by social psychologists. The internal structure of a cognitive agent consists in principle of goals and beliefs. Goals are states of the world desired by a particular agent. This is an assumption for agent activities, whereas beliefs represent particular perspectives or world views of an agent. The cognitive agent architecture is documented in Conte and Castelfranchi (1995). The implementation of agent attributes into a computer program can be achieved by assigning rules to each agent by help of declarative statements. This may be conditional expressions that can be written in declarative programming languages like SDML (Strictly Declarative Macro Language), MIMOSE, PartNet or others. The inter-agent structure is a negotiation process about planning strategies and policy measures including side effects.

The Integrated Assessment model describes the relevant processes related to the management of the Meuse in Limburg. This computer model will include simple hydrological modules to calculate the effects of various river engineering alternatives of the Maaswerken project on the state of the water balance in Limburg. Impact modules will relate these results to consequences for river functions such as safety, shipping and nature. Input to the model will be derived from a set of integrated, perspective-based scenarios that sketch possible changes in climate and socio-economic boundary conditions in a consistent way.
The conceptual framework of this approach, generally, consists of a coupled agent-based model and an (physical) integrated assessment model. The participatory process will be interlinked with the model during the model design phase as well as the model validation phase. In other words the communication between stakeholders and modellers is an essential part of the entire modelling process.
The environment or world as it is perceived by each agent is incorporated within their belief system. The agent may be seen as an independent sub program capable of reflecting on own goals and beliefs by comparing them to the changing environment. A ‘belief update’ can be performed that may lead to a change in goals as well as a change in expectations (how the world might look after implementing a particular strategy). An update of beliefs can be implemented by a changing set of assumptions within various agents. The beliefs can be altered during the process of perceiving a changing world as well as processing information broadcast by other agents. Alterations will be triggered by reaching threshold values like the height of dykes, the area of nature development, the amount of gravel to be extracted, etc.
The implementation of a strategy or measures can be seen as the ‘response’ part of the pressure-state-response-impact (PSRI) concept of the IA model, and initiates a state changing process within a simulation with a time of about ten years. The PSRI model is able to implement ‘objective’ parameters like river bed geometry, land use change or flood probability as well as external and internal (in relation to the catchment in Limburg) pressures like climate change or demand for housing, and surprises (e.g. floods).

The changing (model) world as well as the changing behaviour of other agents is permanently perceived by each agent, and may lead to belief updates and/or (re)actions according to the agents’ endowment. This way we are able to analyse two types of processes:

1. Agent-environment interaction (reacting on changing river bed geometry, nature development, side effects, events like floods, pollution, etc.).
2. Agent-agent interaction (communication about planned measures, negotiation, coalition forming and others).

Conclusion

The aim of this approach is not simply to describe, but, additionally, to explain reasons for particular actions and their consequences on the environment as well as on other actors within a specific target system like a river basin. The combination of models as well as the simulation setup enables modellers and planners to deal with a complex setting of interrelated issues as well as the consequences of human activities in an interactive, consistent and dynamic way. This approach is a step forward to a decision support system (DSS) that enables planners to model not only the physical processes of a particular system, but also incorporate social dynamics from the early stages of planning activities. Moreover, it can improve the communication between planners, decision makers and stakeholders by making the relationship between physical and social processes explicit.

References

Conte, R., and C. Castelfranchi, 1995. Cognitive and social action. UCL Press limited. London. 215 p.

Downing, T. E., S. Moss, and C. Pahl-Wostl, 2000. Understanding Climate policy Using participatory Agent-based Social Simulation. In: Moss, S. and P. Davidsson (Eds.), 2001. Multi-agent-based Simulation: Second international Workshop, MABS 2000. Boston, MA, USA, July. Revised and Additional Papers. Springer 2001. In Lecture notes in computer science, Vol. 1979: Lecture notes in Artificial Intelligence.

Gilbert, N., 1999. The simulation of social processes. *SMAGET conference*, Clermont Ferrand, France.

---

[*] An agent is a computer program representing an actor (here stakeholder) in an observed target system. Agents may be endowed with capabilities to perceive signals, react, act, making decisions, etc. according to a set of rules applied to an underlying theoretical framework (here social psychology). An agent-based model is a set of autonomous agents capable to interact with each other as well as with the environment. See also Gilbert (1999).

Actor analysis to support decision making for water resources management

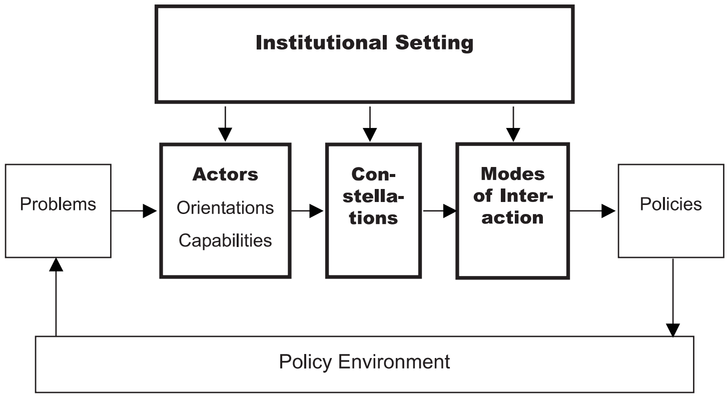
L. Hermans
Faculty of Technology, Policy and Management, Delft University of Technology,
P.O. Box 5015, 2600 GA Delft.
tel. +31-15-2785493.
e-mail: L.M.Hermans@tbm.tudelft.nl

Introduction

Decision making in the field of water resources management is traditionally supported by various types of policy analysis. Different planning tools and models are used, for example to estimate future conditions of water resources systems, and to identify and evaluate policy alternatives. Decision makers, however, operate in a political arena, in which different parties try to influence the course and the outcomes of decision making processes. It is important that the information generated by policy analysts fits the needs of the decision makers and that it addresses the issues that are important in the political arena.

Actor analysis, if adequately combined with more traditional systems analysis, helps in identifying the driving forces and parties related to an issue or problem situation. Such insight is essential for decision makers who need to design appropriate strategies for resolving such problems. Actor analysis investigates the important parties and the issues that they are interested in. It indicates which actors seem to be headed for conflict, along with the issues over which such conflict may arise. This knowledge helps to identify issues that require further analysis as well as possibilities to involve actors in such analysis efforts.

A PhD. research has been started two years ago to explore different approaches to actor analysis, and to investigate how actor analysis is best performed to provide added value to both policy makers and policy analysts.



Source: Scharpf, F.W. (1997) Games Real Actors Play. Actor-Centered Institutionalism in Policy Research. Westview Press, Boulder, Colorado

Interaction oriented focus of actor analysis.

Most analysis for water resources management focuses on the water resources system and its properties, but actor analysis focuses on the interaction processes between actors. Within a certain environment of rules and institutions, different actors form groups that interact with each other in different ways. These interactions will eventually produce policies (Scharpf, 1997).

Social network analysis techniques
Social network analysis

Conflict analysis
Metagame analysis
Hypergame analysis
Graph model for conflict resolution (GMCR)

Transactional analysis
Influence analysis
Linear Systems of Action (LSA)

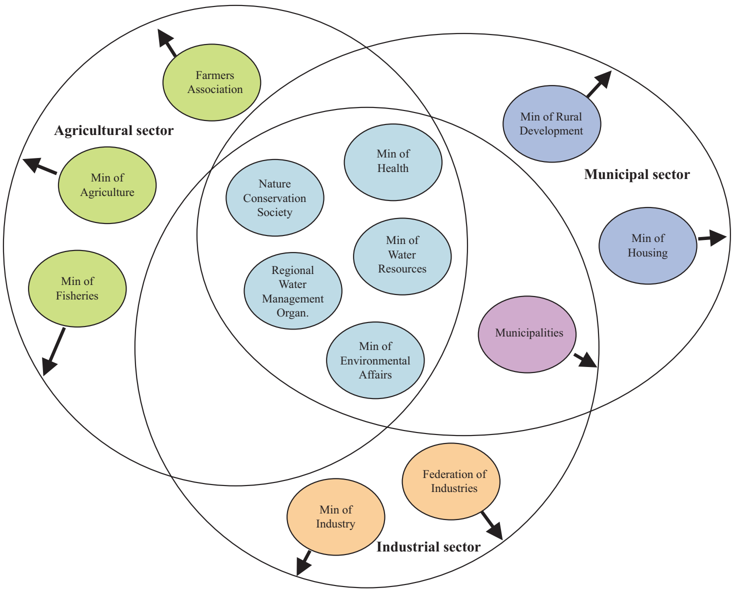
Pluricentric analysis
Configuration analysis
Network or stakeholder analysis

Discourse analysis
Content analysis
Argumentative analysis
Semiotic analysis
Narrative analysis

Cognitive analysis
Q-methodology
Strategic Options Development and Analysis (SODA)
Self-Q interviews
Dynamic Actor Network Analysis (DANA)

Methods for actor analysis.

There are different methods for actor analysis. They can be categorized according to their focus. The selection of a proper method depends on the characteristics of the situation.



Actors and policy arenas.

The actors that play a role in water management are part of one or more different sectoral policy arenas. The different interests of actors may cause conflict, either within one sector or across sectors.

"Water scarcity requires a reduction of water use in sectors such as agriculture"

"Population growth requires economic development and an increase in agricultural production"

"Agriculture should focus on low water using cash crops, creating more value per crop. These crops can then be traded on the international market"

"Agriculture should produce enough foodstuffs to accommodate the needs of the growing population. Dependence on the international market makes the country vulnerable to foreign (uncontrollable) developments"

Perceptions of actors.

Not only the interests between actors may differ, but also their perception of problems and of possible solutions. Certain actors will approach the situation from a water management perspective, while others perceive it to be primarily an agricultural or an economic problem. An analysis of different perceptions may indicate where communication and additional policy analysis could focus on, and which conflicts will be hard to resolve by simply providing more information to the actors.

References

Scharpf, F.W., 1997. Games Real Actors Play. Actor-Centered Institutionalism in Policy Research, Westview Press, Boulder, Colorado.

Dealing with scale issues in river basin management: a theoretical concept paper

By S. Karstens[1,2] and W. Thissen[1]
[1]Faculty of Technology, Policy and Management, Delft University of Technology,
Jaffalaan 5, 2628 BX Delft.
[2]Geo Delft, P.O. Box 69, 2600AB Delft.

Research focus

In this PhD research principles will be developed for a responsible identification and handling of scale issues in river basin management problems in a policy analysis process, in order to prevent or mitigate policy failure due to scale problems.

Introduction

Management of river basins necessitates consideration of both the human and the physical system. Management issues vary from broad (inter)national for strategic issues to local detail for operational issues. Within the river basin functions a variety of spatial and temporal scales can be distinguished. River basins influence, and are influenced by, people at a variety of social scales. The challenge ahead is to arrive at meaningful integration, aggregation and disaggregation of these complex issues, while in the meantime keeping things as simple as possible to be able to manage river basins effectively. Although nowadays the importance of scale in human and physical system interactions is stressed and investigations regarding how to effectively handle scale issues are executed, few strong generalizable propositions have emerged to date.

Scale issues: what is the problem?

It is needed to take cognisance of scale issues in time and space. This becomes even more emerging after the introduction of the European Framework Directive Water. Scale issues are getting more and more attention in river basin management nowadays, but there appears to be little clarity. Much of the lack in progress in resolving scale issues can be attributed to confusing terminology and inconsistent use of scale related concepts (Jewitt, 1998). The problem of scale seems to be recognized by a lot of experts from various disciplines, but perspectives appear to be very different depending mainly on the discipline.

With the growing need for interdisciplinary approaches towards problems, there is also a growing need to address scale issues adequately. In this paper a first attempt will be made to define scale issues and notions that are related to scale issues and place them into the context of river basin management.

Scale issues in different disciplines

Within the physical sciences scale issues have been recognized since some time. A long tradition of attention to space and time dimensions in geography and ecology has produced a relatively sophisticated view of the difficulties involved. In economics also a lot of attention has been paid to scale related matters. In the social sciences the importance of scale issues is increasingly recognized. Within interdisciplinary problems, like river basin management, scale issues form a challenging relatively new area of concern.

Scale issues in river basin management- an example

In case of a water shortage situation along a river a conglomerate of coupled physical processes and choice/ policy processes is involved. Different actors play at different scales, trade-offs will have to be made between actors and functions that operate at different scales and arena's.

At basin scale the main question is how to distribute (as far as possible) overall shortage among nations. At national scale the same question plays a role, but now for regions within the nation, and, partly, functions (e.g. electricity production, shipping) which manifest themselves at national scale). At regional and local scale the direct impacts for the stakeholders (e.g. farmers) become visible and additional trade-offs have to be made regarding priorities in distribution. How can this be handled and coordinated efficiently with respect to modeling, process design and their interaction?

Definitions of scale issues

Because in literature very few definitions on scale issues can be found, I tried to define some terms that are related to scale issues:

Scale = the characteristic spatial, temporal and/or quantitative dimension used to measure, observe and study objects and processes,
Scale issues = all critical choices regarding to scale that are made or (should) have to be made,
Scaling issues = problems associated with the transfer of information across scales.

It is important to realize that the choice of a scale is always a trade-off; there is no perfect scale. When working on a large scale few variables can be taken

into account and a fairly aggregated level will have to be used. An advantage is that the context of the problem is clear.
When working on a small scale however a very detailed analysis can be performed taking into account many variables. The context however is often lost.

System boundaries & cross-scale interactions

Two important notions considered to be important when dealing with scale issues, are the choice of system boundaries and the handling of cross-scale interactions.
When a problem is analysed, it is important to define the boundaries of the system to be studied: what do you consider to be part of the problem and what not? Two important goals of the determination of system boundaries are:

1. To make the problem manageable (place, time, institutions, actors, interactions, factors)
2. To make the problem solvable.

Here also a trade-off has to be made:
- A fundamental and broad approach can be chosen by enlarging the system boundaries. This broadens the scope of solution directions but also involves more complexity.
- Initial problem formulations are often too narrowly focussed and oriented to one specific solution type, leading to the ignorance of more fundamental approaches that may provide far better solutions (Thissen, 2000).

If we look at the Rhine flooding problems in the Netherlands and only take into account solution directions in the Netherlands, you ignore possible (maybe more effective) solutions in Germany.

Cross-scale interactions occur when processes at one level of scale influence processes at other levels. Many cases of river basin management are cross-scale in both time and place. As such, management problems have to be tackled simultaneously at several levels.

Climate change alters river discharge which alters local inundations rates; so processes on a global scale can cause effects on a local scale. Conversely, many small processes (e.g. individual car usage) at local scale can cause problems that manifest themselves at global scale.

Scale issues in the policy analysis process

Scale problems arise when scale issues are not handled adequately, i.e. the policy analysis problem is not studied in the suitable (combination of) dimensions (physically [space and time], disciplinary, governmental or actors). This could possibly lead to policy failure in the end. In the table an overview of scale issues in the policy analysis process is given.

A few examples of problems with scales in the policy analysis process are:
- arbitrary or even neglected definition of scales
- unconscious selection of a scale of analysis
- neglecting the existence of cross-scale linkages
- unconscious alternating between scales of analysis
- lack of matching in scales.

Literature

Jewitt, G.P.W., 1998. Resolution of scale issues in an integrated modelling system for the rivers of the Kruger National Park. Ph.D. dissertation. Dept. of Civil Engineering, University of Stellenbosch.
Thissen, W.A.H., 2000. Issue formulation in a multi-actor context: a five step approach, IEEE International Conference on systems, man and cybernetics.

Table: overview of scale issues in the policy analysis process.

POLICY ANALYSIS PROCESS	SCALE ISSUES
Problem identification, analysis and formulation	· Analysis of cross-scale interactions regarding to processes, causes and consequences · Setting boundaries in space and time · Choosing a level of aggregation · Selection of actors to be advised · Determination of constraints following from a larger scale
Identifying, designing and screening the alternatives	· Select scale for problem solution finding · Modeling effects and disturbances of the system (also at higher and lower scale)
Comparing and ranking alternatives using evaluation criteria	· Selection of scale of valuation of alternatives
Advise for policy action	

RBA Centre
Centre for Research on River Basin Administration, Analysis and Management, Delft University of Technology

E. van Beek, R. Brouwer, E. Mostert and W. Thissen
RBA Centre, Delft University of Technology, Stevinweg 1, 2628 CN Delft.
tel. +31 15 278 4773, fax +31 15 278 7799,
e-mail RBA.Centre@CT.TUDelft.NL,
http://www.ct.tudelft.nl/rba/rba.htm

River basin management

River basins fulfil essential functions. They sustain natural ecosystems, are the paramount source of water and fulfil many non-consumptive uses. Yet many river basins are heavily polluted or overexploited, and vulnerability from extreme events is increasing. To solve these problems, an integrated approach is called for, including:

- **A basin-wide perspective**
- **Attention for surface and groundwater and water quantity and quality**
- **Attention for the relations between land and water resources**
- **Integration of (1) natural limitations, (2) social and economic demands, and (3) legal, political and administrative processes**
- **Multi-disciplinary co-operation**

Scope

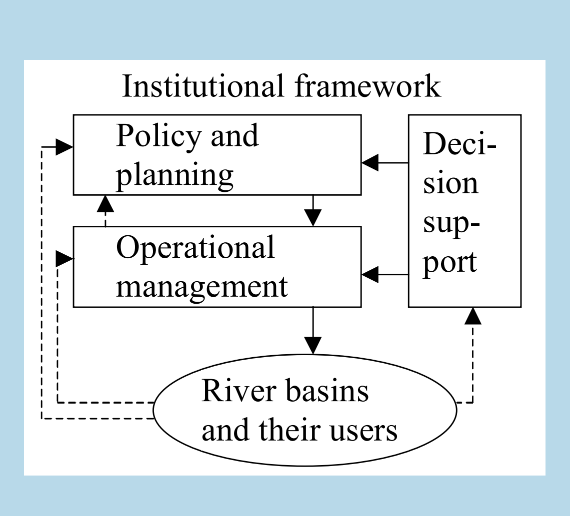
In response to this challenge, the Delft University of Technology has established the RBA Centre in 1989. Its main objective is to serve as an academic centre of excellence for research on integrated river basin management. It tries to accomplish this objective by:

- stimulating and facilitating joint research at Delft University
- promoting the joint capabilities of the participants
- seeking co-operation with other institutions in The Netherlands and abroad.

Expertise

The expertise represented in the RBA Centre includes:

- hydrology
- design, operation and economics of water infrastructure
- ecology
- modelling
- policy analysis and planning
- policy processes and interactive decision-making
- legal and institutional aspects
- financing
- EIA .



Research

The research of the RBA Centre is mostly multidisciplinary and international and includes fundamental as well as strategic and applied research. Ongoing and recently completed projects include:

- Eurowater project and Water 21 project: research on sustainable water management in Europe (European Commission, DG XII)
- Scheldt project: three PhD projects on the management of the Scheldt basin (international co-operation, policy analysis, sediment balance; Dutch Water Management Agency)
- Research on the consequences for the Netherlands of the EU Framework Directive Water (Dutch Water Management Agency)
- Supporting the Dutch government's preparations of the Ministerial Conference (Dutch Ministry of Housing, Spatial Planning and the Environment)
- Development of a decision support system for water allocation of the international Meuse river (TU Delft research funds)
- Development of guidelines on public participation in water management (UNECE-UNEP)
- Integrated management of the Yellow river in China, focusing on water scarcity (Dutch-Chinese co-operation)
- Preparation of parts of the Toolbox Integrated Water Management of the Global Water Partnership (GWP and NWP)
- Methods of stakeholder analysis for policy analysis for water management (PhD research)
- Problems of scale in policy analysis for water management (PhD research, DIOC water)
- Making the concept resilience for flood protection operational by means of a "resilience-index" and application of this index to a number of spatial development alternatives (together with Delft Hydraulics)
- PCCP project: Why in some international basins and aquifers conflicts develop, and in others co-operation? (UNESCO)
- Determination of flow requirements to maintain socio-economic and environmental instream functions (together with Delft Hydraulics).

ECRR (European Centre for River Restoration) and the link with NCR

The Dutch Synergism for Rivers

M.J.R Cals[1] and U. Menke[2]

[1]Cals Consultancy, Biezenkuilen 76, 5502 PE Veldhoven.

e-mail: m.cals@hetnet.nl

[2] National Institute for Inland Water Management and Waste Water Treatment (RIZA),

P.O.Box 17, 8200 AA Lelystad.

e-mail: u.menke@riza.rws.minvenw.nl

Introduction

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

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

Vision

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

Measures of success

- web site hits
- successful matches (co-operation, capacity building)
- member feedback (inquiry, workshop discussions)
- practitioners' contributions to newsletters
- number and quality of conferences, meetings, workshops etc.

ECRR and the Water Framework Directive (WFD)

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

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

ECRR Strategy

- ECRR will facilitate access to any type of practitioners of the network through a web based matching service to allow and encourage the sharing of experience on river restoration and building of ideas.
- ECRR will reinforce the development of this learning community through the organisation of conferences, study tours, training courses, workshops etc. and the delivery of newsletters.
- ECRR will facilitate access to information on research, planning, implementation and monitoring on river restoration through the development of a website.
- ECRR will facilitate establishment of national networks on river restoration.
- ECRR will poll the users to identify how the network can be improved.

Welcome to the Home Page of the European Centre for River Restoration (ECRR).

ECRR foster communication between people working with river restoration in Europe.

ECRR supports the development of river restoration as an integral part of sustainable water management throughout Europe ensuring that projects will be more cost effective, more likely to succeed, and will encompass multifunctional objectives. encourages the application of river restoration technolog routine management activities to promote sustainable a economic 'use' of rivers.

ECRR is a non-profit organisation.

If you are interested in participating, please fill in the en form.

Note: To read the pdf-files you need Acrobat Reader ver

Download for free by clicking the icon:

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

With the aim to enhance sustainable integrated water management, based upon river basin plans, in all European countries, capacity building and exchange of information should occur on all levels. ECRR perfectly suits the key elements of the WFD and its implementation strategy. ECRR wants to play an important role in networking and facilitating the exchange of experiences and best practices of integrated river management projects in Europe. ECRR focuses on scientific, technical and practical questions related to the WFD, not institutional aspects.

Organisational structure

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

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

A secretariat elected by the management board will represent ECRR externally and function as the contact centre.

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

ECRR funding

The operational development of ECRR requires external funding. Support from EU LIFE and COST programmes have been sought.

Practitioners should seek national funding for their own internal activities as the ECRR cannot provide grants or fund them.

ECRR and the link with NCR

The Netherlands Centre for River Studies (NCR) started more or less in the same period as ECRR. NCR is cooperation between the major developers and users of expertise in the Netherlands in the area of rivers. The similarity in objectives of NCR and ECRR is clear and both networks focus on:

- transboundary river systems
- integrated river management
- river basin approach

Of course, there are some differences. NCR is a research oriented cooperation between scientific institutes. ECRR covers a broad field of management, policy, research and monitoring of river restoration. NCR's networking and educational function is concentrated on academic level to meet the national and international societal requirements. ECRR enhances the exchange of information regarding concepts, practices and techniques between practitioners on different levels. Last but not least, NCR fulfils a platform function in the Netherlands and adjacent countries while ECRR is a networking platform on Pan European scale.

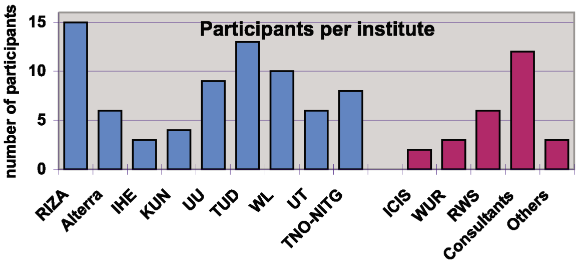
The combination of similarities and differences make NCR and ECRR highly complementary. NCR will function as focus point and intermediate for the scientific part of ECRR's network in the Netherlands. This will facilitate the exchange of information from the Netherlands to European level and vice versa. In this way NCR and ECRR support each other and create a win-win situation: the Dutch synergism for integrated river basin management.

NCR days 2001; Looking back and ahead

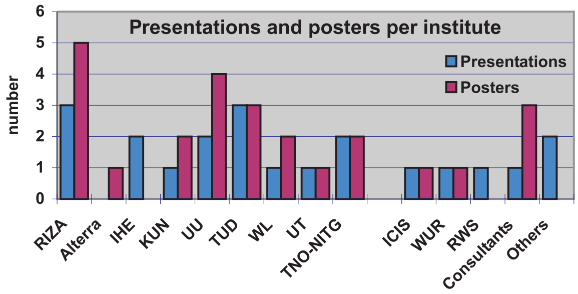
A.G. van Os, programming secretary NCR,
e-mail: ncr@wldelft.nl

These NCR days, organised for the second time since the founding of NCR in 1998 were, if possible, even a greater success than the days of 2000. The organisers clearly took notice of the remarks made during the evaluation in 2000: besides presentations they managed to get quite a lot of posters and they scheduled ample time for these postersessions and bi- or multilateral discussions.
The organisers of the NCR days, RIZA with the co-operation of Bureau Routine, therefore may be complemented for performing an excellent job.

The statistics of the 2001 days are very satisfying: 100 particpants (in 2000 we had 85), distributed evenly over the NCR partners and other institutes and consultancy agencies.

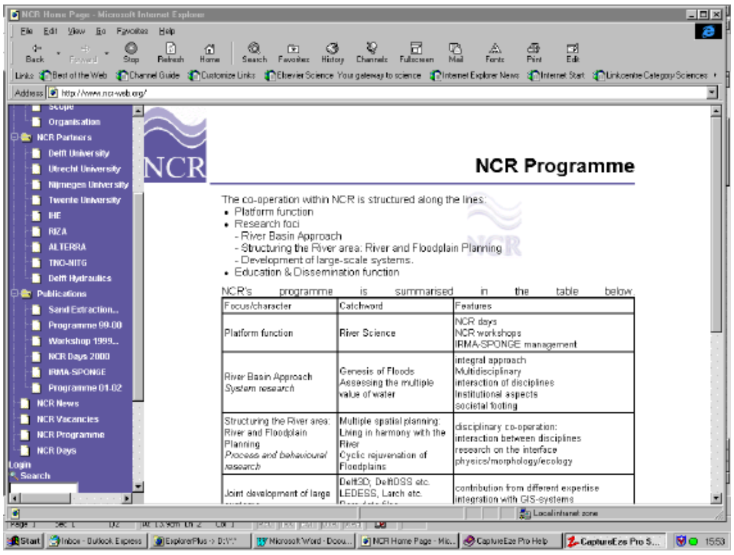


Also the presentations and posters were reasonably distributed over NCR partners and non-NCR participants.
In total 20 oral presentations were given and 25 posters could be seen and discussed. In fact much more presentations were proposed, but the organisers had to limit the amount to approximately 20 to give the participants opportunity for the poster sessions and discussions.



But as we already stated in the preface, NCR is more than NCR days.
At the NCR days in October 2000 a Summary of the NCR Programme was presented for the first time. This booklet (in Dutch) summarises the projects within the NCR programme in a format that enables the reader to see the whole of the project at a glance.
Since then NCR started a series of publications, one of them being the proceedings of the NCR days of 2000 (NCR publication 03-2001), in which to this date eight publications appeared. Their references are given at the end of this publication. They can be obtained for free from the NCR secretariat.

Some of them can be downloaded from the NCR Internet site as well. This is another activity we started last year. The site gives information on NCR and the NCR partners and provides links to Internet sites of



NCR Programme

The co-operation within NCR is structured along the lines:

- Platform function
- Research foci
  - River Basin Approach
  - Structuring the River area: River and Floodplain Planning
  - Development of large-scale systems.
- Education & Dissemination function

NCR's programme is summarised in the table below.

Focus/character	Catchword	Features
Platform function	River Science	NCR days NCR workshops IRMA-SPONGE management
River Basin Approach *System research*	Genesis of Floods Assessing the multiple value of water	integral approach Multidisciplinary interaction of disciplines institutional aspects societal footing
Structuring the River area: River and Floodplain Planning *Process and behavioural research*	Multiple spatial planning: Living in harmony with the River Cyclic rejuvenation of Floodplains	disciplinary co-operation: interaction between disciplines research on the interface physics/morphology/ecology
Joint development of large	Delft3D, DelftDSS etc. LEDESS, Larch etc.	contribution from different expertise integration with GIS-systems

the NCR partners and related organisations. But, most importantly, the site provides a platform to the NCR partners and their individual researchers where they can publish their news, vacancies, interesting links and research results.
The address is: www.ncr-web.org.

In 1999 NCR has been asked to manage a large research umbrella project in the framework of the EU Structure fund IRMA (Interregional Rhine/Meuse Action Programme). In this umbrella project, IRMA-SPONGE, more than 30 research institutes from six European countries (the Netherlands, Germany, France, Belgium, Luxembourg and Switzerland) co-operate to improve the flood forecasting and prevention possibilities in the Rhine and Meuse catchment areas. In 2000 and 2001 this project was in full swing. Many of the chapters of this publication present parts of this project. In June 2000 a conference was organised, another example of the platform function of NCR. The proceedings were published in NCR Publication 04-2001. IRMA-SPONGE will organise a final conference on January 31st and February 1st, 2002. The project will be terminated in March 2002.

NCR Publication 05-2001 is an updated version of the NCR Programme. In total 44 summaries of NCR projects are given.
We made an effort to summarise objectives, methodology and results (expected and achieved) on one page only.
Of course also project-title, project-leader and participating partners were given, along with sources of finance, period of execution and the NCR theme(s) the project is contributing to.

In March 2001 an NCR workshop was organised to identify NCR research themes for the coming years. Three themes have been identified:

- The Genesis of Floods
- Multiple spatial planning: living in harmony with the River
- Cyclic rejuvenation of Floodplains, including dredging spill problems.

Moreover, NCR partners are co-operating on the theme "Assessing the multiple value(s) of water".

Back to the NCR days, to look ahead. The dates for the NCR days of 2002 already have been fixed: they will be held on November 7th and 8th, 2002 in Conference Centre Jonkerbosch, Nijmegen. The University Nijmegen will be our host.

NCR Supervisory Board

December 2001

Prof. dr. E.A. Koster, chairman
Utrecht University
e-mail: E.Koster@geog.uu.nl

A.G. van Os, secretary
programming secretary NCR
e-mail: ad.vanos@wldelft.nl

A.R. van Bennekom
DG Rijkswaterstaat/RIZA
e-mail: a.r.vBennekom@riza.rws.minvenw.nl

Prof. dr. H.J.P. Eijsackers
ALTERRA
e-mail: H.J.P.Eijsackers@Alterra.wag-ur.nl

Prof. dr. P.H. Nienhuis
University Nijmegen
e-mail: nienhuis@sci.kun.nl

Prof. dr. J.D. Nieuwenhuis
Delft University of Technology
e-mail: J.D.Nieuwenhuis@ct.tudelft.nl

Dr. G.S. Rodenhuis
WL | Delft Hydraulics
e-mail: gaele.rodenhuis@wldelft.nl

Dr. H. Speelman
TNO-NITG
e-mail: h.speelman@nitg.tno.nl

Prof. dr. W. van Vierssen
International Institute for Infrastructure and
Environmental Engineering (IHE)
e-mail: wvv@ihe.nl

Prof. dr. C.B. Vreugdenhil
Twente University of Technology
e-mail: C.B.Vreugdenhil@sms.utwente.nl

NCR Programme Committee

December 2001

E.C.L. Marteijn, chairman
DG Rijkswaterstaat/RIZA
e-mail: e.marteijn@riza.rws.minvenw.nl

A.G. van Os, secretary
programming secretary NCR
e-mail: ad.vanos@wldelft.nl

Prof. E. van Beek
Delft University of Technology
e-mail: E.vanBeek@ct.tudelft.nl

Dr. M.J. van Bracht
TNO-NITG
e-mail: m.vanbracht@nitg.tno.nl

K-j. Douben Msc.
International Institute for Infrastructure and
Environmental Engineering (IHE)
e-mail: kjd@ihe.nl

Dr. R. Leuven
University Nijmegen
e-mail: rleuven@scj.kun.nl

Dr. H. Middelkoop
Utrecht University
e-mail: H.Middelkoop@geog.uu.nl.

Dr. J.S. Ribberink
Twente University of Technology
e-mail: J.S.Ribberink@sms.utwente.nl

Dr. C.J. Sloff
WL | Delft Hydraulics
e-mail: Kees.Sloff@Wldelft.nl

Dr. H.P. Wolfert
ALTERRA
e-mail: H.P.Wolfert@alterra.wag-ur.nl

Publications

In this series the following publications were printed:

NCR-publication no:

00-2000 "Delfstoffenwinning als motor voor rivierverruiming; kansen en bedreigingen", editors Prof.dr. A.J.M. Smits and G.W. Geerling (in Dutch; out of stock, but can be downloaded from the NCR Internet site)

01-2000 "NCR Programma, versie 1999 – 2000", editors Dr. R. Leuven and A.G. van Os (in Dutch)

02-2000 "NCR workshop, de weg van maatschappelijke vraag naar onderzoek", editors A.F. Wolters and E.C.L. Marteijn (in Dutch)

03-2000 "NCR dagen 2000, het begin van een nieuwe reeks", editors A.F. Wolters, dr. C.J. Sloff and E.C.L. Marteijn (partly in Dutch)

04-2001 "Umbrella Program IRMA-SPONGE, Background, Scope and Methodology", editors dr. A. Hooijer and A.G. van Os

05-2001 "Summary of NCR Programme, version 2001 – 2002", editor A.G. van Os (also downloadable from the NCR Internet site)

06-2001 "The Netherlands Centre for River Studies, a co-operation of the major developers and users of expertise in the area of rivers", editors A.G. van Os and H. Middelkoop

07-2001 "NCR days 2001, from sediment transport, morphology and ecology to river basin management", editors E. Stouthamer and A.G. van Os

08-2001 "Gelderse Poort; Land van levende rivieren", SOVON (in Dutch)