NCR-days 2003

Dealing with Floods within Constraints

November 6 – 8

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A.G. van Os (eds.)

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Preface

The Netherlands Centre for River studies (NCR) started its activities on October 8th, 1998. So, this autumn of 2003 we celebrated our first lustrum.
From 2000 onwards, NCR organises the so-called NCR-days once a year.

The NCR-days 2000 and 2001 were held in Soesterberg ("Kontakt der Kontinenten") and Wageningen ("De Wageningse Berg"), respectively. The proceedings of these conferences were published in the NCR publication series (NCR publication 03-2001 and 07-2001, respectively). The NCR-days 2002 took place on November 7th and 8th, 2002 in Conference Centre Jonkerbosch (Nijmegen). The proceedings have been published very recently, of course also in the NCR publication series as NCR publication 20-2003.

The NCR-days 2003, of which the publication at hand contains the proceedings, were organised by UNESCO-IHE and Conference Agency Routine on November 6th and 7th, 2003 in Resort Marina Oolderhuuske, Roermond. This resort is situated on a peninsula in the river Meuse. It boasts a number of floating houses in Mediterranean style.

The organising committee took the evaluations of preceding NCR-days seriously, which resulted in a distinct reduction of the amount of presentations in favour of time available for bilateral or multilateral discussions and poster visits. Several participants told us that they appreciated this very much.
Of course this meant that we had to disappoint a number of prospected oral presenters. Fortunately most of them agreed to submit a poster instead. Both presentations and posters are incorporated in these proceedings of the NCR-days 2003.

We would like to thank Huub Savenije and Guy Beaujot of UNESCO-IHE, Tine and Marijn Verheij and Lieke Janssen of the Conference Agency Routine and Jolien Mans of NCR for their help in organising the NCR-days 2003.

We are looking back on a very inspiring conference, an elucidating field trip and fruitful discussions. We hope these proceedings will inspire you to come (again) to the NCR-days 2004, to be organized by ALTERRA.

Klaas-jan Douben,
President of the NCR-days 2003 Organising Committee

Ad van Os,
Programming secretary of NCR

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Abstract

NCR is the abbreviation for the Netherlands Centre for River studies. It is a collaboration of nine major scientific research institutes in The Netherlands, which was established on October 8, 1998.

NCR's goal is to enhance the cooperation between the most important scientific institutes in the field of river related research in The Netherlands by:

- Building a joint in-depth knowledge base on rivers in The Netherlands in order to adequately anticipate on societal needs, both on national as well as international level;
- Strengthening the national and international position of Dutch scientific research and education;
- Establishment of a common research programme.

NCR strives to achieve this goal by:

- Committed cooperation, in which the actual commitment of the participating parties is expressed;
- Offering a platform, which is expressed by the organisation of meetings where knowledge and experiences are exchanged and where parties outside NCR are warmly welcomed.

The committed cooperation and collaboration is based on a programme. This programme was first published in October 2000 and was actualised in August 2001.
The platform function is expressed amongst others by the organisation of the so-called annual NCR-days. The publication at hand contains the proceedings of the NCR-days, organised on November 6-7, 2003.

The proceedings of the NCR-days 2003 are sub-titled “Dealing with Floods within Constraints”. The concept of constraints is widely defined in this context, varying from increasing climate variability to the implementation of tangible technical and organisational measures.

In general, the constraints are defined from a socio-economic point of view (sustainable maintenance and increase of the protection level against flooding). Furthermore the importance of integrated river functions, spatial interests (also on river basin level) and sustainability criteria is increasing within the framework of flood prevention. The complexity and time consumption of decision-making processes are increasing as a result of an intensified public participation and long lasting legislation procedures.

The three different themes of the NCR-days 2003, (i) Flood Management and Defence, (ii) Spatial Development and Land-use, and (iii) Regional Floodplain Management, cover to a large extend the research which is performed in The Netherlands nowadays, regarding safety against flooding. Hydrological, morphological and ecological (riverine planning) problems are clarified with modelling analysis and field survey studies. The progress of strategic policy studies and the development of instruments to enhance perceptions in decision-making processes were presented. Moreover innovative methods for mapping techniques and flood forecasting are not missing, as well as environmental impacts of floods and economical risk analysis.

Samenvatting

NCR staat voor Nederlands Centrum voor Rivierkunde. Het is een samenwerkingsverband dat op 8 oktober 1998 is opgericht door negen wetenschappelijke onderzoekinstituten in Nederland.

Het doel van NCR is het bevorderen van samenwerking tussen de belangrijkste wetenschappelijke instituten op het gebied van rivieronderzoek in Nederland door:

- het opbouwen van een kennisbasis van voldoende breedte en diepte in Nederland omtrent rivieren waardoor adequaat kan worden tegemoet gekomen aan de maatschappelijke behoefte, zowel nationaal als internationaal;
- het versterken van het wetenschappelijke onderwijs en onderzoek aan de Nederlandse universiteiten;
- het vaststellen van een gezamenlijk onderzoekprogramma.

NCR wil dit doel op twee manieren bereiken:

- via gecommitteerde samenwerking; hierin komt het daadwerkelijke commitment van deelnemende partners tot uiting;
- via het bieden van een platform; deze functie uit zich in het organiseren van bijeenkomsten, waarop kennis en ervaringen worden uitgewisseld; andere partijen zijn daarbij van harte welkom.

De gecommitteerde samenwerking geschiedt op basis van een programma. Dit programma is in oktober 2000 voor het eerst in het Nederlands gepubliceerd en geactualiseerd in Augustus 2001.
De platformfunctie komt onder andere tot uiting in het jaarlijks organiseren van de zogenaamde NCR-dagen. Voorliggende publicatie bevat de “proceedings” van de NCR-dagen die gehouden werden op 6 en 7 november 2003.

De proceedings van de NCR-dagen 2003 dragen de subtitel “Dealing with Floods within Constraints”, vrij vertaald “Hoogwaterbescherming binnen strikte randvoorwaarden”. Het begrip randvoorwaarden is in deze hoedanigheid breed gedefinieerd, variërend van toenemende klimaat variabiliteit tot implementatie van concrete technische en organisatorische maatregelen.

De randvoorwaarden worden over het algemeen gedefinieerd vanuit een sociaal-economisch oogpunt (duurzame handhaving en verbetering van het beschermingsniveau). Daarnaast nemen integratie van functies, ruimtelijke belangen (ook op stroomgebied niveau) en duurzaamheidcriteria in toenemende mate een belangrijke plaats in binnen het krachtenveld van hoogwaterbescherming. Besluitvormingsprocessen worden complexer en tijdrovender van aard als gevolg van een intensievere betrokkenheid van de burgerbevolking en langdurige vergunningsprocedures.

De drie verschillende thema’s van de NCR-dagen 2003, (i) Hoogwaterbescherming en beheer, (ii) Ruimtelijke ordening en landgebruik en (iii) Uiterwaard beheer, dekken een groot gedeelte van het hedendaagse onderzoek dat in Nederland wordt uitgevoerd met betrekking tot veiligheid tegen overstroming. Hydrologische, morfologische en ecologische (inrichtings-)vraagstukken worden toegelicht met modelmatige analyses en veldwerk studies. De voortgang van beleidsanalytische studies en de ontwikkeling van instrumentaria ter bevordering van het inzicht in besluitvormingsprocessen zijn gepresenteerd. Daarnaast zijn tevens vernieuwde kartering- en hoogwater voorspellingsmethoden belicht, alsmede milieueffecten van hoogwaters en economische risico analyses.

NCR-days 2003; Introduction

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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, Twente and Wageningen, UNESCO-IHE, ALTERRA, TNO-NITG, RIZA and WL I 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:

- 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.
- Research-orientated and educational co-operation: in which a real commitment of the partners is reflected.

To perform its first 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 ongoing consecutive days scientists present their river studies, in order to maximise the exchange of ideas and experiences 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 fourth time on November 6th and 7th, 2003 in Resort Marina Oolderhuuske in Roermond, the Netherlands.
In the publication at hand the presentations and posters presented are summarized.

The NCR-days of 2003 were, as far as the feed back from the participants indicates so far, a great success. The organisers clearly took notice of the remarks made during the evaluation in 2002: there was ample time for the poster sessions and bi- or multilateral discussions.

The statistics of the 2003 days are very satisfying too: some 105 participants distributed evenly over the NCR partners (apart from ALTERRA) and other institutes and consultancy agencies (Fig. 1). Also the presentations and posters were reasonably distributed over NCR partners and non-NCR participants (Fig. 2).
In total 23 oral presentations were given and 20 posters could be seen and discussed. In fact much more presentations were proposed, but the organisers had to limit the amount to approximately 20 (plus 3 key note presentations) to give the participants opportunity for the poster sessions and discussions.

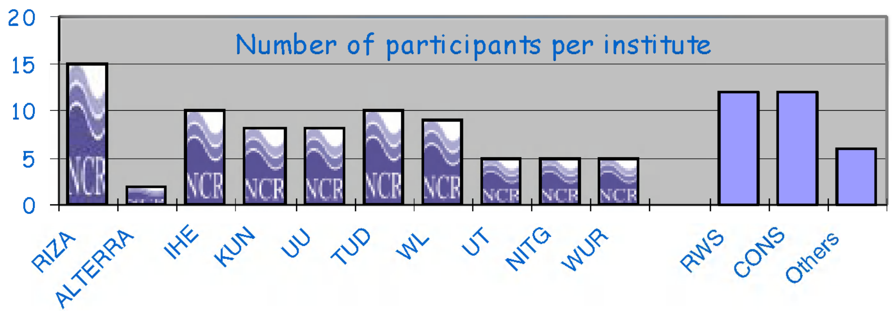

Figure 1. Number of participants per institute.

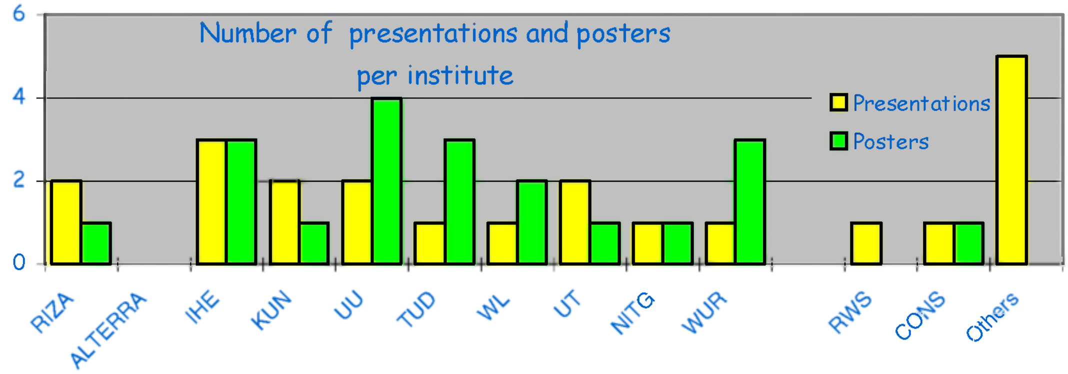

Figure 2. Number of presentations and posters per institute.

To celebrate the first 5-year lustrum anniversary, the NCR Programme Committee decided to establish the NCR-days Presentation and Poster Awards. They both consist of a Certificate and the refunding of the participation costs for the NCR-days.
The participants determined the winners. To that end each participant received four evaluation forms (two for a specific presentation and two for a specific poster) at the registration desk. They were selected at random.

The participants took their 'evaluation job' very seriously. This added considerably to the liveliness of the discussions during the intermissions and poster sessions.
The poster sessions are a very important part of the NCR-days. We use the 'Hyde Park Corner approach' where the primary poster authors are given the opportunity in 'two-minute-talks' to give the participants an appetite to come and see the posters and discuss the content with the authors. This worked again very well.

The winners of the NCR-days Awards were announced at the end of the NCR-days.

The NCR-days Presentation Award 2003 (Fig. 3) was won by Nadine Slootjes for her presentation 'Is the Southern Dutch Delta the Solution to Future Flood Water Levels in the Tidal River Area?' (see page 20).
The NCR-days Poster Award 2003 (Fig. 4) was won by Simone van Schijndel for her poster 'Reduction of siltation in harbours' (see page 74).

Figure 3. NCR-days Presentation Award 2003.

Figure 4. NCR-days Poster Award 2003.

Opening address NCR-days 2003

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Summary
"It's not about accuracy, stupid, it's about uncertainty".

Introduction
The river investment scheme "De Maaswerken" is a comprehensive integrated scheme. Comprehensive given it's size and integrated given its objectives. The objectives cover flood protection, nature development, sand and gravel mining and inland navigation. The trigger to plan for this investment schema is in the past: the flood disasters of 1993 and 1995. As a policy response, the objective set for flood protection is a 1/250 protection level for settlements along the river. The river stretch to be covered is the upstream section of the river Meuse, where the river flows in a valley. This section is located between Maastricht in the south and 's-Hertogenbosch, roughly 200 kilometres. Objectives of other sectors of government: nature development, mining and inland navigation are integrated in one investment plan. The result of plan development is an agreement to line up investments in nature development and mining activities with flood protection. The investments for upgrading the Rhine-Meuse inland navigation channel have been optimised with flood protection. Optimisation is especially gained through combined planning for: (i) the soil removal, soil transportation, upgrading and storage scheme, (ii) the hydraulic and hydrological impact assessment, and (iii) multi purpose land use planning in the river valley.

The comprehensiveness of the investment scheme is given in approximate figures in Table 1. The planning phase of "De Maaswerken" is concluded in 2003 and the implementation phase is under preparation.

Flood protection	Inland navigation
• Public investment € 550 million • Private investment € 600 million • Ready 2015 – 2018 • Embankments • River deepening – widening • Nature development 1600 ha • Sand and gravel mining 60 million m^3	• Public investment € 500 million • Private investment € 0 million • Ready 2015 – 2018 • Lock enlargement, replacement • Channel improvement • Bridges

Table 1. Investment scheme "De Maaswerken".

Role of applied science
The comprehensive investment scheme - "De Maaswerken" - is information intensive, in plan development as well as in the implementation phase. Information from physical sciences (hydraulics, hydrology and morphology) may have some emphasis in the frame of "De Maaswerken" objectives; also other information is of importance. Information from other natural sciences as biology, ecology and social and economic science is playing an important role, in strategy and policy development as well as the implementation. If NCR's objective is formulated as 'to facilitate decision making processes for sustainable development of rivers and river basins' the focus should be broader then physical sciences only.
There are many stakeholders involved in decision-making processes for flood protection plan development as well as for its implementation. These processes are therefore extremely communication sensitive. The plan development phase of "De Maaswerken" took 6 years to conclude and addresses multiple national and local planning schemes and environmental impact assessments. For its implementation many thousands licences will be needed. All decisions are to be built on a sound scientific foundation that can sustain a longer time frame, that can convince stakeholders and at the end of the day the "Raad van State": the national court of appeal.

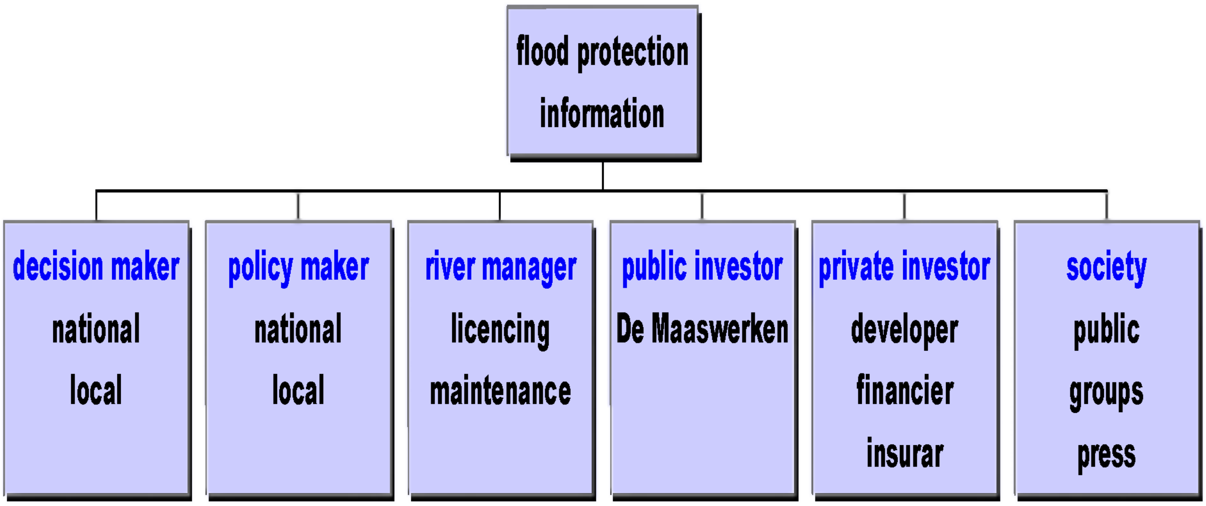

Figure 1. Stakeholders of flood protection information.

The stakeholders for flood protection information are given in Fig. 1 and include decision makers at national and local level, the river manager, public investors, private investors and the public at large.

Experiences in developing and implementing “De Maaswerken” scheme learn that many stakeholders have different perspectives, expectations and interpretations about what applied science can deliver. The notion is that the prediction of extreme events, given a recurrent frequency, is by definition uncertain; however, stakeholders have different expectations, as summarized in Fig. 2.

The decision maker can handle uncertainty, however hates instability, meaning that a decision should sustain his or her period of governance. The policymaker is investing in applied science in the perception that the uncertainty may be reduced. The river manager has to compare development options for land use for licensing reasons and is judging in millimetres rather then centimetres. The public investor, as “De Maaswerken”, has accounted for uncertainty and inaccuracy in plan development and the design of the individual measures. The private investor hates uncertainty and needs absolute figures ‘for high water free’ development. Finally, the public at large is demanding absolute safety and is blaming government for all risks. The aspirations and expectations of stakeholders, as summarized in Fig. 2, demonstrate a communication failure, hindering decision-making processes. These stakeholders are the end users of applied science for flood protection. The notion is that applied science, represented here today by NCR, needs to address this communication failure.

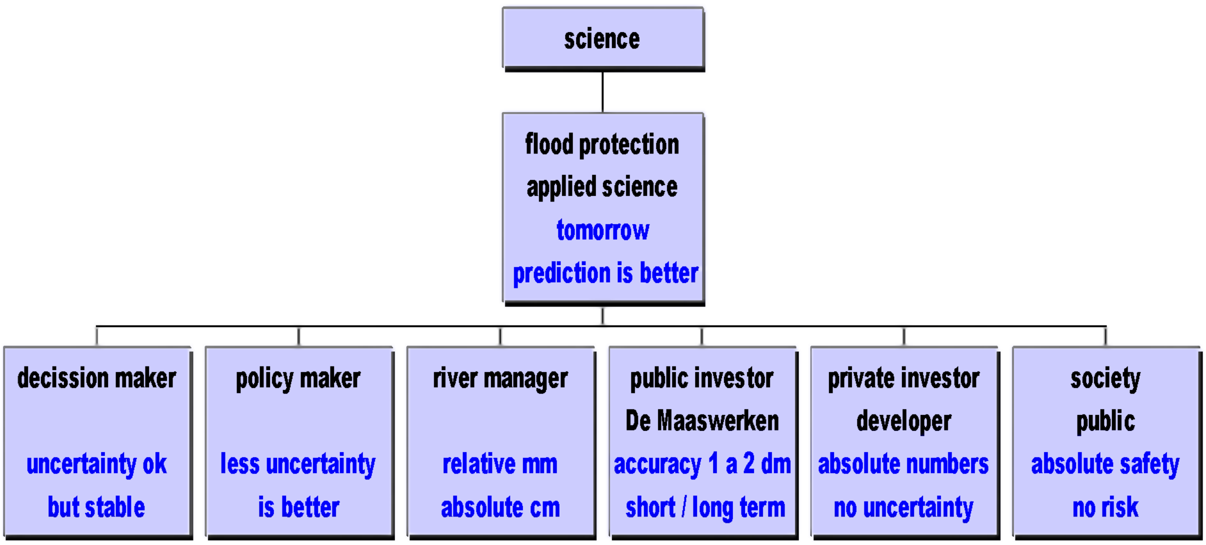

Figure 2. Communication failure with stakeholders in flood protection information.

NCR's challenge

Accuracy of predictions of extreme events is of importance and my plea is not to neglect the issue. However, model inaccuracy is only one of the elements that contribute to uncertainty in the prediction. Other contributors are amongst others: boundary conditions, river behaviour, land use change, climate change, process schematisations and parameterisation. The end result is, by definition, uncertain and uncertainty lies roughly in the order of magnitude of 0.5 to 1 meter for 1/250 to 1/1,250 exceeding frequencies (95% reliability interval).

On the other hand, the perception and expectation of NCR's end users of applied science information is scattered and biased from reality. In fact there is a communication failure amongst stakeholders on flood protection issues. This situation is hindering the sound development of flood protection policies and its implementation. Therefore a shift is needed in NCR's focus from accuracy issues to uncertainty issues. The question how society - NCR's end users - best can deal with uncertainty should be on the foreground.

Consequently, I would recommend the following shift in NCR's programmatic focus:

- Given the communication failure in society concerning: how to deal with uncertainties in flood protection; there is a need for a shift in applied science for river management.
- This shift should move in the direction of information and education of safety and risk concepts - including its uncertainties - in society at large.
- In order to do so, there is a need for better integration of science and information, including economic and social sciences.

In order to do so, there is a need for better integration of science and information, including economic and social sciences.

I would like to congratulate NCR with its lustrum and wish the organization all the best in helping to address societal challenges in the field of flood protection.

Hydrological challenges in the Rhine- and Meuse basins

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Introduction

Society is facing more and more socio-economic problems as result of flood occurrences in Western Europe. One of the world's largest re-insurance companies, Munich Re, describes in its Annual Review of Natural Catastrophe 2002 that floods account for 30% of all loss events and 42% of all fatalities due to natural catastrophes in 2002 (Munich Re, 2003). The total economic loss by floods was estimated at US$ 27 bn in that year. Furthermore, Munich Re (2003) ranked Rotterdam-Amsterdam ("Randstad") metropolis in the hazard index at position 18 of the 50 mega cities in the world. Although this is a first attempt to index hazard risk of metropolis, and in case of the "Randstad" the hazard is based on flood and wind, it shows that there is a major economic and societal risk, partly induced by floods.

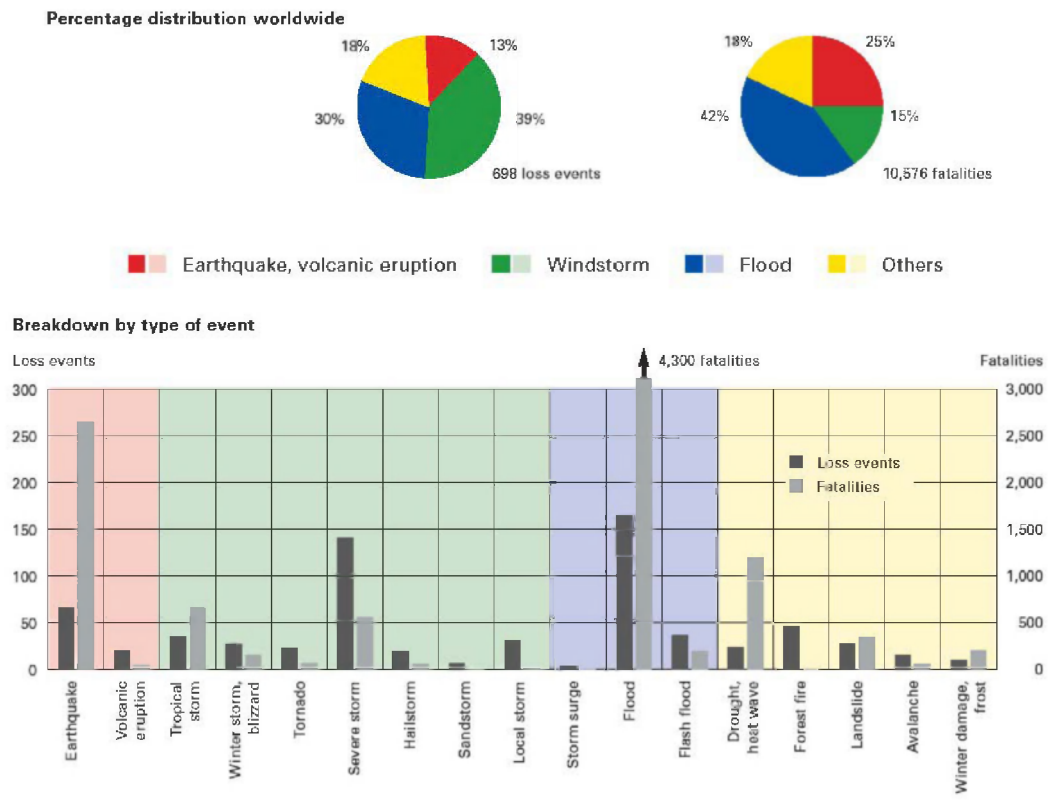

Figure 1. Statistics of natural hazards in 2002, according to the Munich Re (2003).

NCR initiatives: 'Hydrological Triangle' and 'Genesis of Flood' theme

For Dutch water management, knowledge of the hydrological processes in the Rhine and Meuse basins upstream of the Netherlands is essential. Both for flood forecasting as for long term spatial planning. In 2003 at least two reconnaissance of hydrological research were made and published; the Dutch 'foresight committee on Hydrology' (KNAW, 2003) and Geosciences, the future (IUGG, 2003). Both reports were written after several discussions and meetings. Although different from set-up both reports come up with similar scientific bottlenecks and challenges for hydrology: 1) incomplete understanding of the hydrological processes; 2) incomplete theory and data sets

for modelling; 3) data integration and model calibration; 4) scale issues.
NCR has stimulated two initiatives. First of all, a NCR hydrological working group (Hydrological Triangle) was initiated by RIZA in order to stimulate and tune the hydrological research in the Rhine and Meuse basins within the Netherlands. A number of Dutch universities, technical institutes, and governmental institutes participate in this working group. Main aims of the group are to bring together skills, knowledge and manpower of different research groups and stimulate data sharing and collaboration and define those research questions that are both relevant for water management and challenging for scientists.
Furthermore, NCR defined the 'Genesis of Floods' theme, which aims at studying the genesis of floods, or more broadly, discharge generation in upstream areas. The 'Genesis of Flood' theme now resides under the Hydrological Triangle. The overall objective of 'Genesis of Floods' is to improve our understanding of the spatial and temporal controls of discharge generation under changing hydrometeorological behaviour and land use management. The research questions have been grouped into: i) discharge forecasting, ii) determination of design discharge, iii) influence of climate change, and iv) influence of land use change. Some examples will be given of ongoing projects on these topics. Besides some research topics will be listed that have potential for further joint study.

Examples

It is generally accepted that continuation of the engineering approach of controlling the natural river system is not sustainable. More and more it is discussed that river systems should get more room to allow for their natural behaviour. The reasoning is that a river stream can (temporarily) store more water and diminishes flood related problems along a river. Besides storage of discharge in the river system itself, the discussion also focuses on retardation of rainfall in the upstream area of the river catchments. Land use has changed enormously during the last century, especially with urbanisation and an intensification of agriculture and forestry. The overall believe is that these activities result in an accelerated drainage of the upstream areas. The WWF has initiated a discussion on combining nature restoration and water storage with their report 'Mountains of water' (WWF, 2000). This 'enhancing the natural sponginess of river basins' could provide an enjoyable network of rivers, water and nature, solve floods and droughts and stimulate business in tourism and recreation. As the public was told that deforestation, soil drainage, and sealing of surfaces was the cause for the increased flood frequency and magnitude, why should doing the reversed not have the opposite effect?
However, the Munich Re (2003) report is very clear about the effects of river restoration: River restoration measures make sense and are very welcome; but their effectiveness in extreme cases is often overestimated or misrepresented. As a rule, they are incapable of preventing really catastrophic floods and in many cases will not even bring about any significant reduction. The volumes of water that amass in extreme events are simply too huge.
De Wit et al. (2003) focused on the Meuse and discussed the limited effects of reforestation, re-meandering, increased inundation of floodplains, nature recovery and uncontrolled retention on the peak discharge of the Meuse at Borgharen.
But this is all based on the extreme events, when storage is already or otherwise quickly used. What are the effects of the proposed measures on floods of lower return periods and lower magnitudes? It is challenging to try to quantify in what cases the water storage could be beneficial for flood prevention, or to quantify the criticism on the WWF report.

In the field of process knowledge the challenges are to be found in the temporal and spatial dynamics of soil moisture and the interaction between the hydrological cycle and terrestrial ecosystems. Another research item is the quantification of groundwater effects on discharge generation in the Ardennes. An example of this research is given in Fig. 2. Here one sees the groundwater dynamics in only 6 months of a small catchment in Luxemburg.

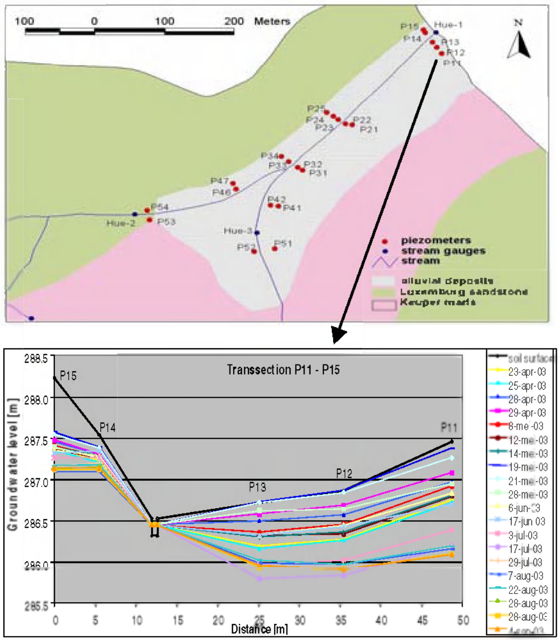

Figure 2. Fluctuation of piezometric level Huelerbach catchment Apr. 2003 - Sep. 2003.

Challenging new model concepts like there are the Hillslope-storage Boussinesq formulation and the Representative Elementary Watershed concept are brought forward in the last few years that also describe the questions of water storage and water flow, but tackle the problems with the Richards equation based, distributed, models.

On the operational side of the discharge forecast there is a clear trend from modelling towards data processing: from point data towards spatial time series and from one forecast towards several forecasts and uncertainty. This is a logical trend, more and more attention should be given to all available data sources. This asks for powerful data assimilation tools to integrate observations and model predictions. Also the post-processing needs attention as model outputs shifts from one output towards output ensembles, which should lead to insight and quantification of the uncertainty of the model results.

The scale issues relate to all hydrological sciences and include the research of dominant processes and interaction between processes that occur at different spatial scales. How to come from process knowledge to a flood forecasting?

In the above, the NCR initiatives of the Hydrological Triangle and Genesis of Flood were presented and discussed. The overall aim is bring together skills, knowledge and manpower of different research groups and stimulate data-sharing and collaboration and define those research questions that are both relevant for water management and challenging for scientists. The objectives of the NCR theme Genesis of Floods fit perfectly within this network. The meetings that were organised by the Hydrological Triangle can already be called a success. Different research groups were brought together and different research topics have been addressed and discussed. Initiatives have seen daylight like a field excursion to the Ardennes to look for collaborative field research site in the framework of the Genesis of Flood theme. For further information the reader is referred to the authors or to the NCR web page: http://www.ncr-web.org

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Economic safety standards for dike rings

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Abstract
After the flood disaster in 1953 Prof. D. van Dantzig was asked to solve the economic decision problem concerning the optimal height of dikes. His formula with a fixed upper bound for the exceedance probability (Econometrica, 1956) is still in use today in cost benefit analysis of the optimal size of flood protection measures, as the height of dikes. However, this formula is wrong. In the real optimal safety strategy not the exceedance probability but the expected yearly loss by flooding is the central variable. Under some conditions it is optimal to keep this expected loss in the future within a constant interval. Therefore, when the potential damage increases by economic growth, the flooding probability has to decline in the course of time in order to keep the expected loss between the fixed boundaries. The paper gives the formulas for the optimal boundaries. One is that the rate of return at the moment of investment (FYRR) has to be zero (or positive). In case of a positive rate of growth of the expected damage the net present value (NPV) of a safety investment, which passes the FYRR criterion, will be very positive. Therefore, the well-known NPV criterion in cost benefit analysis of a single project is not the right criterion for investing in this type of projects.

Introduction
What is – from an economic point of view - the optimal strategy for protecting a dike-ring against flooding? In designing such a strategy the social costs of investing in water defences have to be compared with the social benefits of avoiding damage by flooding. In the end the choice of safety standards is a political decision. In the Netherlands the Act on the Water Defences gives for different types of dike-rings a standard for the maximum exceedance probability of the design water level a dike-ring must sustain. This approach is in accordance with the formula of Van Dantzig (1956) concerning the optimal height of dikes. However, this formula is wrong because the influence of economic growth in the form of increasing potential damage in the course of time is not properly taken into account.

Deriving optimal safety standards
For the simplest case of one dike-ring, one failure mechanism: overflow, one type of defence: dikes, and social costs and benefits which all can be monetarized, the correct reasoning is as follows.

The expected yearly loss by flooding S_t is supposed to increase by β% a year as a result of economic growth and rising frequencies of high water levels caused among others by climate change. To cope with these systematic changes more than one defence action u_t is needed in the future. Because the existence of a rate of discount δ we like to postpone investment costs I(u) as much as possible. This asks for actions closely in line with the need for better protection and therefore points to frequent and small investments. But a lot of the investment costs are fixed costs, not dependent on the size of the action. In order to keep the costs per centimetre heightening low, we should do rather big investments at once. In doing so, the protection level will be high just after an investment resulting in a low expected yearly loss by flooding S^+, but safety will gradually decline afterwards. When a certain low level of safety with a high-expected loss by flooding s^- is reached, we decide that a new action is profitable and we invest again. Taken together the strategy consists of keeping the expected yearly loss by flooding S_t within an interval $[S^+, s^-]$ by repetitive investment in the heightening of dikes. The relative size of the fixed costs plays an important role in determining the width of the interval.

Under certain conditions the future will exactly look the same every time the system is back on the re-order level s^-. Then we will also take the same optimal decision again to bring the expected loss back to the S^+ level. So in this case the interval $[S^+, s^-]$ will be constant over time. The most important conditions are:

- All (growth) parameters are constant in time;
- $\delta > \beta$;
- Investment costs I(u) are not dependent on the height of the existing dike and not dependent on time, the derivative $I_u > c > 0$ en $I(\varepsilon) >> 0$, so both the marginal and the fixed costs are clearly positive.

The assumptions on the investment costs seem not to far from reality. And about developments in the far future we know so little, that keeping the growth rates constant in a calculation is not a problem, provided the far future doesn't have a great influence on the results. It is the second condition $\delta > \beta$ that makes sure that only the near future is important, but also that the future will always look the same. This condition is not always fulfilled in practice, but it is too complicated to handle this problem in this paper.

With fixed boundaries the size of the investments u and the time between investments D will also be fixed. The total costs of damage by flooding and investment in protection measures can then be written as follows, starting from a situation that the system is on the re-order level s^-:

$$K_{hulp} = \left(\frac{1}{\delta - \beta} S^+ \left(1 - e^{-(\delta - \beta)D}\right) + I(u) \right) \left(1 - e^{-\delta D}\right)^{-1}$$

Total costs are these costs plus the costs in the waiting period till s^- has been reached.

There are two independent instruments, which can be used to minimize total costs: the investment size u and the waiting time. Differentiating total costs to these two variables gives two optimality conditions. The first, looking at u, is:

$$I_u^1 = \frac{\theta}{\delta - \beta} S^+ + \frac{\theta}{\beta} \delta e^{-\delta D} \left(\frac{-1}{\delta - \beta} s^- + K_{hulp} \right)$$

The marginal costs of investment must be equal to the marginal diminishing of the loss directly after investment, corrected for the effects of lengthening the interval between investments. A marginal period with high-expected damage costs is added at the end of the interval and the total costs in further periods are a bit shifted to the future. Since the decision to invest has been taken already, it is only marginal costs that matter in the determination of u.

$$s^- - S^+ = \delta I(u)$$

The second optimality condition looks at the timing of the first investment:
The second criterion is the well-known First Year Rate of Return (FYRR). The benefits of the jump in safety at the moment of investment must be equal (or bigger) than the total investment costs on a yearly basis. Because this criterion involves the decision to invest or not, all costs are relevant. Together with the definition equations relating S^+, s^-, u, D (and waiting time), this system of equations can be solved.

Conclusions

Not the exceedance probability but the expected yearly loss by flooding is the central variable in an optimal safety strategy.
Under certain conditions it is optimal to keep the expected yearly loss within a fixed interval. Because the yearly costs of investment stay the same, but the benefits of protection increase by β% a year, the net present value (NPV) will be very positive for a safety investment which passes the FYRR criterion. Therefore, the well-known NPV criterion in cost benefit analysis of a single project is not the right criterion for investing in this type of projects.

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Modelling of surface water – groundwater interaction on the Alzette river basin in Luxembourg

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Abstract
Detailed field measurements of water table levels and river stages operated on the Alzette river basin in Luxembourg have pointed out that the runoff response of the catchment due to rainfall is strongly dependent on the groundwater level behaviour and consequently on the water storage of the catchment. This is due to the soil structure and geology of the area, which allow the formation of fast preferential flow that quickly reaches the aquifer and rapidly increases the near-stream saturated area.
In order to simulate such situation an integrated approach that allows the simulation of coupled groundwater and surface water flows is necessary; for this purpose the 'Representative Elementary Watershed' (REW) model is selected.
The model considers the total watershed area as subdivided in a number of sub-watersheds according to the Strahler stream order system. Each sub-watershed is considered as a spatial unit, and is divided in various zones according to the different physical processes observed. Only averaged quantities are considered within each zone, and mass exchange processes are evaluated between the various zones and the various sub-watersheds.
In particular the mass exchange between the saturated zone and the channel reaches is simulated, allowing an interaction between groundwater and surface water.
Calibration of the model is performed by means of piezographic measures as well as channel flow data available from the Centre de Recherche Public Gabriel Lippmann (CRP-GL) of Luxembourg.

Introduction
Since 1995 a dense hydro-climatological observation network comprising rain gauges, stream gauges and piezographs operates on the Alzette catchment. By analysis of the data some insights on the flood-generating processes in the Alzette catchment has been gained. In particular, channel flow data and piezographic measures show that the catchment runoff response to a rainfall event is strongly dependent on the observed water table level.
The objective of this study is to simulate water table variations and the interaction between dominant hydrological processes that affect the hydrograph generation.
The REW approach is particularly suitable for simulating hydrological processes interactions, and for this reason it is selected for this study.

Study area
The Alzette River basin is located almost entirely in Luxemburg, and has an area of 1,176 km^2. For this study the Hesperange sub-catchment in the south Alzette is selected.
The Hesperange sub-catchment covers an area of 268 km^2, its elevation ranges between 260 and 450 m a.s.l. and average slope is 3.8°. Watershed geometrical properties are extracted from a digital elevation model with a grid size of 50 m.
Soil cover is mainly represented by pastures and forests, while the geology of the study area is characterized by Mesozoic rocks, dominated by marls and schists.

Model description
The REW model is a physically based, semi-distributed, deterministic model, based on the application of balance equations directly at the sub-catchment scale.

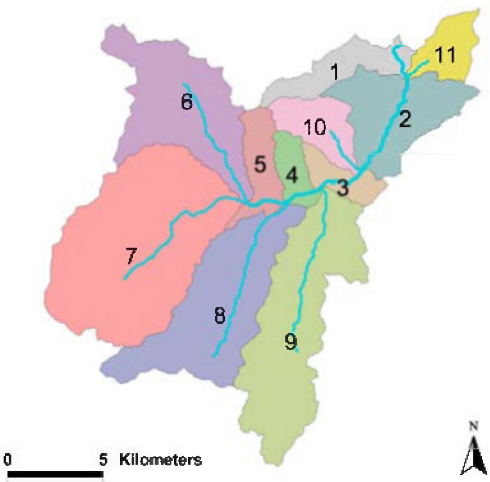

Figure 1. Hesperange sub-catchment sub-divided in REW's.

The river network is generated directly from the DEM of the area, and the watershed is discredited into a number of sub-watersheds or REW's depending on the Strahler order that is selected (Fig. 1).

In the approach balance laws of mass and momentum are spatially averaged over a REW, and constitutive relations (such as Darcy's law, Chézy formula, and the Saint Venant equation) are derived directly at the REW scale.
Each REW therefore is a spatially lumped unit that is represented by spatially averaged parameters and variables.
The REW model, compared to other hydrological models, presents the advantages to posses a low number of parameters, and to require small computational efforts.

Processes interaction

Each REW is subdivided in five zones based on the major hydrological processes that take place within an REW, their different geometries and time scales. The five zones are: saturated zone (below the water table), unsaturated zone (above the water table), channel reach, concentrated overland flow (soil surface corresponding to the unsaturated zone), saturated overland flow (soil surface corresponding to the saturated zone).

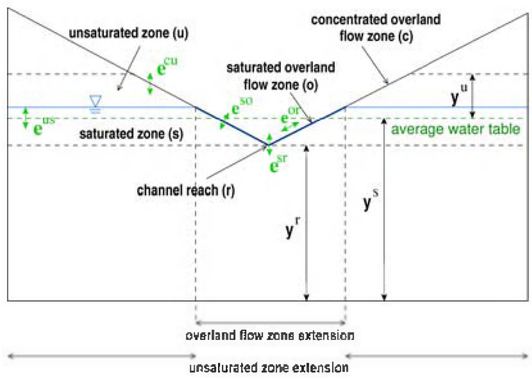

Figure 2. REW cross section.

Fig. 2 shows a cross section of an REW based on the five zones above mentioned, where the mass exchange e^{ij} is allowed for the zones i and j. The position of the water table determines the extension of the various zones.

Model sensitivity and calibration

A model sensitivity analysis is performed in order get some insights in the model behaviour and to help model calibration. A sensitivity analysis varying one parameter at time while keeping the others constant is performed. The change in some hydrograph properties is investigated, and in particular the variation in peak discharge, time to reach the peak and time to reach equilibrium is defined. The same analysis is executed on the simulated water table level. The calibration procedure is carried out by trial and errors, trying to maximize the objective function given by the Coefficient of Determination (R^2).

Results and discussion

Observed water table levels at a piezographic station nearby the catchment outlet and simulated counter parts for REW1 are shown in Fig. 3. The R^2 for the entire simulation period is 0.80, showing that there is a good fit between observed and simulated averaged water table levels.

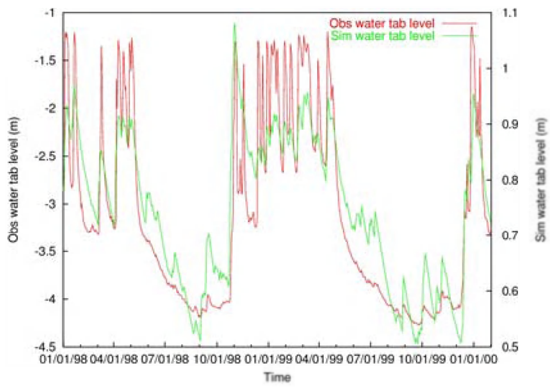

Figure 3. Water table level simulation.

The hydrograph simulation of Fig. 4 shows a R^2 of 0.64. Even though the high peaks as well as the base flow trend is quite well simulated, some hydrograph peaks for low water table values are not observed in reality. This is the main reason why the R^2 is not higher.

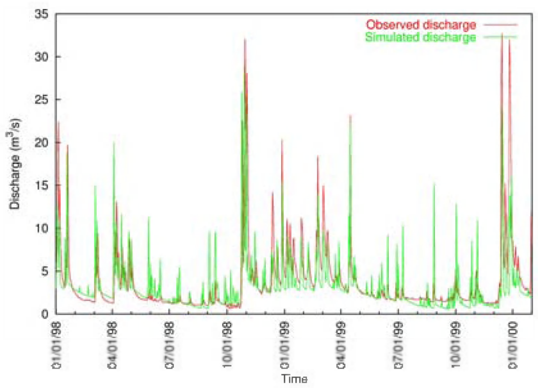

Figure 4. Hydrograph simulation.

The recession limbs of the hydrograph could be simulated more accurately, but this objective was beyond the intentions of this study. The REW model in its current configuration does not consider processes with time scales in between the 'very fast' direct runoff coming from the saturated overland flow zone and the 'very slow' groundwater flow from the saturated zone.

Future research and conclusions

This application allows us to define the subjects for future research.
The first objective is improving the water table level – saturated overland flow zone relation by improving the manner topography is simulated. When considered that peak discharges are mainly dependent on the extension of this area, the role of topography is evident. Future research will then focus on the derivation of the soil profile for each REW from geometrical properties directly obtainable from the DEM of the study area.
A second subject deals about the simulation of the recession limbs of the hydrograph. This task will probably require the implementation of other components that consider additional hydrological processes, such as rapid groundwater flow, or perched subsurface flow.
We conclude that the REW model for this application has given satisfactory results, and it is a promising tool to simulate interacting hydrological processes.
This work shows that catchment runoff is well simulated after model calibration by means of piezometric observations, indicating that the water table level represented by the selected piezometer graph is a good indicator of the catchment behaviour.

Acknowledgments

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Environmental impact of flooding

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In 2001 a Delft Cluster research project started to quantify the consequences of a flood resulting from a river dike breach in the Netherlands. In the past much attention has been paid to casualties, economical losses and losses to buildings. One of the goals of the Delft Cluster project is to quantify the environmental consequences of the release of pollutants during flooding. Only after this information is known a realistic assessment of the relative importance of environmental damage can be made as compared to economic losses, structural damage and casualties.

First an extensive literature study has been performed into the environmental consequences of floods that have occurred in industrialised countries. Results particular emphasis on the relative importance of aspects like water height, water velocity, contaminated suspended sediments and types of pollutants.
In the Delft Cluster study a conceptual framework was defined, based on the sequence of events during flooding. This chain reaction is depicted and explained below (Table 1):

- A dike breach releases water;
- The scour of the water flow or the high water level can damage or destroy source objects (constructions, houses, industrial complexes and farms);
- The damaged source objects may fail and subsequently release chemicals and micro-organisms into the water;
- Pollutants will be dispersed through air, water and suspended matter;
- The polluted water and suspended matter will affect people and ecosystems in the inundated area.

Dyke breach and flood	→	Source object fails	→	Pollutant is released	→	Pollutant is dispersed	→	Pollutant affects target	→	Qualification and quantification of the impact
Initiating mechanism				Dispersion mechanism						Consequence mechanism

Table 1. Sequence of events.

To asses the environmental impacts as well as other impacts socio-economic, casualties and damage to infrastructure and buildings a case study was used In this study a dike breach of the river Rhine near the city of Krimpen was simulated and this causes inundation of the region Rotterdam to The Hague.

The following simplifying assumptions were made:

- Toxic substances are stored in various types of containers in-, and outside buildings, in the soil and in cars; parameter C_s (g/m^2); The volumes of pollutants that will be released from the source objects are estimated on the basis of expert knowledge and information from the literature study.
- Two criteria for the release of toxic substances into the flooding waters were used, labelled 'v' and 'h':
  - ➢ High flow condition ('v'): release will occur once the water velocity v > 2m/s;
  - ➢ High water level condition ('h'): release will occur once the water height h > 1m.
- Substances, dissolved in water (C_w) (g/m^3) are subject to transport, supply from the soil, sedimentation and decay; the decay is simulated as a first order process.

In the sediment- and flow models release, dispersion and sedimentation of the various pollutants are simulated using a dedicated, integrated modelling tool (Sobek-Delwaq model of Delft Hydraulics) and also by a riverine sedimentation model. The maximum extent of the inundated area was 654 km^2, storing $1.37 \cdot 10^9$ m^3 of water. The 'h' criterion was exceeded in a very large area, and is responsible for the releases of most pollutants. The 'v' criterion was reached in a small area near the dike breach only.

Both the Emerged Retention Areas (ERA) and the Delwaq models were used to simulate transport and sedimentation of suspended particles. Given 0.284 kg/m^3 of suspended material in the river, approximately 388*10^6 kg of sediment (i.e. a uniform sediment layer of 0.35 mm) was deposited in the flooded area ($\rho_{sediment}$ ≈1,700 kg/m^3). The sedimentation pattern is depicted in Fig. 1 and 2. The area around the dike breach shows a concentric zone were no deposition occurs because of high stream velocities. Up to 6 kilometres from the dike breach, the layer thickness varies between 2-8 mm, in the lower parts of the area from 0.4-2 mm, elsewhere < 0.4 mm.

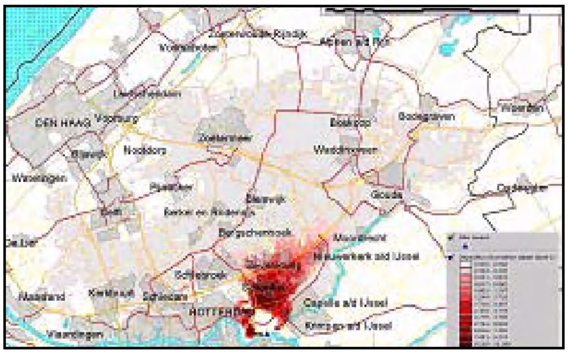

Figure 1. Deposition of sediment during the inundation stage, according to the ERA model [kg/m^2].

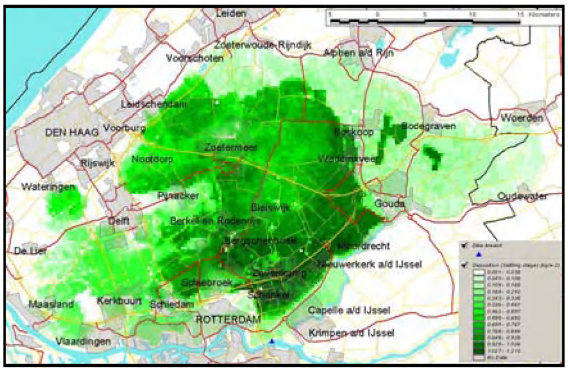

Figure 2. Deposition of sediment during the settling stage, according to the ERA model [kg/m^2].

The results of the simulations show that the floodwaters contain amounts of benzene, Perchlorethylen (PERC; DNAPL) and pesticides well in excess of Dutch Intervention values. These compounds accumulate at the borders of the flooded area. Clearly, one should be careful with the intake of surface water for drinking purposes during this time. As long as the flood lasts, most components are likely to decay naturally to sub toxic levels. Simultaneously, growth of algae is likely, causing oxygen depletion and growth of toxic organisms like blue algae. The deposition of

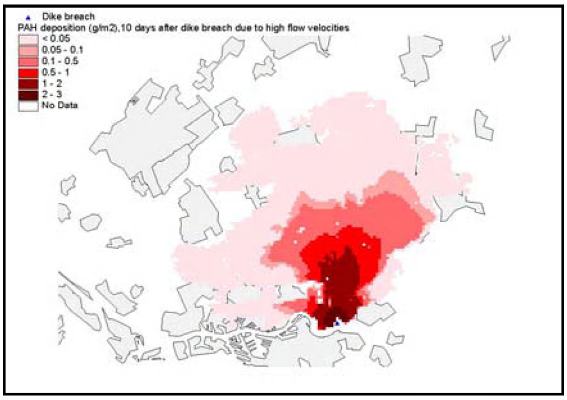

Figure 3. Concentrations of PAH's, released following the 'v'-criterion, 10 days after the dike breach.

polluted sediment may cause health risks and adverse effects on ecosystems.

As example the results for Poly-aromatric Hydrocarbons (PAH) are shown. PAH's will adsorb to and settle with floating particles. The deposition PAH's as simulated with the Delwaq model is shown in Fig. 3 and 4. PAH's, imported with the incoming Rhine water are responsible for the bulk of the contamination. Erosion of (contaminated) particles within the flooded area with the Delwaq model was severely underestimated due to conceptual shortcomings of this model. This shortcoming of Delwaq resulted in an underestimation of the release of land based material, which can be easily observed in Fig. 3, which only shows material that was simulated to be released relatively close to the dike breach. It can be expected that PAH's. (and other substances) will be deposited further away from the dike breach as well. The contamination levels of the sediment slightly exceed the Dutch intervention value for PAK10, i.e. 40 mg/kg dry matter for a 'standard' soil.

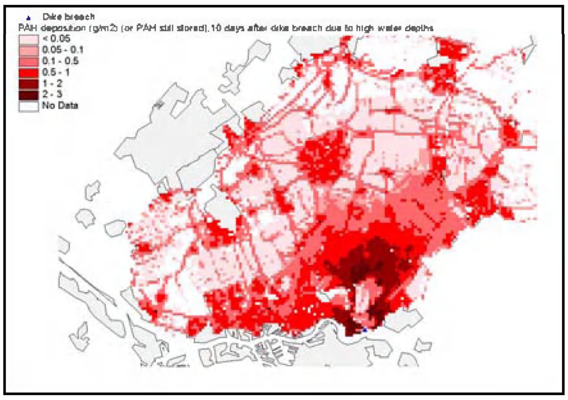

Figure 4. Concentrations of PAH's, present after 10 days, either deposited after release subject to the 'h' criterion, or as unreleased source.

Fig. 4 clearly illustrates that a significant land-based source of PAH's is formed by cars: motorways can clearly be identified.

Finally the impact of the pollutants on the threatened objects in the area is determined and cleanup costs are estimated. The total clean-up cost are estimated to be M€ 350-550 when a 10 cm layer of ground is removed is at all places were sediment is deposited. If not all sediment is removed a reduction of the land use potential for agriculture due to Cd- and Zn-contamination is assessed using the Dutch 'LAC-alert values'. Mixing agriculture land may eliminate possible risks in arable and pasture land to values below LAC-values.

Assuming that crop damage is 100% after 72 hours continuous inundation, which is the case at all agricultural fields in this simulation, the damage was calculated by multiplying the produce (€/ha) with the associated acreage (ha), yielding a total damage due to flooding of M€ 853 (worst case scenario).

The model needs still improvement. Notable is that small but numerous sources such as cars can give high amounts of toxic chemicals in water and sediment during and after the flood, while large sources such as chemical plants only give problems near a dyke breach at high water velocity.

Uncertainty assessment due to time series inputs using disaggregation for flood forecasting

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Introduction

The disaggregation (or reconstruction) of data, especially time series data, observed at lower frequency into higher frequency is a well-recognised problem in water systems modelling. Common examples are the time series of quantities like precipitation and river discharges. For an example, precipitations are observed in terms of accumulated sums for a certain period or are forecasted in terms of uniform rates of precipitation depth per unit time. Normally, the accumulated sum is uniformly distributed throughout the period for which it is observed. When such data are used for flood forecasting, e.g. using rainfall-runoff models, the assumption of the uniform distribution may introduce significant uncertainty in the estimated flows especially when the period is large compared to the catchment reaction time. This paper presents a methodology to assess the uncertainty in the forecasts due to the uncertainty in time series inputs using temporal disaggregation into sub periods. The characteristics of this methodology are: (i) it is independent to the structure of the forecasting model, and (ii) it can be applied in the framework of the Monte Carlo (MC) method as well as the fuzzy Extension Principle (EP).

Methodology

This methodology can be described into three steps:
1. Uncertainty in the magnitude of the input;
2. Temporal disaggregation of the input;
3. Propagation of the input uncertainty.

The uncertainty in the input quantity, which could be measured or forecasted, is explicitly taken into account in this methodology. Depending on the framework used (MC or EP) for its implementation, the input uncertainty is represented by a Probability Density Function (PDF) or by a Membership Function (MF).
The application of temporal disaggregation for uncertainty assessment is the main feature of this methodology. It consists in dividing the temporal period over which the accumulated input is known into a fixed number of sub periods and random disaggregation of the accumulated sum over sub periods. The disaggregated input should aggregate up to the accumulated sum. For simplicity, disaggregation coefficients $b_{i,j}$ (i = 1, …, m; j = 1, …, n), are defined such that the disaggregated signals are given by $x_{i,j} = X_i b_{i,j}$. Where, n is the number of sub basin, m is the number of sub period and X_i is the accumulated input quantity over the period for the sub basin i. The coefficients $b_{i,j}$ are subject to the constraints: $0 \le b_{i,j} \le 1$ (for all i,j) and $b_{i,1} + \ldots + b_{i,n} = 1$ (for all i). Allowing the coefficients $b_{i,j}$ to vary over the sub periods accounts for different possible temporal distributions over various sub basins, whereas varying the coefficients over sub basins accounts for the spatial variations of the rainfall field.
Finally, the disaggregated signal is used as an input to the forecasting model and the uncertainty is propagated using either the MC method or the EP. In the former approach, the disaggregation needs to be repeated for each value of the accumulated quantity obtained from its PDF. In this case, the model output uncertainty is also represented by a PDF. The later approach has been implemented by the α-cut method. This method requires an optimisation algorithm to find the minimum and maximum of the model outputs. In this study a Genetic Algorithm (GA) is used as an optimiser. In this approach, the output uncertainty is represent in the form of a MF.

Result

The methodology is applied to a rainfall-runoff model of Klodzko catchment (Poland) taking the precipitation as an uncertain input. A sample result obtained from the fuzzy EP method is presented in Fig. 1. In this example the time period is taken as 3 hours, which is divided into three sub periods of one hour each. Fig. 1 shows the difference between upper bound and lower bound of the output discharges at different forecast hours with and without disaggregation. It is clearly seen that in all forecasts the output uncertainty is much larger with than without disaggregation.

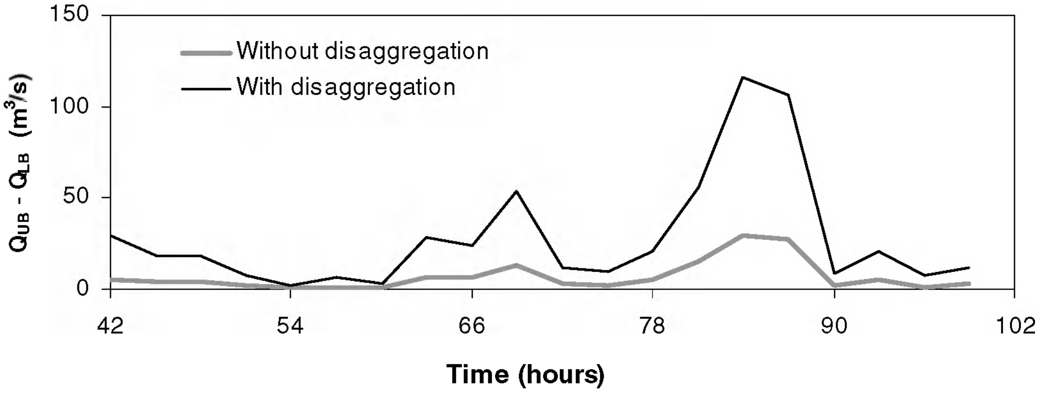

Figure 1. Uncertainty range in forecast discharges ($Q_{UB} - Q_{LB}$) for α-cut level 1.

Conclusion

The results show that the output uncertainty due to the uncertainty in the temporal and spatial distributions can be significantly dominant over the uncertainty due to the uncertain magnitude of precipitation. This suggests that using space- and time-averaged precipitation over the catchment may lead to erroneous forecasts. The results also show the great potential of the fuzzy extension principle combined with a genetic algorithm for uncertainty propagation. The application of this method, however, requires a careful analysis of (i) the methods for the generation of disaggregation coefficients, and (ii) the selection of the appropriate number of sub periods.

Is the southern Dutch delta the solution to future flood water levels in the tidal river area?

NCR-days Presentation Award 2003

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Abstract
Climate change will lead to higher design discharges en sea level rising. This is especially important for the tidal river area of the river Rhine and Meuse in the Netherlands. This area will deal more often with high water levels and maybe even with flooding when nothing is done to increase the safety. During storms at sea, the storm surge barriers are closed to protect the Dutch inland and the water levels in the tidal river area will rise because of the river discharge. At that specific moment it will be a measure to led water into the southern Dutch Delta (from Hollandsch Diep to Volkerak-Zoommeer and Oosterschelde). According to this study the water levels in the tidal river area will decrease maximum about 11 cm. Other studies show actually a decrease in water level with a maximum of 30 cm. It seems that this difference is caused by the different approach of the leaking discharge of the Oosterschelde storm surge barrier.

Introduction
Flood protection in the Netherlands is based on a maximum tolerable risk of flooding, which is set at a probability of 1/1,250 per year. Based on this safety standard, the so-called design discharge has been defined. This is the peak flow that is exceeded on average once every 1,250 year. Climate change may lead to an increase of the design discharge and also may lead to a sea level rise. Depending on the rate and magnitude of the assumed climate scenario the design discharge may increase 5 to 20 % for the river Rhine and Meuse over the next century relative to the present day conditions. Sea level may rise up to 60 cm by the year 2100. Increasing river discharges in combination with sea level rise is a future problem for the Dutch estuary. The chances that storm at sea and peak river discharges will take place at the same time will increase.
During storms at sea, the storm surge barriers are closed to protect the Dutch inland. But what will happen if there is a peak river discharge at the same time? The western part of Holland will fill like a bathtub…
Raising the river dikes is no longer considered a desired option, because increasing flood water levels may lead to greater inundation depth of the hinterland and can cause dike failure. A possible solution to this problem is to lead water into the southern Dutch delta through the lake Volkerak-Zoommeer.
The objective of this study is to investigate:

- The effect at the water levels in the tidal river area of this measure;
- How often this event will take place;
- What the water levels at the southern Dutch delta will be and especially at Volkerak-Zoommeer.

Study area
Fig. 1 shows the study area. The arrows show the direction of the transition of water into the southern Dutch delta.

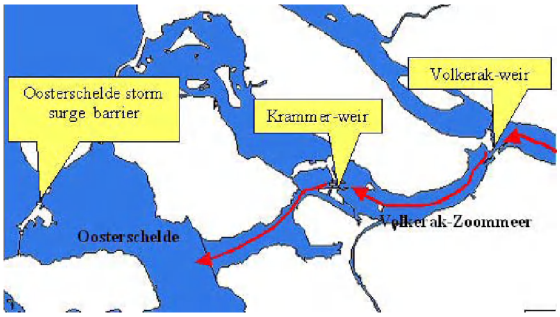

Figure 1. Study area.

Method
For the model calculations the 1D hydraulic model SOBEK is used. This model contains the rivers Rhine and Meuse from the border of the Netherlands to the North Sea including the southern Dutch delta. Model conditions for the calculations are a design discharge of 18,000 m^3/s for the river Rhine and 4,600 m^3/s for the river Meuse. The sea level rise is 60 cm and the calculations are made for 6 different storms. Transition of water into the southern Dutch delta will be when the water level at the Volkerak-weir reaches 2.58 m above sea level.

Results
The effect on the water level in the tidal river area caused by the transition of water into the southern Dutch delta is showed in Table 1. Also a comparison is made to the preceding “Spankracht” study.

River Branch	Location	Reduction water level	Reduction water level
		Study Volkerak-Zoommeer	“Spankracht” study
Nieuwe Maas	Rotterdam	0.00	0.04
Oude Maas	Dordrecht	0.04	0.21
Hollandsch Diep	Rak-Noord	0.11	0.39

Table 1. Effect on water level in tidal river area caused by the transition of water into the southern Dutch delta.

The transition of water into the southern Dutch delta during storm and high river discharge will take place around every 32 years up to 2100. The chance that water levels at Volkerak-Zoommeer will be higher than 1 m is once in 45 year and the chance that water levels will be higher than 2 m is once in 700 years.

Discussion

The effect on the water level in the tidal river area according to this study seems to be less effective than according to the “Spankracht” study. This is probably caused by a different approach of the leaking discharge of the Oosterschelde storm surge barrier. The “Spankracht” study uses a leaking discharge that results in an increase of water levels at the Oosterschelde of about 5 cm/hr. This study uses a certain leaking discharge calculated with the difference in water level at both side of the storm surge barrier.

Conclusion

The maximum effect at the water level in the tidal river area is 11 cm.
The chance that transition will be needed is every 32 years
The chance that water levels will be higher than 1 m and 2 m is respectively 1/45 year and 1/700 year at the Volkerak-Zoommeer.

Further research has to be done to the leaking discharge of the Oosterschelde storm surge barrier, the effect on ecology in the southern Dutch delta and the draining problems for the surrounding areas of the Volkerak-Zoommeer.

Dealing with hydraulic models from a user's perspective

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Abstract
The regional Rijkswaterstaat Directorate in Limburg uses hydraulic models for several purposes, such as flood forecasting and the prediction of hydraulic effects of water management projects. These models consist of three main components that are regularly updated: the software, the river schematisation and the boundary conditions. For some purposes a frequent updating of these components is desired, but for other purposes it is disturbing. In order to tackle this controversy and to clarify the process and responsibilities related to model development, Rijkswaterstaat Limburg developed a model management plan.

Introduction
I represent the Rijkswaterstaat Limburg Directorate in the field of water management. I am not a researcher, but a client. For our work we use hydraulic models that may have been developed by some of you, researchers. I believe it is a good idea that I, your client, inform you about the challenges we face when using these models.

Where do we apply hydraulic models?
At Rijkswaterstaat in Limburg we use hydraulic models to predict discharges, flow velocities, flow directions and water levels for different purposes/clients. We use the Sobek (one dimensional) model for flood forecasting and master plan and feasibility studies, when quick results are needed. When more precision is required, e.g. for determining design flood levels (so called "normwaterstanden"), licence related effect predictions (so called "WBR-calculations") and detailed design studies, we use the Waqua (two dimensional) model.

Responsibilities
The hydraulic models basically consist of three components: the software, the river schematisation (mainly geometry, hydraulic weirs and roughness values) and the boundary conditions (e.g. upstream and lateral inflow, downstream water levels). It is not our responsibility to develop the hydraulic model software, this is for our counterparts, the researchers. RIKZ is responsible for the Waqua software development and RIZA for Sobek. We receive new versions automatically, sometimes several times a year. The boundary conditions are determined every five years by the DWW, another Rijkswaterstaat research institute. Our directorate is responsible for providing the information on river geometry (changes).

Challenges
Although the above mentioned responsibilities seem clear, we have spent a lot of time and energy on discussing which model (version) to use, questioning the model output quality and the status of output results and on initiating ad-hoc improvement actions.
Another question is how to deal with contradictory requirements with regard to updating the model components. For flood forecasting we generally wish to use the most recent updated model, believing that this provides the most reliable predictions. But for predictions or calculations that have a legal status (such as the determination of design flood levels or licence related effect predictions), frequent updating of software, schematisation and/or boundary conditions is disturbing. Frequent updating may lead to different model output, which may be confusing, not credible and/or which may have negative legal consequences. In a courtroom we are not able to convince the judges that our assessments are consistent, verifiable and independent from time. Every request for a licence should be dealt with in a similar matter, as the law describes. Therefore, for official purposes a certain constancy in model output is required.
So the challenge was to make our internal model development process clear, to exactly define what we need and to plan accordingly.

The model management plan ("modellenbeheerplan")
In order to tackle the problems mentioned above, Rijkswaterstaat Limburg developed a model management plan (van Roode, 2002). The main topic is the policy on updating software, schematisations and boundary conditions.
The basis of the model management plan is the division of our hydraulic model applications into three categories:

1. Quick results and up-to-date (e.g. flood forecasting, master and feasibility studies);
2. Detailed and constant (e.g. design flood levels, licence related predictions);
3. Detailed and up-to-date (e.g. design studies).

In short, the model management plan prescribes the Sobek model for category 1. This involves an annual installation of the latest Sobek software and an annual evaluation of the river geometry changes (which may lead to updating the river schematisation).
For category 2 (for official purposes) we use the Waqua model, updated 5-yearly. We intend to use the Waqua HR model (software and schematisation) developed 5-yearly by the DWW for the official determination of the boundary conditions. After the HR model is handed over to us, we install it, test it, and subdivide the overall Meuse schematisation into several smaller sub-schematisations. Apart from the official Waqua software version, we may install newer versions for non-official purposes to cover category 3. An updated Waqua schematisation will then be retrieved through the annual Sobek updating process.

There is no rule without an exception, and this is also the case for the model management plan. In exceptional cases we may update the official Waqua software and/or schematisation before the 5 year period expires. This can only be done if the update has a large positive impact on model outcome and only after successful re-calibration of the model. For further details I refer to the model management plan.

Implementation

The plan was not made for the bookshelf and it appears very helpful in discussions and in planning processes. However, at times it is a challenge for the RWS organisation to stick with the plan! Let me give you some examples of new challenges we face that are not covered in the plan:

- What to do when the official Waqua HR software contains bugs?
- What to do when the official Waqua HR schematisation appears not well calibrated?
- Can we stick with the 5-year principle when we are asked to provide design flood levels, knowing that they will change?
- What to do when our official design flood levels disagree with those used and issued by Directorate Maaswerken?
- When are calibration results acceptable?

Above questions have in some cases lead to re-thinking and fine-tuning of the model management plan.

Conclusion

The model management plan has created much awareness within our organisation. It is a very good basis for discussion and makes (financial) planning and decision making much easier. However, not all aspects are entirely covered. Therefore, the plan needs some fine-tuning and will be updated periodically.
For you, researchers, I would like to give you some – in my view - interesting final conclusions:

- We will not automatically install new software versions!
- We need clear info concerning new software versions!
- The 5-yearly HR models need to be good!

Reactions on this presentation are very welcome; it can only make our plan better.

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Appropriate spatial sampling resolution of precipitation for flood forecasting

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Introduction

For the implementation of lumped conceptual models in flood forecasting, point precipitation time series records need to be aggregated into regionally averaged time series. Therefore a question arises: how many rainfall gauges inside a specific river basin are needed to provide sufficient precipitation records for the rainfall-runoff models?

The variability of rainfall recorded at a single spot is generally much larger than that of the discharge recorded at the outlet of the basin considered. This is quite understandable considering the damping effect of the rainfall-runoff transformation process. For a given physics-based hydrological model, the greater the diversity between the input (rainfall) and the output (discharge), the greater difficulty will be encountered in establishing the mapping from the input to the output. Therefore any measures, which can help to decrease the variability of the input, or increase the similarity between the input rainfall, time series and the output discharge time series will promote the performance of a calibrated physical model.

The operation of aggregating the point-sampled rainfall time series into regional-averaged time series has the expected smoothing-out effect. One important aspect that has to be addressed here is that the purpose of the appropriate spatial sampling of rainfall is not to master the regime of the rainfall events as detailed as possible, but to serve the practice of flood forecasting. Therefore the appropriate spatial sampling is defined as that which can possibly lead to accurate forecasting of discharge in the river channel.

The problem is attacked in two steps. The first one is based solely on the statistical analysis of recorded rainfall and discharge data, trying to identify the appropriate amount of rain gages for flood forecasting. The second step is to verify the results obtained in the previous step by running a physical hydrological model: HBV, which is developed by the Swedish Meteorological and Hydrological Institute (SMHI, 2003). Qingjiang river basin in China is adopted as the case studied in this research, and the area upstream of the Yuxiakou flow station is considered here, as shown in Fig.1.

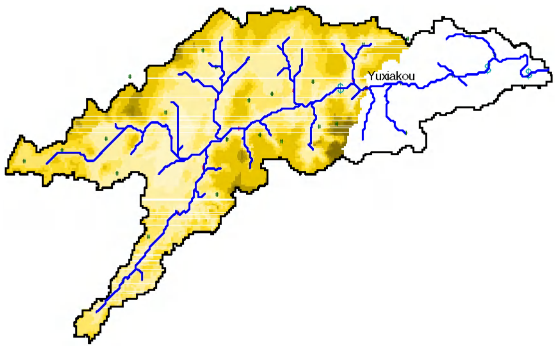

Figure 1. Qingjiang river basin.

Both rainfall and discharge data are measured at 6 hours time interval.

Statistical analysis on rainfall-discharge data

Variances (square of the standard deviation) of rainfall time series give an indication of the variability of rainfall at a location or of a region. The recorded rainfall data on the neighbouring rain gages can be treated as mutually correlated random variables if they are not separated over long distance. The variance of the sum of these individual time series (which is one method of estimating the aerial rainfall) is given by (Osborn & Hulme, 1997):

$$S_n^2 = \overline{s_i^2}\left[\frac{1+(n-1)\bar{r}}{n}\right] \qquad (1)$$

where $\overline{s_i^2}$ is the mean of the station variances; s^2_n is the variance of the average of the combination of n station time series; $\bar{r}$ is the mean inter-station correlation between all pairs of stations within the basin which is calculated from Fig. 2; n is the amount of rain gages included in the aggregation.

As can be seen from equation 1, the variance will be reduced with an increasing number of rain stations n involved in averaging. This is proved by the curves in Fig. 3, from which can be seen that the variance is reducing hyperbolically as n increases, but after a certain threshold it levels off, which implies that the effect of smoothing on the variability (variance reduction) is no longer significant when n is greater than about 10.

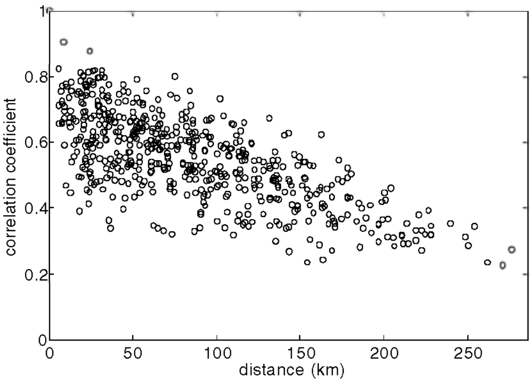

Figure 2. Correlation between pairs of point rainfall time series versus their separation distance for all possible combinations of station pairs in Qingjiang river basin.

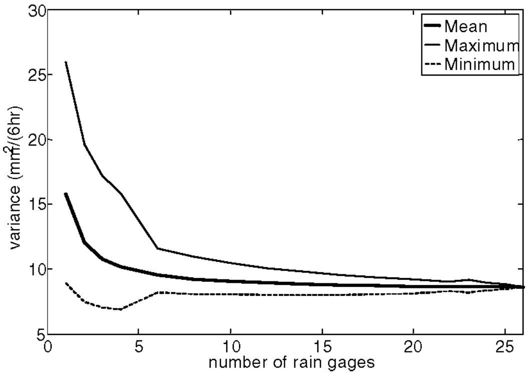

Figure 3. Variance of rainfall time series obtained by averaging n station time series together for different n.

With the decreasing variability of the rainfall, it is expected that the similarity between the rainfall time series and discharge time series will be increased, which will benefit to the rainfall-runoff modelling. This similarity is measured with the maximum cross correlation between rainfall time series (with different n) and discharge time series as shown in Fig. 4.

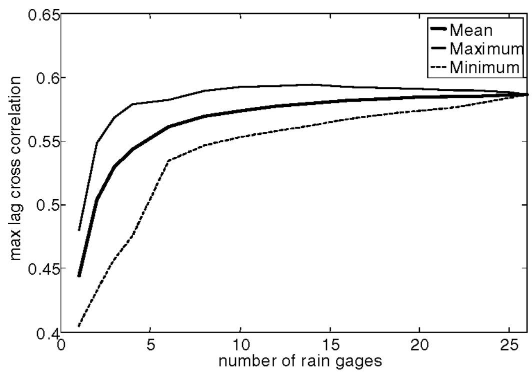

Figure 4. Maximum cross correlation (at time lag 3) versus different values of n.

The use of the concept of maximum cross correlation stems from the fact that the correlation between two time series differs according to different time lags. For the area upstream to Yuxiakou the hydrological response time can be identified as 3 time unites (18 hours) (see Fig. 5).

It is assumed that with the averaged rainfall time series becoming more similar to the discharge time series, as indicated by the increasing values of correlation coefficients in Fig. 4, the performance of a given hydrological model will be increased. Fig. 4 reveals that, when n is increased to 10, the correlation between averaged rainfall time series and discharge time series hardly increases any more, therefore 10 will be identified as the appropriate number of rain gages that determines the appropriate spatial resolution of rainfall sampling for the area upstream to Yuxioakou in Qingjiang river. This result is verified by performing real flood forecasting with HBV model.

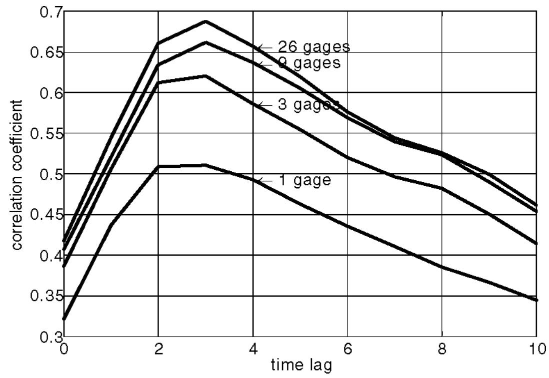

Figure 5. Cross correlation between averaged rainfall time series (with different n) and discharge time series for different time lags.

Verification with HBV model

The area upstream to the Yuxiakou flow station is treated as one sub basin as seen in Fig. 1. The one-sub basin HBV model is calibrated with rainfall, evaporation and discharge data ranging from 1989 to 1996. Then it is validated with data from 1997 to 1999. The effect of the amount of rainfall stations on the forecasting results is shown in Fig. 6, where Nash-Sutcliffe efficiency coefficient R2 and relative accumulated difference between computed and recorded discharge are used as the criteria to judge the performance of forecasting. The validation results compare favourably to the ones obtained in the preceding step.

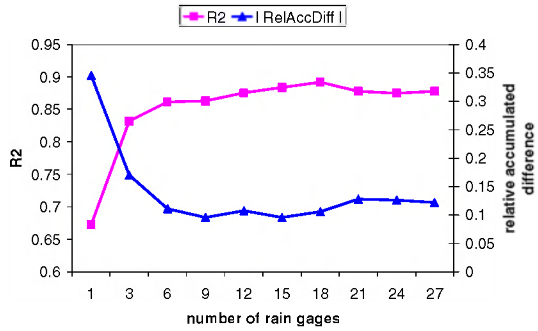

Figure 6. Verification using HBV model.

Conclusions

Among 27 rain gages used in the studied area, 10 are found to be the effective amount for flood forecasting. This is deduced first from the observed rainfall and runoff data, by calculating the variance reduction effect of all combinations of rain gages from one to the total amount of the cluster, and their correlation with discharge time series. The result is further verified by running rainfall-runoff model-HBV, with only one combination for a certain number of rain gages. Although the latter verification process is not as robust as the preceding statistical method (which is not practically possible for running hydrological models), it provides a reasonable prove on the statistical result from a different point of view.

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Searching for the right problem - a case study in water management on the relation between information and decision making

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Abstract
The solution of complex, unstructured problems in integrated water management is faced with policy controversy and dispute, unused en misused knowledge, project delay and failure, and decline of public trust in governmental decisions. Concept mapping is a technique to analyse these difficulties on a fundamental cognitive level, which can reveal experiences, perceptions, assumptions, knowledge and subjective beliefs of stakeholders, and can stimulate communication and learning.

Introduction
Integrated assessment consists of gathering, synthesising, interpreting, and communicating knowledge from various expert domains and disciplines, to help responsible policy actors think about problems and evaluate possible actions. But in the decision-making discourse scientific information is not taken for granted, can be explained in different ways, and is 'just another' element in the policy making process. And values, assumptions and limitations that are inherent in scientific models are often not communicated explicitly. Furthermore paradigm differences between actors from different stakeholder groups, between policy actors and scientists, and between scientists from different discipline groups influence the use and interpretation of information. But the assumptions and limitations present within a paradigm are seldom openly communicated. These difficulties result in lack of information and insight on policy alternatives, lack of exchange of information and communication, and lack of co-operation.
Current theories about the relation between science and policy give the following recommendations on the issue of knowledge production and knowledge use: 1) knowledge must not be produced from one single dominant paradigm, but from the whole range of paradigms that are present in the policy arena; 2) open debate is needed concerning choices and basic assumptions, which underlie the production of knowledge; 3) debate should also include non-scientific stakeholders from the policy arena, the intensity of this communication depending on the complexity of the problem.
The present research develops a new methodology that may support integrated assessment in the light of the difficulties and recommendations mentioned above.

Theoretical basis: Mental models
We start from the observation that in complex, multifunctional and multidisciplinary problems the meaning of information is socially construct, and guided by different frames of perception (Funtowicz & Ravetz, 1994; Schon & Rein, 1994). Frames are the structures of belief, perception and appreciation underlying policy positions. The frames held by the actors determine what they see as being in their interests. Frames are grounded in the institutions that sponsor them. Frame differences cause communication barriers that prevent mutual learning and understanding. Policy controversies are seen as disputes between conflicting frames. It is within the frames that information is judged and synthesised into a problem solution.
Instead of analysing frames, the present research follows Courtney (2001) and analyses the mental models that underlie frames. A frame contains actors' knowledge, assumptions, interests, values and beliefs. But it is the mental model that determines what data the actor perceives in the real world (as a 'filter' through which the problem situation is observed), and what knowledge the actor derives from it. Therefore the perspective from which alternative problem solutions are deliberated en decided upon is ultimately based on an actor's mental model. Different mental models of the problem situation, and mismatch of decision data with the mental models, will result in different opinions on the problem solution, and in this way constitute the basis of many problems in the policy cycle.
Ambiguity and confusion exists in the definition of 'mental model' between the many disciplines that use this term. Doyle (1998) argues that it should be used to refer to only a small subset of the wide variety of mental phenomena to which it is often associated, and proposes the following definition (:17):

"A mental model of a dynamic system is a relatively enduring and accessible, but limited, internal conceptual representation of an external system whose structure maintains the perceived structure of that system".

A mental model includes not only knowledge but also information about interconnection and organization of that knowledge (in nodes and links). A mental model does not include ends (goals), means (strategies, tactics, policy levers) and connections between them (the means-ends model) – these are 'inputs' for the mental model. 'Running' a mental model is equivalent to propagating information through the conceptual structure. The 'model output' is used to plan actions, explain and predict external events.

Elicitation of a mental model

Novak (1984) used the term 'concept map', to denote the external representation of the mental model. This map is the researcher's conceptualisation of a subjects' mental model. All fields of research indicate that elicitation of mental models will reveal the experiences, perceptions, assumptions, knowledge and subjective beliefs that a 'model user' operates to reach his conclusion about some issue. Concept mapping assess tacit knowledge, broadens the narrow understanding of a problem by confronting one stakeholders' map with the map of others, makes aware of alternative perspectives on the problem, encourages negotiation and helps to reduce destructive conflict. The basic idea is to externalise a person's knowledge and consequently make it discussable. This is precisely how concept mapping may link to the needs signalled by many authors in the field of integrated problem solving.
Several tools are available to support concept map generation. The present research uses the IHMC CmapTools from the University of West Florida (Coffey, 2000). This tool facilitates generation and manipulation of concept maps, and allows map sharing over the Internet. It has been used to support learning processes and expert system development

Application of concept mapping

The Zwolle storm surge barrier is used as a case study to investigate the practical applicability of the methodological concepts described above. The research looks for confirmation of the theory. The research starts with analysis of available documents, e.g. the environmental impact assessment report (mer), and associated reports such as "Richtlijnadvies" and "Toetsingsadvies" of the EIA-commission, as well as research reports and publication. Documents from the earlier phases of the project are available to monitor the development of the conceptual model in time. Media messages are used to detail stakeholders' concepts. Based on this analysis a first version of stakeholders' conceptual maps will be constructed. Based on this selected actors will be interviewed to validate and refine the maps.

Conclusion

The complex, multifunctional and multidisciplinary nature of problems causes a large range of mental models to spring into existence. When all actors are not adequately involved early in the problem solution process, to share each others mental models, the (often implicitly) developed mental model could be insufficient to legitimise the preferred solution, and incomplete or even wrong knowledge could have been produced in the project or selected for inclusion in the project report. Comparison of mental models, decision process structure and actual use of knowledge will reveal potential points of conflict, which then could be dealt with. Concept maps can also identify blind spots in knowledge, give scientists clues they need to produce knowledge that fits into the frames of the diverse stakeholders in order that knowledge they produce can be of use to the stakeholders, enlarge insight in possible and desirable problem solutions, and support communication between actors. Applying concept-mapping techniques in the early phase of decision-making for these purposes thus could improve the problem solving and decision making process.
A main advantage of the analysis of mental models above the analysis of frames is the unchallenged institutional and normative position of the actors, because concept mapping does not doubt the validity of an actor's frame, but merely wants it illuminate it by focusing on the information used within a frame. Of course, this can be the starting point of a learning process or critical dispute.

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Grensmaas laag water

Combining integrated river modelling and agent based social simulation for river management; The case study of the Grensmaas project

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Abstract
In this paper we present a coupled Integrated River Model – Agent Based Social Simulation model (IRM-ABSS) for river management. The models represent the case of the ongoing river engineering project "Grensmaas". In the ABSS model stakeholders are represented as computer agents negotiating a river management strategy. Their negotiating behaviour is derived from the so-called Theory of Reasoned Action. The Integrated River Model represents stakeholder knowledge by describing possible long-term impacts of river management options such as broadening, floodplain lowering, and dike building. The computer agents are allowed to specify values for a set of 'uncertain parameters' in the IRM for representing subjective stakeholder knowledge. We show how the coupled model framework can aid to assess the robustness of river management strategies, both with respect to environmental uncertainty and societal support.

Introduction
River management is a typical example of a complex problem involving a variety of stakeholder interests and fundamental environmental uncertainties. The Dutch government aims to take the different interests and views explicitly into account by allowing stakeholders to participate in the planning process. The aim of our research is to analyse stakeholder influence on the decision-making process, and its possible consequences for the river system, using Integrated Assessment modelling and Agent Based Social Simulation.

Methods
There are numerous mutually comparable theories of individual and collective stakeholder behaviour, stemming from the fields of social and individual psychology, economics, and artificial intelligence. In this paper we apply the so-called Theory of Reasoned Action (Ajzen & Fishbein, 1980). According to this theory the individual's intention to perform a behaviour is determined by its attitude (personal desire) towards performing the behaviour and a subjective norm, see Fig. 1.

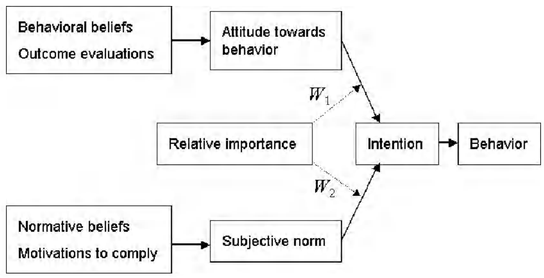

Figure 1. Relations among beliefs, attitude, subjective norm, intention, and behaviour according to the Theory of Reasoned Action (After Ajzen & Fishbein, 1980).

The Integrated River Model concept is depicted in Fig. 2. The model concept is implemented in computer code as a cross-section model of the Meuse at Borgharen. The modules are based on basic principles of river engineering (Jansen, 1994), groundwater dynamics (Strack, 1989), nature development (Maaswerken, 1998), etc.

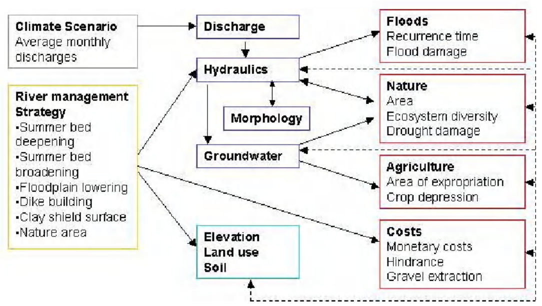

Figure 2. The concept of the Integrated River Model.

The concept of model coupling can be described as follows (Krywkow, 2002). The 'behavioural beliefs' of agents (see Fig. 1) are represented as their 'perspectives on uncertainty': value settings for uncertain IRM parameters related to climate change, hydraulic roughness, morphological developments, and costs and benefits. The agents feed these settings into the IRM to

Strategy variables / Stakeholders	Citizen	Gravel extr.	Policymaker	Nature org.	Farmer
Summer bed deepening (m)	0	4	0	0	0
Summer bed broadening (m)	250	125	250	250	0
Length of floodplain lowering (m)	0	250	500	500	0
Dike building (m)	1	0	1	0	0
Clay shield surface (m)	0	2	0	0	0
Nature area (m)	250	0	750	750	0

Table 1. Egocentric strategies for the salient stakeholders of the Grensmaas project. The strategy variables apply to a river cross-section.

calculate values for a number of decision-making criteria for a given river management strategy. These values form the basis of their outcome evaluation of the river management strategy.

Results

As a first step towards model experiments we have determined 'egocentric' river engineering strategies for the salient stakeholders of the Grensmaas project, see Table 1.
The egocentric strategy of an agent is obtained by maximizing over its attitude, given its perspective on uncertainty, while neglecting subjective norms. Obviously, no one of the egocentric strategies receives broad societal support (see Fig. 3), the strategy of the policy maker being still the most accepted option.

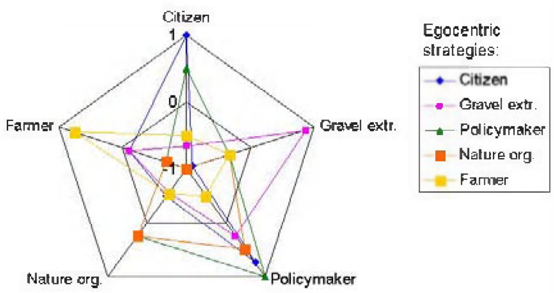

Figure 3. Stakeholder attitude towards the different egocentric strategies. A value of 1 indicates a highly favourable position towards the strategy, 0 indicates a neutral position, and –1 indicates a highly unfavourable position.

In particular, the positions of the nature organization and gravel extractor deviate. Their disagreement, however, does not result from conflicting goals, but rather from a difference in uncertainty perspective. This is represented clearly by Fig. 4, which shows a huge difference in the estimations of costs and benefits of river engineering measures between the gravel extractors and the other parties involved.

Conclusion

We have shown an 'egocentric' model of stakeholder behaviour coupled to a schematic river model. This methodology seems promising to assess robustness and societal support of a broad range of river management options and reveals underlying motives for stakeholder disagreement. Furthermore, the method may be used to elicit stakeholder goals and perspectives on uncertainty, and enhance communication. Further developments will include participatory model use, and the development of more advanced models of collective action and negotiation to assess plausible outcomes of operational river management.

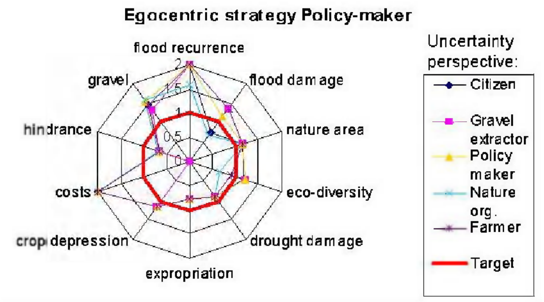

Figure 4. Decision-making criteria for the egocentric strategy of the nature organization according to different perspectives on uncertainty. The values are scaled with respect to a target value.

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Holocene fluvial dynamics in the Geul river catchment

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Introduction

The small, pristine, tributary valleys of the Maas River at the northern edge of the Ardennes offer excellent conditions for agriculture, drinking water extraction and nature protection. Water managers and nature developers agree that a reconciliation of commercial use and conservation of these river valleys is important. In order to support a sustainable development of the valuable tributary valleys of the Maas River, we must understand the past and ongoing processes in the river valleys and assess the impact of the main factors that influence those processes. The aim of this research is to reconstruct the Holocene evolution of the Geul River valley and to determine, quantify and model the impact of changes in climate and land-use on fluvial processes and catchment development for the Geul River. This will be done by field and modelling studies. In this paper we present the first results from field studies on the fluvial dynamics of the Geul River.

The Geul River catchment

The Geul River originates in eastern Belgium (near the German border) and flows into the Maas River west of Meerssen. Its length is 56 km and the catchment area is about 350 km^2 (Fig. 1). The gradient decreases from 0.02 m m^{-1} in the source area to 0.0015 m m^{-1} near the confluence with the Maas River. The average discharge near Meerssen is 3.4 m^3s^{-1} with occasional peak discharges of about 45 m^3s^{-1}.

Figure 1. The Geul River catchment.

Present-day fluvial processes are dominated by lateral erosion and sedimentation on point-bars (Fig. 2). These processes are especially active during peak discharges, when the river is capable of transporting coarse sediments and several meters of lateral erosion can happen during a short high discharge event.

Figure 2. The present-day Geul River with sedimentation on the point-bars and steep cut-banks.

Methods and results

Seven detailed cross-valley transects were cored between Gulpen and the Dutch-Belgian border (Fig. 1). The drillings were performed using an "edelman" hand auger. Sediments were described every 10 cm until a gravel layer was reached. The cross-sections show several distinct fluvial/sedimentological units (Fig. 3, the "Schoutenhof" transect):

- A basal gravel unit of Pleistocene origin (Van de Westeringh, 1980), which has been reworked by the Geul throughout the Holocene.
- A medium to coarse loamy sand layer, sometimes containing coarse organic material (branches, leaves): these are point-bar deposits or sometimes channel-fill deposits. Also finer point-bar deposits are found (loams).
- Organic loam and silt loam sediments are channel-fill and/or backswamp sediments.
- The upper unit in the valley consists of fine grained (silt loam) floodplain deposits.
- Silt loam with small fragments of brick and charcoal: this is colluvium and is deposited on the transition of the valley bottom to the valley slope, often in the form of alluvial fans (not indicated in the "Schoutenhof" transect).

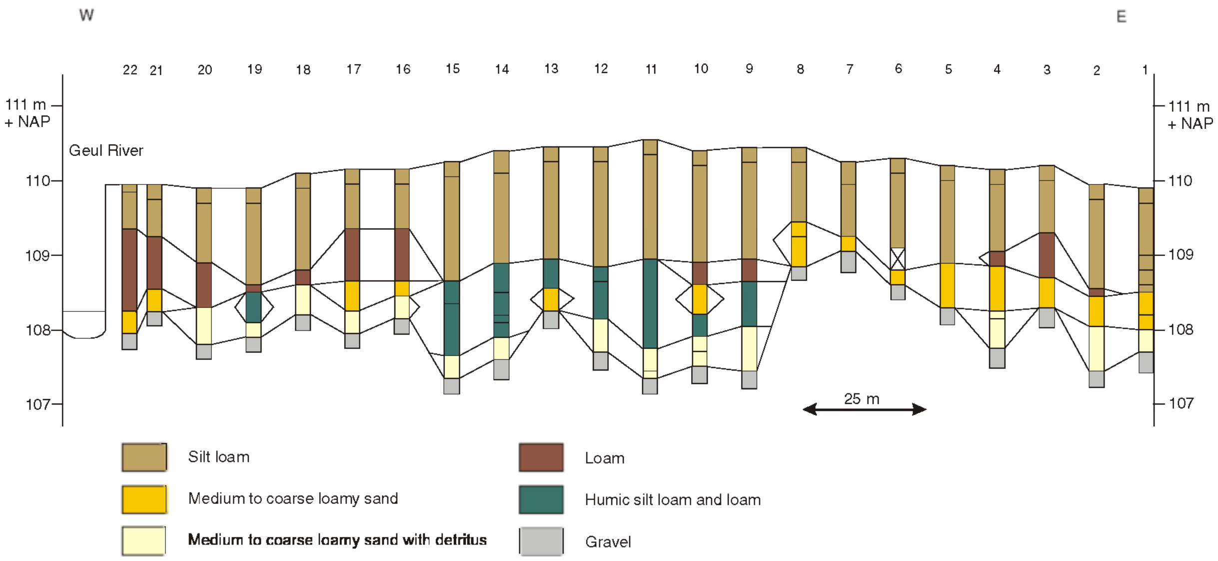

Figure 3. The "Schoutenhof" transect.

Discussion

The cross-valley transects show a uniform distribution of Holocene fluvial deposits in the river valley. The presence of point-bar and channel-fill deposits throughout the whole valley indicates a widespread lateral migration of the Geul River as well as reworking of the sediments by the river. Lateral erosion mainly takes place during high discharge events. Stam (2002) has shown that this lateral erosion can be as fast as 30 meters in 25 years. A future increase in high discharge events will probably accelerate the lateral erosion rates and thereby intensify the reworking of the sediments. This process clearly will affect landowners, who are in danger of loosing their arable land due to the rapid lateral migration.

The point-bar deposits are covered by 1.5 – 2 m of floodplain deposits. The main source for the fine floodplain sediment is loess from the valley slopes. The presence of these fine, loess-like, deposits in the river valley supports the idea that intense deforestation in historic times caused severe erosion of loess from the valley slopes (e.g. van de Westeringh, 1980). The loess was transported as colluvium to the river valley, where sedimentation and reworking of the sediments took place. Due to this massive input of fine-grained sediments, the Geul River probably changed from a braided river to a meandering river. This change clearly illustrates that land-use (i.e. deforestation) has a big impact on the river.

The results obtained from the field studies will be used as input for the modelling of historic and future scenarios of valley development. This combined approach of field and modelling studies will provide a detailed insight in the development of a small tributary of the Maas River and its sensitivity to changes in climate and land-use.

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The RIVER 21 concept: envisioning the future of international river basins

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Abstract
The RIVER 21 concept, as developed by universities in France, Belgium and the Netherlands, is a tool for teaching vision-building processes on international river issues. The concept is based on a combination of traditional knowledge transmission and interactive, outdoor learning activities in an international context. In a two weeks project, staff and students experience important steps of a decision making process in a multi-stakeholder context with absence of central authority. The concept inspires students to be visionary thinkers and learn how to deal with uncertainties of the future. Vision building enables stakeholders to share information and to reach a common understanding of stakes and goals. It can be a tool for planners by looking at an entire river basin system and structuring problem solving. Finally, vision building is important for politics: a shared vision makes it easier to hold stakeholders accountable.

Introduction
Decision making processes on international river issues are highly influenced by the hydro-geographic context (upstream-downstream relationships), the absences of central authority, the presence of multi-level negotiation games (multinational, bi-national, intra-national, inter- and intra-organisational), socio-economic characteristics, power balance, institutional and cultural differences (Clevering, 2002; Santbergen, 2000; Meijerink, 1999).
Experiences from the Scheldt River Basin, shared by France, Belgium and the Netherlands, learn that the International Scheldt Commission (installed in 1998) mainly deals with unstructured, wicked problems in which no consensus on values and knowledge has been reached and ill-structured problems in which consensus only on knowledge (and not on values) exists (applied after de Bruijn & ten Heuvelhof, 2002; Table 1).
Related to the Scheldt river basin, Meijerink (1999) speaks about a pluricentric perspective of decision making in which interdependent stakeholders play games in multi-level networks, driven by self-interest and maintaining autonomy.

	No consensus on values	**Consensus on values**
No consensus on knowledge	Unstructured problems	Moderately structured problems
Consensus on knowledge	Ill-structured problems	Structured problems

Table 1. Four types of policy problems (de Bruijn & ten Heuvelhof, 2002).

Above all, a lack of political ambition of the riparian states on a shared (and supported) long term vision on sustainable development and management of the Scheldt river basin, seems to hinder progress, more than the impact of historical grown distrust, language barriers and cultural differences (Santbergen, 2000). Or to quote a former Dutch chairman of one of the working groups: “Now, when we look back at the first five years of the International Scheldt Commission, I think we will have to admit that we have been too blind to our common interests”.

Expectations are that the European Water Framework Directive, aiming at river basin management plans for all European river basins, will cause a window of opportunities for transboundary river basin commissions like the International Scheldt Commission. The river Scheldt pilot project on testing the guidance’s on the implementation of the Water Framework Directive will improve the international cooperation on integrated water management and will result in a shared international management plan for the entire river Scheldt district (Scaldit, 2003). According to universities in the Scheldt river basin, such a river basin management plan should be based on a shared long-term vision of all stakeholders involved. The first step in achieving future cooperation is to train students and young professionals in ‘transboundary river basin thinking’ (Ruijgh-van der Ploeg & Verhallen, 2002). Therefore, the ENGREF Montpellier Center of the National School of Water Management and Forestry, the University of Ghent, the University of

Antwerp, Delft University of Technology and Wageningen University and Research Centre, developed a concept in which students and staff undergo a two weeks vision-building process together. This concept, RIVER 21 (aiming at envisioning the future of the world's rivers in the 21st century), has been developed and applied in the Scheldt river basin (2000, 2001, 2002 and 2003) and partly in the Tisza river basin (shared by Romania, Ukraine, Hungary and Yugoslavia; 2002).

Materials and methods

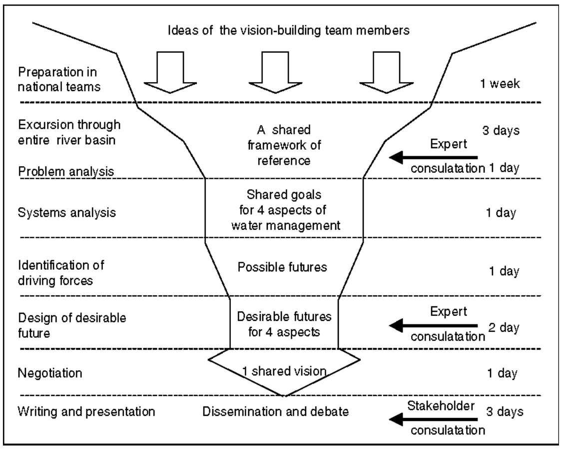

Figure 1. The River 21 concept (in: Ruijgh-van der Ploeg & Verhallen, 2002).

Fig. 1 summarizes the RIVER 21 concept and includes the following steps:

- Teaching principles of integrated water management, policy analysis and systems analysis (at each individual university).
- Preparations in national teams: literature review by staff and students, interviews with stakeholders.
- Joint excursions and meetings with stakeholders in the river basin: in the field, students are introduced to the major water-related issues of an European transboundary river and asked to explore the future of water management in the basin in a systematic manner, together with their European peers.
- Systems analysis in international sub-groups aiming at formulating shared goals for several aspects of river basin management.
- Integration of systems analysis for the different aspects in a plenary session.
- Scenario analysis in international sub-groups aiming at identification of driving forces and possible futures.
- Design of desirable futures for the different aspects in international sub-groups.
- Negotiation and decision-making on one shared vision in a plenary session.
- Presentation of the vision to the involved stakeholders of the riparian states.

Results

Lessons learned so far are:

- The RIVER 21 concept is a good instrument to learn how to deal with cultural diversity and to express oneself in a not native tongue.
- The RIVER 21 concept offers possibilities to develop negotiating skills; to experience one's own strengths or weaknesses in negotiation and the gap between one-side statements and common interests.
- A lot of participants were not familiar with vision building and learned that the systems analysis and vision building language is not a common language. For example: ways of learning at universities in Hungaria and Romania are different than in the Netherlands.
- The multi-disciplinary and visionary perspective was new for most participants and the usefulness of the underlying systems analysis was acknowledged as a tool to structure available information and to come to joint fact-finding.
- There is not one central way to integrated river basin management. Involvement of different disciplines doesn't automatically lead to an integration of knowledge from α, β and γ sciences.
- By applying the RIVER 21 concept, views, issues and interests of the different riparian countries become clear; students bring in new and fresh ideas but also are tempted to defend their own countries interests.

Discussion

The RIVER 21 concept is no new method or a blueprint, but a concept in which existing methods like systems and scenario analysis are combined in a multi-stakeholder context. The essence of the approach is that stakeholders undergo an entire process together, from problem definition to envisioning the future and defining actions. In this sense, the concept can be seen as an active form of public participation as mentioned by the European Water Framework Directive (article 14). Although only completely tested by university staff, students and young professionals in the Scheldt river basin, the concept can be applied in other transboundary river basins as well as by planners, decision-makers, scientists and other stakeholders at different institutional, spatial and temporal scales and at strategic, normative and/or operational levels. Students and young professionals are the water managers of tomorrow. Unfortunately, universities do not have much of interactive, transboundary programmes in regular their bachelor-master curricula. The problem of how to secure these intensive courses needs to be addressed urgently.

Conclusions and recommendations

Transboundary water management issues can be tackled by considering the river basin as a unit including everyone affected, and, while temporarily ignoring boundaries, discovering the issues and possible solutions for the future. Building a vision challenges us to be creative and allows us to dream. According to the students, vision building enables stakeholders to share information and learn from each other in order to reach a common understanding of the stakes and goals. Vision building can be a tool for planners: it structures problem solving when spatial scales are large and time scales are long. It demands that planners look at the entire system. Vision building is important for politicians; a shared vision makes it easier to hold stakeholders accountable. According to the staff, the concept can help delegation leaders of international river basin commissions at the highest levels to overcome business as usual, if they are willing and political supporting the creation of a shared vision by actively participating in the process. The concept can be further developed and improved in transboundary river basins with different hydro-geographic, political-institutional, cultural and socio-economic contexts. In 2004, the fifth Scheldt edition will take place involving university staff, students and stakeholders from all riparian states (including Brussels and Wallonia). Plans are developed to apply (and improve) the concept in former Soviet states and accession countries to the European Union.

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Extreme floods in the Meuse basin over the past century: aggravated by land-use change?

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Introduction
In the recent decade, Western Europe has experienced frequent floods. Concern is rising among the public about the effects of climate variability and land-use changes. The Meuse river is one of two largest rivers in The Netherlands and experienced severe floods in 1993/1994, 1995, 2002 and 2003. It is often assumed that rapid land-use changes in the basin since the 1950's have aggravated the floods in the river. This possibility has provided the motivation to analyse the flood peaks in the Meuse river and causal extreme precipitation in the basin during the past century. The historical land-use changes were also traced out. The present paper summarises the preliminary results.

Data and methods
Study sites and data
The Meuse river is roughly classified as rain-fed, with a total drainage area of about 33,000 km^2 (see Fig. 1). Extreme floods in the river often occur in the winter season. Borgharen station (with a drainage area of about 21,260 km^2) is normative in The Netherlands and has a long record of daily discharge (1911-2002) for statistical analysis. Because downstream of Liège (Belgium) several canals extract a significant percentage of water from the Meuse river, the discharge of the 'undivided' Meuse at Monsin (Belgium) has been reconstructed (1911-2000) for analysis too (RWS, personal communication). Other selected gauging stations in the tributaries include: Membre in the Semois, Stah in the Roer (Rur), Nekum in the Jeker and Meerssen in the Geul (see Fig. 1). Membre station has a relatively long record dating from 1929, while the other stations have the reconstructed records starting from the 1950's.

The long records of daily precipitation (1911-2002) from seven Belgian stations were collected (see Fig. 1). The daily values for these stations were simply averaged (not weighted) to obtain the estimates of relative daily values of aerial precipitation in the basin upstream of Borgharen, although the Ardennes has the largest annual precipitation in the basin.

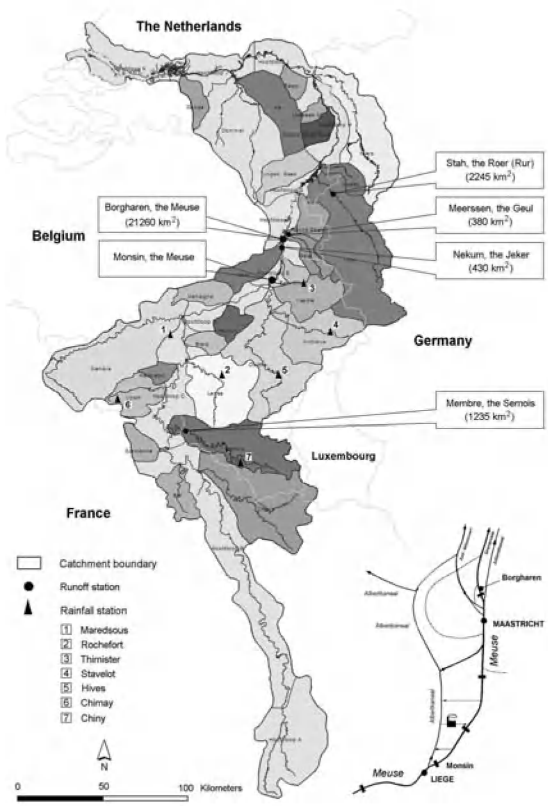

Figure 1. The Meuse basin and locations of the selected stations.

Hydro-meteorological variables
Extensive examination concentrated on the flood peaks and volumes at Monsin, and the extreme precipitation depths in the basin. The hydrological years (November to October) and hydrological winter (November to April) and summer (May to October) half-years were considered separately. The derived hydrological variables for Monsin include annual maximum k-day moving average discharge (k = 1, 3, 5, 7, 10, 15 and 30) (denoted as AMAXD, AMAX3D, …, AMAX30D) as well as maximum k-day moving average discharge for both the winter half-year (denoted as WMAXD, WMAX3D, …, WMAX30D) and summer half-year (denoted as SMAXD, SMAX3D, …, SMAX15D). For other gauging stations, only AMAXD, WMAXD and SMAXD are included. For the aerial precipitation, annual extreme k-day precipitation depth (denoted as AEXTP,

AEXT3P, …, AEXT30P) was derived as well as extreme k-day precipitation depth for both the winter half-year (denoted as WEXTP, WEXT3P, …, WEXT30P) and summer half-year (denoted as SEXTP, SEXT3P, …, SEXT15P). The water year is designated by the ending year.

Statistical methods
Spearman's rank correlation method was applied to evaluate the absence of linear trend in the time series. Then, change-point analysis was performed by both the Pettitt test (Pettitt, 1979) and the SNHT test (Alexandersson, 1986; Alexandersson & Moberg, 1997). A probability of 80% was used to judge the significance of change-points in the Pettitt test, while the 90% level was given preference in the SNHT test. A change-point year in the series refers to the first year after the change.

Land-use changes
Over the past centuries, agricultural development has brought about a radical change of land covers in the Meuse basin, generally from forests to agriculture and pastures. However, during the 20th century, the forest area has been stable in Wallonia, Belgium, where most of the Ardennes rivers contribute to the extreme floods in the Meuse river, and even shows a slight increase dating from the year 1984. Of the forest area, the percentage of the conifer production forest has obviously increased, e.g. from 14% in 1895 to 50% in 1984, while the percentage of the broad-leaved forest has dropped (DGRNE, 2000). Lorraine-Meuse in the upper French part also exhibited a slight increase in forested area. After the late 1940s, intensification of agricultural land and rapid urbanisation have contributed the most important land-use changes in the middle and lower part of the basin. The period 1950-1960 is often seen as a turning point corresponding to the industrialisation of farming and to considerable urban development and to the expansion of transport infrastructure. In Wallonia, the arable agricultural area had obviously decreased between the 1950's and the 1970's, slightly reduced during the 1980's, but thereafter showed a marginal increase. The extent of urbanisation has increased from 10.5% in 1980 to 12.7% in 1996.

Test results

Flood peaks and volumes
No significant upward trend was found for the flood peaks and volumes at Monsin over the past century. Since 1984, AMAXD and WMAXD at both Borgharen and Monsin have significantly increased. However, the flood volumes at Monsin with increasing k-values (k $\geq$ 5) did not show such abrupt change. For the tributaries, the Semois and the Roer exhibited a significant increase in AMAXD and WMAXD after the end of the 1970's, while the Jeker showed such an obvious increase only in SMAXD. Fig. 2 shows the change-point results for WMAXD in these rivers. As an exceptional case, a decrease after 1971 was observed for the flood peaks in the Geul.

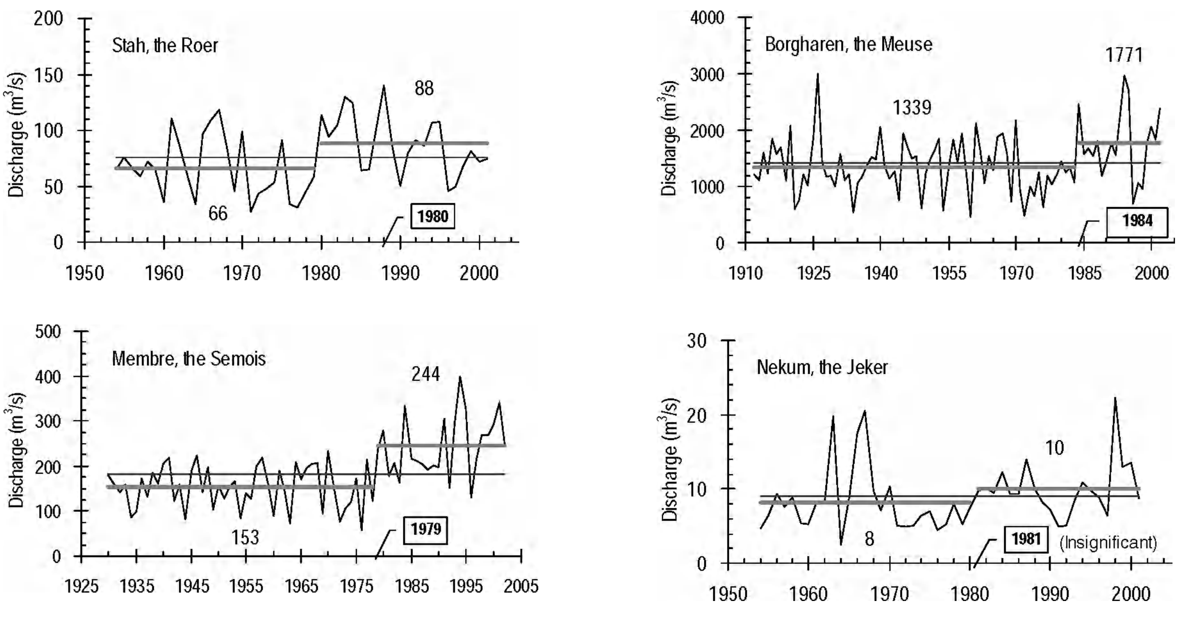

Figure 2. Change-point results for the winter maximum daily discharge (WMAXD) in the Meuse basin.

Extreme precipitation depths
In the long term, most winter extreme precipitation depths in the basin ($k \leq 10$) showed an upward trend with high probabilities (> 90%) or were marginally significant (only for WEXT5P). Except for AEXTP and AEXT30P, most annual extreme series exhibited a significant increase after 1980, which was also found for SEXT5P, SEXT7P, SEXT10P and WEXT7P over the shorter period post-1950. Winter extreme series with k-values ≤ 10, with the exception of WEXT5P, showed an abrupt increase in the 1930's.

Antecedent precipitation depths
Further investigation was made on the effects of the k-day precipitation depths (denoted as ANTP, ANT3P, …, ANT30P) in the basin prior to and on the day of WMAXD at Monsin. A significant increase since 1984 was also identified for ANT3P, ANT5P, ANT7P and ANT10P over the full period, of which ANT7P, closely followed by ANT10P, showed stronger correlation ($r = 0.771$) with WMAXD at Monsin. Statistical tests were also carried out for the runoff coefficients for Monsin during different antecedent k-days ($k = 3, 5, 7, 10$), which were derived based on the Rational Method. No significant change-points were shown in these series.

Discussion and conclusions
The test results indicate that the flood peaks in the Meuse river have significantly increased since the 1980's. On a global scale, the largest change in terms of land area, and arguably also in terms of hydrological effects, is from afforestation and deforestation. However, the forest area in the upstream Meuse basin has changed little over the past century and most changes in the forest type, agricultural land and urbanisation occurred before the 1980's. Therefore, the global tendency for the land-use changes in the upstream basin cannot convincingly explain the increased flood peaks in the main river after the 1980's. At the larger basin scale, the influence of land-use changes in upland catchments on the major floods downstream may hardly be detected. The increased flood peaks in the Meuse river since the 1980's are affected more by change in the antecedent (e.g. 7-day) precipitation in the basin. Precipitation-induced increase in flood peaks was also observed in the selected tributaries except for the Geul, where the decreased flood peaks may possibly be attributable to storage effects after 30 years of nature development. Therefore, the apparent changes in frequency and magnitude of floods in the Meuse river over the last two decades can broadly be ascribed to climatic variability. Ongoing work will investigate the relation between the European Atmospheric Circulation Patterns and the precipitation change in the Meuse basin.

Acknowledgements
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Monte Carlo method applied to a two-dimensional morphodynamic model

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Introduction
For a reach of the river Rhine close to the Dutch-German border a two-dimensional morphodynamic model has been applied in order to investigate the morphological impact of possible measures to increase the navigability (WL I Delft Hydraulics, 2003). This investigation used a single hydrograph that was repeated for several years in order to investigate the long-term morphological impact of structural interventions. This approach includes the discharge variation during only a single year and is therefore considered very much deterministic. The actual variation of the discharge can be much more significant and is not included in this approach (see Fig. 1).

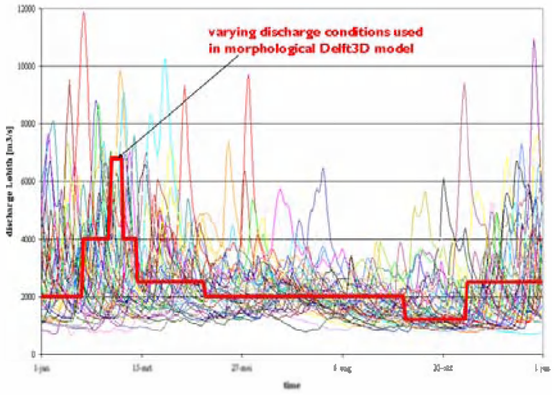

Figure 1. Historical Rhine discharge data in comparison with the hydrograph used in earlier model investigations.

Van der Klis (2003) analysed the uncertainty of discharge fluctuations and the impact on the riverbed development. She examined the applicability of Monte Carlo simulations to quantify the uncertainty of a one-dimensional morphological numerical model. She concluded that the Monte Carlo method is the best method to quantify the impact of river discharge uncertainties on the riverbed morphology. The Monte Carlo method makes it possible to analyse the morphological and hydraulic output of simulations with normal statistical methods.
The objective of the present research is to investigate whether the application of this Monte Carlo method to a two-dimensional morphodynamic model would provide additional useful information that is consistent with prototype observations. For this reason, the number of simulations has been limited to only ten.

Case Study
In the investigation a detailed two-dimensional morphological Delft3D model has been used that was developed by Baur et al. (2002) (Fig. 2).

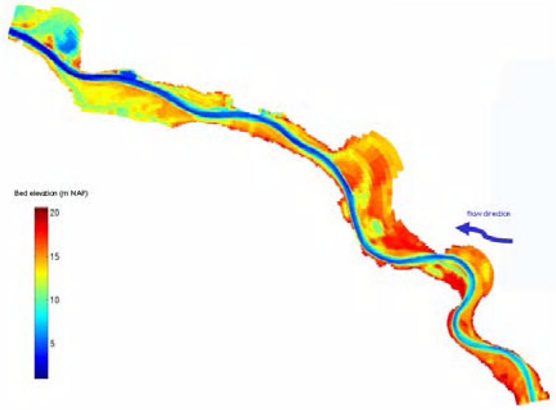

Figure 2. Morphological Delft3D model.

The model schematisation includes the main channel and floodplains over a length of 42 km. The average cell length and width in the main channel are 150 m and 35 m, respectively.
The boundary conditions for the model simulations consisted of the water level at the downstream boundary and the discharge distribution over the grid cells of the upstream boundary. In case of a Monte Carlo simulation this implies that for every discharge value to be used a separate set of water level and discharge distribution values is required.
The historical data have been converted to see which set of discrete discharge values would have similar characteristics as the historical dataset and still would be workable as input for the Delft3D simulations.
For now, it was concluded that discretisation with steps of 500 m^3/s would represent the actual discharge values well enough for a first approach.

Monte Carlo approach
The principle of Monte Carlo simulation is to run a deterministic model many times. Each model run is driven by a different realisation of

the input time series (synthesized on the basis of randomly generated parameters). The output of all model runs is used to determine the statistical properties of the bed levels, like the expected bed level position, its variance and the percentile values. In case of non-linear systems, the statistical mean of the morphological responses is not equal to the morphological prediction based on the 'mean' value of each model input (Gardner & O'Neil, 1983).
The random discharge generator is based on a method derived by Duits (1997). The seasonal dependency and the correlation between successive river discharges are considered in this method. The basic data represents 55 years of daily measured Waal discharges at the location Lobith. A statistical description has been derived in five steps:

- Each year is split into 36 periods of 10 days;
- The measured daily discharges are averaged over these 10-day periods;
- For corresponding 10-day periods through the years, a shifted lognormal distribution function is estimated;
- The correlation between discharges in successive periods is estimated. Duits shows that the discharge in 10-day period i depends on that in the two preceding 10-day periods, i –1 and i -2.
- Construction of a multivariate lognormal distribution function per 10-day period.

This method has been previously applied to the same data by Van Vuren et al. (2002) and Van der Klis (2003). With this statistical model, discharge hydrographs have been synthesized by random sampling from these multivariate lognormal distribution functions. The set of results is used to determine the statistical properties of the predictions.
The averaging process of the Monte Carlo sampling adjusts the discharge values, so that the sediment transport generated by the averaged discharge data for the period of 10 days equals the sediment transport generated by the daily average discharge data.
In fact a few hundred simulations are required for a good statistical analysis of the morphodynamic behaviour of the riverbed (Van der Klis, 2003). The objective of the present research, however, is an initial test to see the applicability of a Monte Carlo simulation with a two-dimensional morphological model. Therefore the number of simulations is limited.

Simulations

During the simulations, the hydraulic and morphological output is stored with time steps of five days. Two types of analyses can be carried out with the output data of the simulations. The first analysis considers the impact of discharge fluctuations on the morphodynamic behaviour of the riverbed, by statistically analysing the output of the bed elevation data.
The second analysis considers the impact of discharge fluctuations on the navigability. In this case the bed elevation output for each 5 days time step has been merged in a new model schematisation with which steady state simulations have been carried out under OLR-conditions. For each model grid the fulfilment of the OLR-criteria (water depth of 2.8 m and channel width of 170 m) can be analysed statistically to investigate the impact of the morphological development under varying discharge conditions on the navigability.

Results

The morphological sensitivity to discharge fluctuations for the present situation has been analysed with figures of the maximum bed level difference (maximum minus minimum bed level) and with the standard deviation of the bed elevation during the Monte Carlo simulation. For each grid cell, the statistical output for each of the presented parameters is based on 2,190 values.

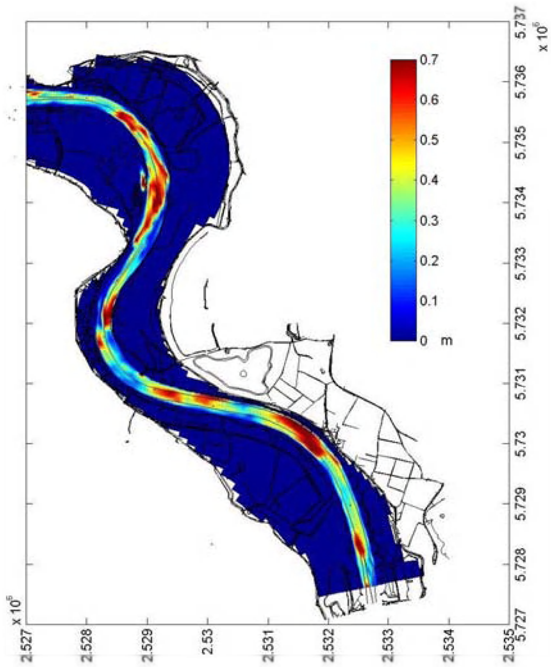

Figure 3. Absolute maximum bed level difference during Monte Carlo simulation.

The magnitude of the morphodynamic variations under varying discharge conditions is presented in Fig. 3 and 4. Fig. 3 presents the absolute maximum bed level differences for a certain model reach. Fig. 4 presents the standard deviation of the bed elevation of another model reach. High values imply that the local riverbed (elevation) is highly sensitive to discharge fluctuations.

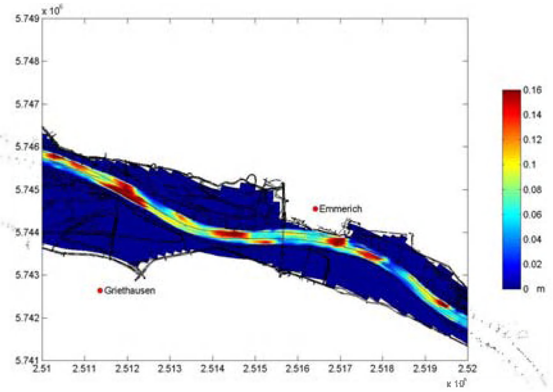

Figure 4. Standard deviation of the bed elevation as an indicator for the morphodynamic behaviour.

The impact of the morphodynamic behaviour on the navigability has been analysed, focussing on the navigation channel depth and width. The navigation channel width has been analysed with the standard deviation, and the maximum and minimum width for a minimum water depth of 2.8 m. Fig. 5 presents the frequency that the water depth during OLR-conditions is smaller than the OLR-criteria of 2.8 m. High values indicate that the OLR criterium is frequently not fulfilled.

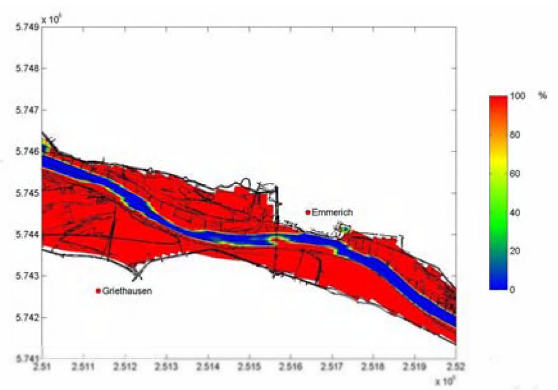

Figure 5. Frequency that the water depth during OLR-conditions is smaller than the OLR-criteria of 2.8 m.

With the statistical information it is possible to determine the chance that the OLR-criteria will not be fulfilled and that the navigability in a certain reach will face difficulties. This information could be used to make a decision whether, where and when dredging should be carried out to guarantee navigability.

The results of the Monte Carlo simulation are consistent with prototype observations. The reaches where navigability problems occur in the prototype are clearly represented in the results of the Monte Carlo simulations.

Conclusions

The application of a Monte Carlo simulation to a two-dimensional morphological model is considered to be a promising method to obtain insight in the morphodynamic behaviour of the riverbed.
The results of this non-deterministic modelling approach clearly provides insight into the impact of discharge fluctuations on the morphodynamic behaviour of the riverbed.
This additional information is considered valuable when insight is required about the impact of the morphodynamic behaviour on other functions of the river.
The impact of discharge variations on the morphodynamic behaviour is clearly visible in the results of the Monte Carlo simulation. The results appear to be consistent with prototype observations.

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Impact of land use changes on breeding birds in floodplains along the rivers Rhine and Meuse in the Netherlands

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Introduction
Over the last decades the habitat availability and quality for breeding bird species in floodplains along the rivers Rhine and Meuse significantly changed as a result of physical reconstruction measures and land use changes aiming at flood defence and ecological rehabilitation (e.g. excavation of floodplains, removal of levees, digging of side channels and transition of agricultural land in nature). This paper presents spatial patterns and trends in breeding bird diversity on various levels of scale, i.e. river branches, floodplain areas and riverine ecotopes. In addition, breeding bird composition of rehabilitated floodplains is analysed. The relations between species richness and several landscape ecological characteristics (e.g. surface area of various riverine ecotopes) are described.

Material and methods
Data on presence and abundance of breeding birds in floodplains were obtained from bird watch organisations, floodplain managers and (scientific) literature (Erhart & Bekhuis, 1996; Faunawerkgroep Gelderse Poort, 2002 & SOVON Vogelonderzoek Nederland, 2003). Relations between cumulative species richness and surface area of several riverine ecotopes were analysed using Biodiversity Professional Beta 1 (McAleece, 1997). The surface area of ecotopes per grid or floodplain was calculated with Arcview 3.2, using the river ecotope map of Rijkswaterstaat (1997). Canonical Correspondence Analysis (CCA) was performed with Canoco for windows (Jongman, 1995).

Results
Over the period 1973-2000 more than 70 percent of the grids surveyed along the rivers Meuse and Rhine in the Netherlands showed a decrease in the number of red-listed breeding bird species (Fig. 1). This particularly holds for bird species that are characteristic of reed marshes and wet grasslands. However, the diversity of characteristic species of riverine ecotopes such as lakes, side channels, pioneer vegetation and softwood forest tended to increase. Similar trends were observed at the regional scale. For instance, in the international wetland “Gelderse Poort” a decrease was observed in distribution of 21 out of 35 red-listed breeding bird species over the period 1975-2000 (Erhart & Bekhuis, 1996 & Faunawerkgroep Gelderse Poort, 2002). Rehabilitated floodplains showed a strong increase of breeding bird diversity.

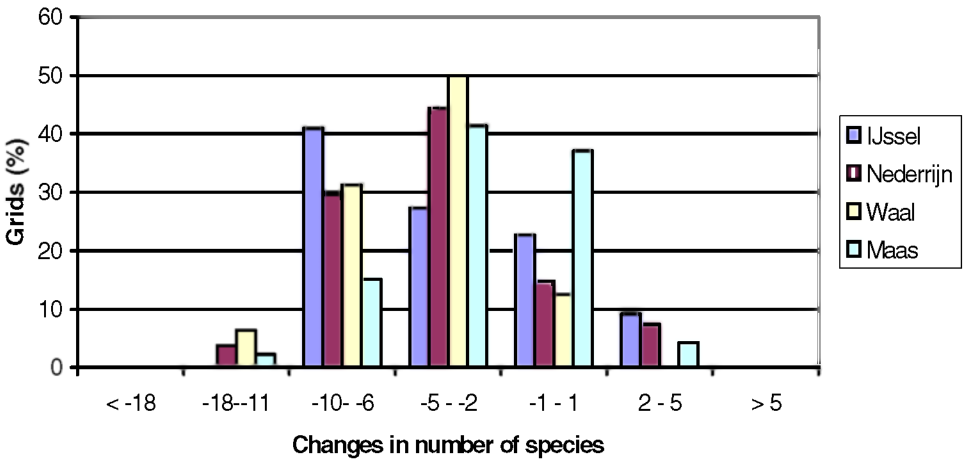

Figure 1. Changes in number of red-listed breeding bird species between 1973-1977 and 1998-2000 atlas surveys of 5 x 5 km grids in Dutch river district, only probable and confirmed breeding records included (Data: SOVON Vogelonderzoek Nederland, 2002).

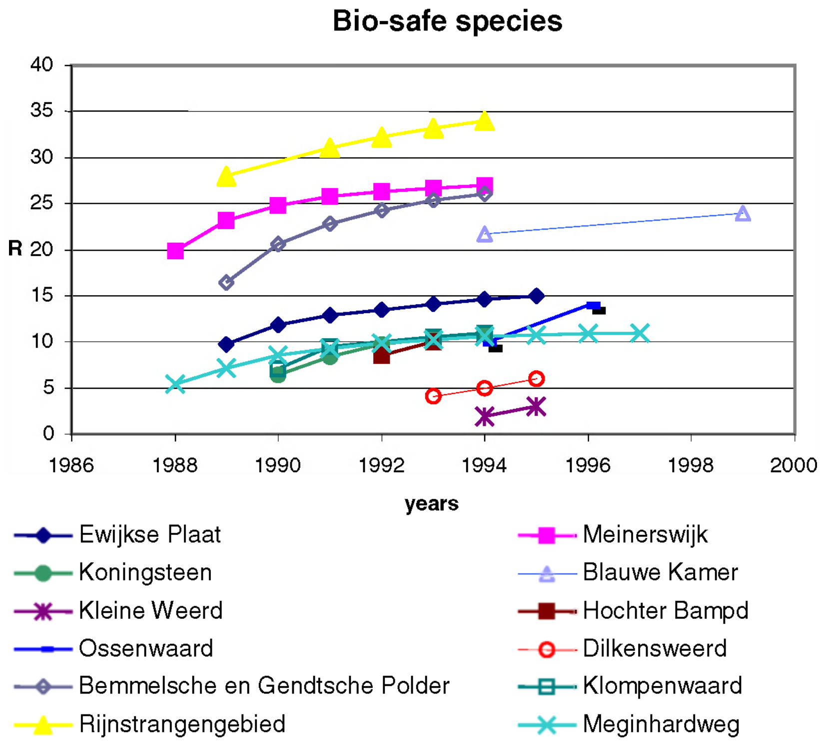

Figure 2. Cumulative species richness (R) of protected and endangered bird species in ecological rehabilitated floodplains along the rivers Meuse and Rhine.

In most study sites the number of bird species quickly reached a meta-stable equilibrium. Graphs of cumulative species richness indicate relatively high species turnover rates (Fig. 2). Fig. 3 shows the relation between cumulative species richness of breeding birds and surface area of reed marshes in floodplains of the Gelderse Poort. The species pool of reed marshes saturated at about 35 ha. Table 1 summarises data on minimum surface areas required for saturation of species pools of various riverine ecotopes.

Ecotope type	Total surface area available (ha)	Surface area required for species saturation (ha)
Open water	1613	680
Grassland	409	83
Forest	288	200
Reed marsh	96	34

Table 1. Surface area of various riverine ecotopes in floodplains of the Gelderse Poort required for saturation of the species pool.

Discussion

The number of endangered and protected breeding bird species in the Dutch river district strongly decreased over the period 1973-2000, due to deterioration and fragmentation of their habitats (e.g. as a result of land use changes and physical reconstruction of floodplains). Ecological rehabilitation of floodplains had positive effects on species diversity of breeding birds. However, species turnover rates in rehabilitated sites were high owing to vegetation succession. Some protected and endangered species were also negatively affected by floodplain rehabilitation (e.g. species associated with wet grasslands such as Black-tailed Godwit, Common Redshank). Decrease of these species was caused by succession of wet grasslands into herbaceous vegetation, shrubs and soft wood forest. Preliminary results of multivariate analyses revealed that bird diversity was strongly correlated with habitat availability (surface area) and landscape heterogeneity (Houlliere, 2003). Other studies also showed that distribution of species associated with reed-dominated marshes (e.g. Great Bittern and Great Reed Warbler) was strongly limited by habitat availability and fragmentation (Foppen, 2001). Habitat quality (e.g. sediment and soil contamination) limits the distribution of birds of prey, such as Little Owl and Kestrel (Kooistra et al., 2001). Abundance of herbivorous waterfowl was significantly correlated with nutrient contents in river water, flooding regime and winter temperature (Schaap, 2003).

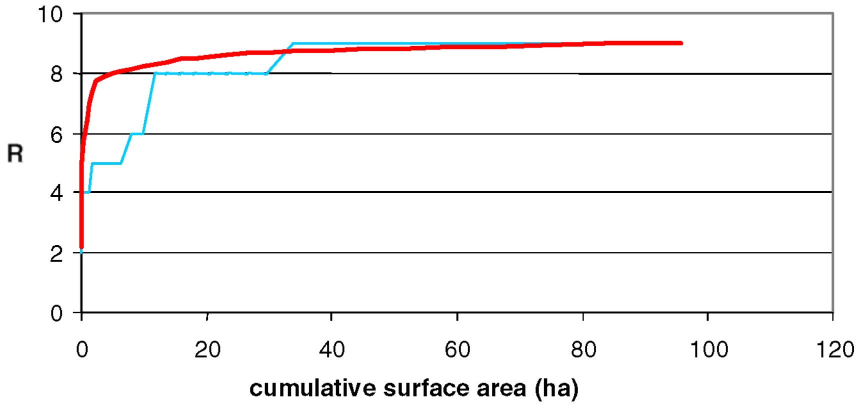

Figure 3. Breeding bird diversity – surface area relations for reed marshes in river floodplains of the Gelderse Poort (Blue line: arranged from small to large ecotope patches; Red line: average of 50 random samplings).

In spite of numerous ornithological surveys in the Dutch river district, it appeared to be very difficult to construct a consistent database on long-term landscape dynamics in relation to the distribution of breeding birds. Cumulative species richness – habitat surface area graphs are very useful for guidelines for floodplain reconstruction. Future research will focus on development and validation of GIS-based models for the evaluation of effects of riverine landscape dynamics on presence, abundance and population viability of (breeding) birds. These models must be suitable for integration in decision support systems for river management and will particularly be used for the evaluation of strategies for cyclic floodplain rejuvenation and multiple spatial planning. Remote sensing techniques and additional field surveys will have to be performed to acquire consistent data on spatial patterns and trends of (breeding) birds in relation to landscape ecological factors (e.g. availability, quality and configuration of habitat, land use and flooding regime).

Conclusions

Recently, a strong decline in the number of red listed breeding birds has been observed in the Dutch river district due to habitat deterioration and fragmentation. Ecological rehabilitation yields positive effects on bird diversity in river floodplains. However, breeding bird communities still show high species turn over rate, due to vegetation succession. Negative effects of rehabilitation measures have been observed for species associated with wet grasslands. GIS-based models for ecological impact assessment of multiple spatial planning and cyclic floodplain rejuvenation strategies require validation of species-habitat-ecotope algorithms.

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Developing integrated water system models from a groundwater perspective - case Water Board Regge and Dinkel groundwater model

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Water management in the Netherlands is focused on the water system as a whole (integrated water management). Management tools need therefore be available for integrated water system management, for example to provide detailed information for GGOR (target groundwater and surface water regime). However, the models on which management tools can rely, are far from integrated. Surface water and groundwater modelling are different worlds, most importantly due to the temporal and spatial discretisation differences. Groundwater flows slowly throughout the whole subsurface (3D), while surface water flows much faster usually in predefined channels (1D/2D). In many surface water models the groundwater interaction is modelled with an average infiltration or drainage flux, in which groundwater dynamics are not included. In groundwater models, on the other hand, the surface water component consists usually of stationary river stages as static boundary conditions.

This study focuses on integrated water system model development in order to fulfil the need of regional water managers for detailed, regional models. As in the Netherlands discharge is strongly dominated by groundwater, to start from a groundwater perspective is a natural choice. The case study of the Water Board Regge en Dinkel groundwater model will be used to exemplify the current status of our research.

The water board Regge en Dinkel (WRD) has asked the groundwater department of TNO-NITG to develop a state-of-the-art groundwater model to support their (ground)water management. The regional WRD groundwater model has a 100 * 100 m horizontal discretisation and 3 model layers (quasi 3D). Four different model variants exist in relation to the temporal discretisation: 1) stationary, 2) 1-year duration (representative meteorological year) with 14-day time step, 3) 10-year duration (1991-2000) with 1-month time step, 4) 1-year duration (1998) with 1-day time step. In the case of the research presented here, the latter (1998-model) is of special interest.

The WRD groundwater model is developed in MODFLOW. The latest developments in groundwater modelling are incorporated in the WRD model. With respect to our intents to develop an integrated water system model, the most important development is a new technique to obtain the stages of small channels and ditches.

Usually in surface water modelling only about 20% of the watercourses is explicitly taken into account. The remaining 80% is modelled with lumped parameters. By doing so, the non-linearity of the water system receives too little attention. Modelling of groundwater discharge becomes a ‘fitting’ procedure, as the exact moments that channel reaches contribute to the catchment discharge are unknown. Besides this, local convexity between smaller channels is not taken into account. For GGOR, for example, this local information is of great importance.

In the WRD model the stages of all channels are incorporated. For the larger channels (canals and channels managed by the water board) measured stages were available. The stages of the smaller channels are retrieved from elevation information. For this purpose, we developed the AHN filtering technique consisting of three steps. In step 1 noise and non-hydrological structures are removed using image analysis techniques. In step 2 we scale up from 5 * 5 m to 25 * 25 m. During this step at known locations of channels and ditches (from topographic information; Top10Vecor) we select the 10% percentile during upscaling instead of the median value, in order to detect the water level instead of the average surface level. In step 3 the water levels are smoothed to prevent ‘bumpy’ levels within individual reaches.

The advances of using stages of all channels in the groundwater model can be seen in Fig. 1 and 2. Fig. 1 shows the groundwater levels in WRD at a winter and summer moment. Clearly in winter more channels are active in the water system than in summer, where there is much less spatial detail in the groundwater levels.

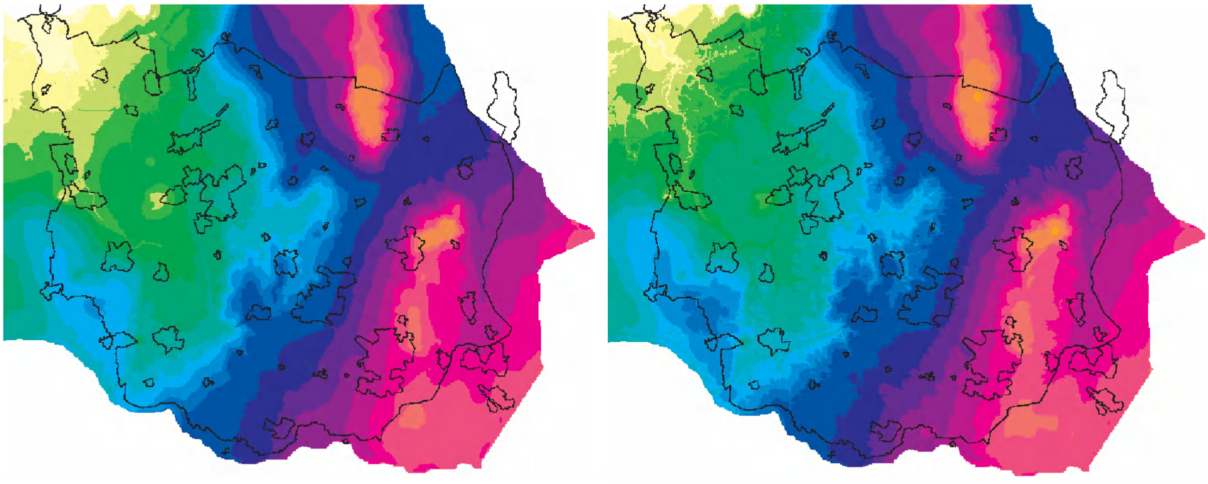

Figure 1. Groundwater levels in summer (left) and winter (right) in Water Board Regge en Dinkel (colour scale: white: 0 m. orange: 60 m.).

Fig. 2 shows modelled discharge versus measured discharge for a sub-catchment in the WRD area. The resemblance is striking, especially considering that no calibration or fitting to discharge measurement was used during the modelling process. Imperfections can be seen especially in the falling limb of discharge peaks, where the model does not lower fast enough. Most probably, this is due to the fact that no routing and surface storage (re-infiltration) is taken into account.

In order to improve the model and especially the discharge prediction, there are several possibilities. First of all, routing will be incorporated in the model. Promising experiments are being carried out with the stream-package of MODFLOW. Furthermore, the description of the unsaturated zone and surface processes as infiltration and surface storage will be improved in the model. Last but not least, we have started with non-steady calibration on head and discharge measurement, especially to decrease the uncertainty in the resistance values of the channel bottom. In this way, we expect to further expand our groundwater modelling approach to an integrated water system modelling approach.

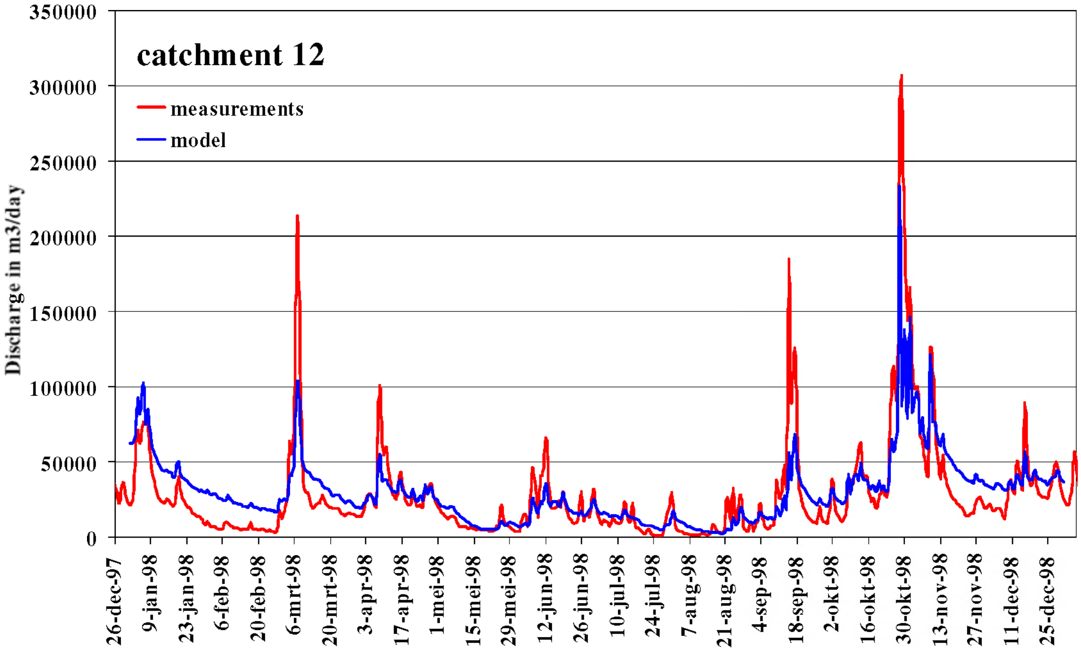

Figure 2. Discharge prediction and measurements for a sub catchment of the Regge en Dinkel area.

Mapping of vegetation characteristics using lidar and spectral remote sensing

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Abstract
The spatial distribution of vegetation characteristics is an important factor in floodplain hydraulics. In the Netherlands, these characteristics are currently mapped based on manual interpretation of aerial photographs. Lidar (LIght Detection And Ranging) provides a fast and detailed alternative. The aim was to compare the structure of the lidar derived point cloud with field measurements of vegetation height and density. We collected lidar data at different flying heights and with different gains, focussing on low vegetation, which is the dominant type in Dutch floodplains. Regression equations for vegetation height and density are given.

Introduction
The distribution of vegetation structural characteristics and inherent roughness is the main knowledge gap in hydraulic modelling of floodplains (Cobby et al., 2001). Vegetation slows down water flow, thereby creating higher water levels and increasing the flood risk. Dynamic management of floodplains induces succession of floodplain vegetation. This leads to a high spatio-temporal variation of vegetation structural characteristics, i.e. vegetation height and density. To provide hydraulic modellers with input, the spatial distribution of vegetation characteristics is needed. To catch up with succession the method of vegetation mapping has to be detailed and fast.
Lidar (LIght Direction and Ranging) is such a detailed and fast technique for vegetation mapping. Lidar scans the surface under a helicopter and generates a cloud of data points in a local coordinate system. Some of these points represent the ground surface, others the vegetation, see Fig. 1. Two parameters influence the distribution of the points in the data cloud: (1) the flying height and (2) the gain (Wehr and Lohr, 1999). Gain defines the amount of amplification of the return signal at the receiver in the helicopter. Low flying height and a high gain increase the intensity and therefore increase the chance of detecting the top of the vegetation. However, no method existed to map vegetation characteristics from lidar data.

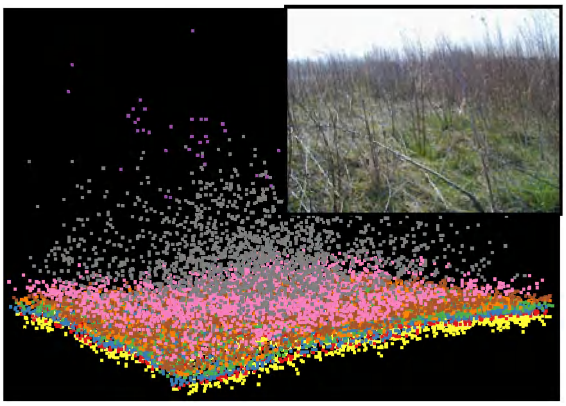

Figure 1. 3D Lidar and field image of herbaceous vegetation. The lidar data represent a box of 15 by 15 by 2 m.

Our main question is: can vegetation height and density of low vegetation be predicted using lidar for homogeneous areas. We focussed on low vegetation, as this is the dominant vegetation height in Dutch floodplains. We subdivided into three sub questions:
1. What is the effect of data segmentation in ground and vegetation points on the prediction of vegetation characteristics?
2. What is the effect of flying height and gain on the prediction of vegetation characteristics?
3. What do semi-variograms tell about the spatial distribution of vegetation characteristics?

Data and data processing
In a study at the Gamerense Waard floodplain, the following data is gathered:
- Summer 2002: True color and color infrared images at a 20 cm resolution;
- March 26, 2003:
  - FLI-MAP Lidar data flown at 70 m height, normal gain, 30 points/m^2;
  - FLI-MAP Lidar data flown at 50 m height, maximum gain, 20 points/m^2;
  - Field reference of vegetation height and density data at 47 locations in 15 by 15 m blocks.

	Regression equation	adj. R^2	SE
Unsegmented data	$Hv = 0.022+1.05D_{95}+0.21Sk-0.0097Kurt$	0.82 (0.55)	0.22 (m)
	$Dv = -0.479-0.521D_{99.8}+2.23D_{80}+0.0075CV$	0.56	0.0595 (m/m^2)
Segmented data	$Hv = -0.338+2.53D_{70}+0.00645CV$	0.82 (0.40)	0.24 (m)
	$DV = -0.123+1.5D_{50}-0.216D_{99}-0.414D_{99.8}+0.3Range+0.0043CV$	0.62	0.056 (m/m^2)

Table 1. The effect of data segmentation on prediction of vegetation height and density.
Abbreviations: Hv = Vegetation height (m), Dv = Vegetation density (m/m^2),
SE = standard error of the estimate, Norm. SE = SE divided by the average (-),
Sk = Skewness, Kurt = Kurtosis, CV = Coefficient of variation, SD = Standard deviation.

FLI-MAP is the lidar system of Fugro-Inpark. Lidar data processing consisted of:
1. Selection of data points within field plots using a quadtree indexing to facilitate processing of large volumes of data;
2. Data segmentation in ground and vegetation points;
3. Calculation of 25 statistical parameters for each field location based on:
   a) Segmented and unsegmented data;
   b) Data collected at high altitude and normal gain and low altitude and high gain.

In subsequent multiple linear regression analyses, vegetation height and density as measured in the field were regressed to the lidar derived statistical parameters. The results were checked for co linearity.

Multiple linear regression equations
Predictions of vegetation height from segmented and unsegmented both data have an explained variance of 0.82, but the predictors differ, see Table 1. The field data also showed two types of outliers, see Fig. 2: (1) a cluster of short grasses with a height lower then 10 cm and (2) one outlier with a vegetation height 80% higher the second highest point. The explained variance with the outliers left out dropped to 55 and 40% for unsegmented and segmented data respectively.

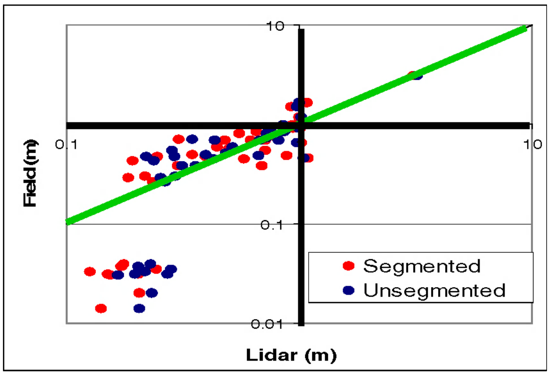

Figure 2. Log-log scatter plots of field and predicted vegetation heights using equation in table 1. Lidar overestimates vegetation heights of very short vegetation.

The explained variance for both vegetation height and density are higher for the data collected at a low flying height and a high gain, while the predictors are the same (Table 2). Semi-variograms for segmented data fit to a nugget model, whereas for unsegmented data they fit to an exponential model. The sill of the semi-variogram of the unsegmented data is 20% of the nugget of the segmented data.

Discussion
Data segmentation affects the parameters that predict the vegetation height. No difference in explained variance was found for the two methods. For unsegmented data the skewness, kurtosis and 95 percentile are the strongest predictors. All describe the tail of the vertical distribution.

	Regression equation	adj. R^2	SE
High altitude, normal gain	$Hv = 0.612+8.5D_{70}-5.3SD$	0.41	0.26 (m)
	$Dv = 0.126-0.0165Sk+5.3*10^{-4}Kurt$	0.073	0.045 (m/m^2)
Low altitude, high gain	$Hv = 0.33+2.52D_{70}-1.64SD$	0.80	0.15 (m)
	$Dv = 0.212-0.169Sk+0.282Kurt$	0.75	0.023 (m/m^2)

Table 2. The effect of flying height and gain on prediction of vegetation height and density, based on segmented data (for abbreviations, see table 1).

For segmented data, the 70 percentile and the coefficient of variation are the strongest predictors. This is as expected as the variation in the lidar point cloud increases as the vegetation height increases. The vegetation density is predicted using many different vegetation parameters. No clear difference is present in the regression equations between segmented and unsegmented data.

The cluster of data points with low vegetation heights (see Fig. 2) is caused by the segmentation method. The method classifies too many points as vegetation. Different methods of data segmentation exist (Sithole & Vosselman, 2003). It is unlikely though that any method can detect vegetation heights of 2 to 3 cm since even non-vegetated areas have a 20 cm wide band of scatter which all represent the ground surface.

The effects of low flying and a high gain are very positive. The explained variances for the predicted vegetation height and density both increase for a lower flying height and a high gain. These relations are based on eleven points. The increase is significant. The individual effects of low flying or a higher gain could not be established.
Semi-variogram parameters do not show any relation to vegetation height or density. We believe this would only show with a point density of 500 points/m^2, because in that case the point spacing of lidar points representing the vegetation would coincide with a typical stem spacing of herbaceous vegetation.

Conclusion

We have made a first step to provide hydraulic modellers with input of vegetation characteristics of floodplains based on lidar data. Contrary to previous studies (Asselman, 2002) we found strong correlations between lidar and field data. For homogeneous areas, the relations in Table 2 should be used to derive vegetation height and density from lidar data. These relations are valid for segmented data and should be collected by flying at 50 m high and with a maximum gain. The relations are calibrated for a vegetation height range between 39 and 149 cm and vegetation density between 0.016 and 0.155 m/m^2. Spectral remote sensing could further improve the mapping by eliminating the lowest vegetations from further processing.

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Alien amphipod invasions in the river Rhine due to river connectivity: a case of competition and mutual predation

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Introduction

Each river basin harbours a characteristic flora and fauna, including species that remain endemic due to biogeographical barriers isolating the populations in the watersheds. Linking river systems by constructing waterways leads to mixing of species and to new interactions between species in the food web (Bij de Vaate et al., 2002; Van der Velde et al., 2002). Competition between invasive and indigenous species can cause a decrease in the densities of indigenous species and changes in the community structure, and can even change the functioning of food webs. The outcome of competition depends on the behavioural, physiological and morphological traits of the species involved, in relation to environmental conditions and anthropogenic disturbances (Van der Velde et al., 2002; Wijnhoven et al., 2003). This means that the impact of an invader on existing food web is difficult to predict.

In Europe, a network of canals connects nearly all large rivers, so that invasions starting in eastern and southern Europe can penetrate through the canals towards other rivers. One of the latest connections to be constructed is the Main-Danube canal, which was officially opened in 1992. This canal facilitates invasions by Ponto-Caspian species, that is, species originating from the area of the Black Sea, Asov Sea and Caspian Sea, towards the river Rhine.

As a result, the number of Ponto-Caspian invaders in the river Rhine has greatly increased. The most successful of these Ponto-Caspian invaders have been amphipods (Crustacea). They have had a great impact on the Rhine food web as they have become dominant in numbers and biomass within a very short time (Van der Velde et al., 2000 & 2002; Haas et al., 2002). Subsequent amphipod invasions by gammarids and corophiids have made dominance patterns shift among the various invasive amphipod species. The indigenous species Gammarus pulex decreased in numbers after the North-American species Gammarus tigrinus, which was introduced as fish food, invaded the river in 1982. In 1989, the Ponto-Caspian mud shrimp Chelicorophium curvispinum entered the Rhine through the Mittelland Canal and became dominant in number and biomass, covering the hard substrates with muddy tubes. Another Ponto-Caspian amphipod, Echinogammarus ischnus, made its way through the Mittelland Canal to the Rhine in 1989. The Main-Danube canal enabled one of the most abundant of the current invader species, the stone-dwelling amphipod Dikerogammarus villosus, to enter the Rhine. This species is currently the largest amphipod species in the Rhine and is a strong, omnivorous predator. Since D. villosus entered the Rhine in 1995, the densities of other macroinvertebrates, including Gammarus tigrinus and Chelicorophium curvispinum, have declined, which may be due to predation by D. villosus on all kinds of macroinvertebrates, including other amphipod species, and competition for food and space with other gammarids.

Our research questions were: (a) does competition among invasive gammarids explain the replacement of these species in the river Rhine and (b) if so, by which mechanism does this competition take place?

Methods

Interspecific competition for substrate by the exotic gammarid species D. villosus, G. tigrinus and E. ischnus was tested in microcosm experiments in the laboratory. The substrates used in these experiments reflected those occurring in the river Rhine and provided

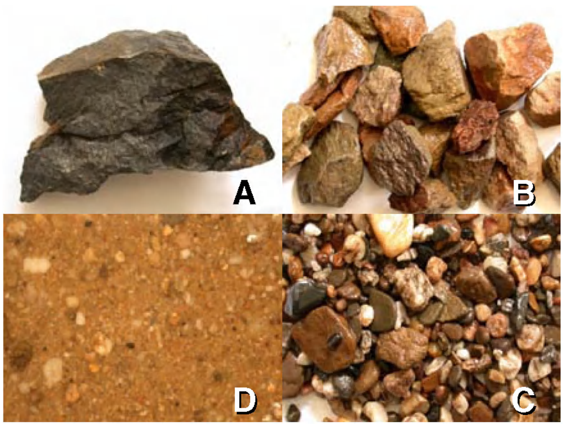

Figure 1. Substrata used in the experiment
a) groyne stone, b) stones, c) gravel, d) sand.

the species with various opportunities for and degrees of shelter (Fig. 1). Shifts in substrate preference after the addition of another species and interspecific predation were assumed to indicate interspecific competition.

Collecting Gammarid species
Dikerogammarus villosus and Echinogammarus ischnus were collected from stone substrates in the river Waal, the main Rhine branch in the Netherlands, near Nijmegen (5°48'E, 51°51'N). Gammarus tigrinus was collected from the IJsselmeer lake. All specimens were kept separately, in aerated basins (40 * 40 * 50 cm) at 15°C, with a 9/15 hours dark/light regime before being released into the experimental aquaria. The gammarids were fed chironomids during captivity.

Experimental design
The experiments were carried out in a climate room at 15°C with a 9/15 hours dark/light regime (2 36W/840TLD-lamps). Aquaria (25 * 25 * 30 cm) were filled with Rhine water and aerated. Four different types of Rhine substrate – groyne stone, stones, gravel and sand (Fig. 1) – were put into cups (Ø 11.5 cm, 6.5 cm height), which were placed in each aquarium at random. Fifty gammarids of the same species were allowed to choose between substrates. After 24 hours, the cups with substrates were collected and the gammarids inside each cup were counted and their body lengths measured from rostrum till telson. In addition, we established the number of gammarids that had been consumed. The experiment was repeated for combinations of G. tigrinus with D. villosus and E. ischnus with D. villosus. In these mixed experiments, 50 individuals of G. tigrinus or E. ischnus were allowed to hide for 2 hours before 50 individuals of D. villosus were added.

Results
In the absence of other gammarid species, all species preferred stones (Fig. 1b). In the presence of D. villosus, G. tigrinus shifted from its preferred stone habitat to gravel and sand. D. villosus, however, remained at its preferred stone substrate once it has established itself

Species	G. tigrinus consumed	D. villosus consumed	E. ischnus consumed
G. tigrinus	0.38 ± 1.41	2.00 ± 0.60	-
D. villosus	26.80± 4.66	5.57 ± 1.41	7.43 ± 1.32
E. ischnus	-	5.14 ± 2.03	4.14 ± 0.85

Table 1. Interspecific and intraspecific predation (mean percentage of individuals consumed ± SE; each experiment repeated 14 times). - = no data.

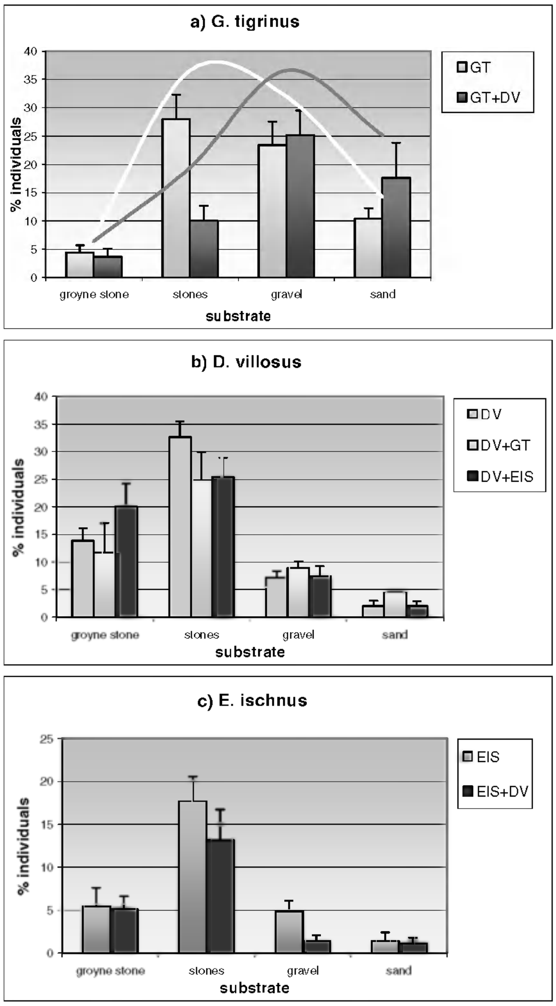

Figure 2: Substrate preference of (a) Gammarus tigrinus, (b) Dikerogammarus villosus and (c) Echinogammarus ischnus in the absence and the presence of a second Rhine invader (DV = D. villosus, EIS = E. ischnus, GT = G. tigrinus).

and displaced G. tigrinus (Fig. 2a,b). These results indicate direct competition for substrate between the two invasive species, with D. villosus being the strongest competitor. Competition between D. villosus and G. tigrinus was characterized by a high level of predation on G. tigrinus (Table 1).
As neither D. villosus nor E. ischnus changed their substrate preference in each other's presence (Fig. 2b,c), and their mutual predation did not increase (Table 1), a direct competition between these Ponto-Caspian invaders is unlikely.

Conclusions
Connecting river systems leads to mixing and interactions among species. Interspecific competition for substrate and mutual predation determines the colonization success of a gammarid species in the ecosystem. Increasing the heterogeneity of the ecosystem

provides chances for weak competitors to survive. Once rivers have become connected, and exotic species have successfully colonized a new ecosystem, these species become important residents, often dominating in terms of numbers and biomass. They should therefore be taken into account in water quality assessments. Continuous biomonitoring provides insight into the development of populations of macroinvertebrates in the Rhine, allowing new invaders to be discovered. Ecological field and experimental studies are necessary to examine the ecology of these species and to predict the impact of these invaders.

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Data-driven modelling in context to sediment transport

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Abstract
Artificial neural networks (ANN) have been used to develop a sediment transport model using measured data for predicting total transport rates. During the initial modelling attempts with a relatively small dataset it has been observed that the predictive accuracy of the ANN model is better than that of the models of van Rijn and Engelund-Hansen.

Introduction
It is essential to have a reasonable estimate of sediment transport in context to several water management issues. The transport mechanism is utterly complex and the available deterministic transport models have been developed with simplifying assumptions that often leads to large-scale prediction errors. An alternative may be a data-driven modelling approach that is particularly useful in modelling processes about which adequate knowledge of the physics is not available. In the present paper a methodology for developing data-driven models of sediment transport using artificial neural networks (ANN) is presented. The predictive accuracy of the ANN model is compared with that of the models of van Rijn and Engelund-Hansen.

Modelling
The parameters controlling a transport process can be described as:

$$q_t = f(u, h, D, S, g, \rho_s, \rho_w, \mu) \qquad (1)$$

where, u = velocity, h = depth of flow, D = particle size (mainly D_{50}), S = energy slope, g = acceleration due to gravity, ρ_s = density of sediment, ρ_w = density of water, μ = kinematic viscosity and q_t = total transport rate. Based on this information the input variables to the model were chosen as: {u, h, D, S}, leaving aside the other nearly constant variables. The output of the model was chosen as q_t.

Data from a series of laboratory experiments conducted at the USWES (1935) was considered. Data points with a specific gravity 2.65 were considered. Frequency distribution of the output variable (q_t) revealed a non-uniform distribution of data. Most data-driven modelling methods perform well when the data has a distribution close to the normal. A (natural) log transformation of q_t showed a distribution much closer to the normal and therefore, was adopted. The distributions of the input variables were close to the normal and so the inputs were not transformed. The training and testing datasets were formed with 2/3rd and 1/3rd of the total data points respectively. In data-driven modelling it is important to maintain (nearly) equal statistical distribution in the training and testing data. Data exploration revealed that selection of two consecutive data points for training followed by one data point for testing would ensure closer distribution between the training and testing dataset and accordingly, was chosen. In total there were 513 and 255 data points for training and testing respectively.

A Multi-Layered Perceptron network trained by the back-propagation algorithm was used for the ANN modelling. The hyperbolic tangent function (bounded between –1 and +1) was used for the hidden layer with linear transfer functions at the output layer. The number of nodes in the hidden layer was set as an optimisation parameter and was found as 7.

Preliminary results
The transport rates predicted by the ANN model on the testing dataset were found to be reasonably accurate (Fig. 1). A large scatter outside the lines of 2-times and 0.5-times measured transport rates were observed in the rates predicted by the models of van Rijn (Fig. 2) and Engelund-Hansen (Fig. 3) whereas in case of the ANN model the predicted rates

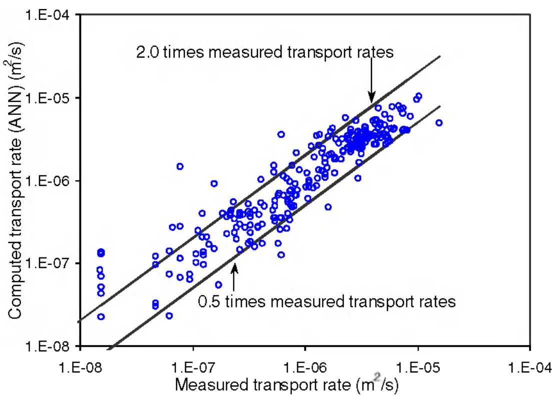

Figure 1. A comparison of the total transport rates predicted by the ANN model with the measured transport rates.

	Training			Testing		
	RMSE 10^{-7} m^2/s	NRMSE	r	RMSE 10^{-7} m^2/s	NRMSE	r
Van Rijn	50.8	0.935	0.63	51.5	0.924	0.66
Engelund-Hansen	28.8	0.799	0.71	31.8	0.815	0.68
ANN	12.1	0.623	0.85	11.9	0.623	0.85

Table 1. Training and testing statistics of the different models.
(RMSE: Root mean square error, NRMSE: Normalized root mean square error, r: Coefficient of correlation).

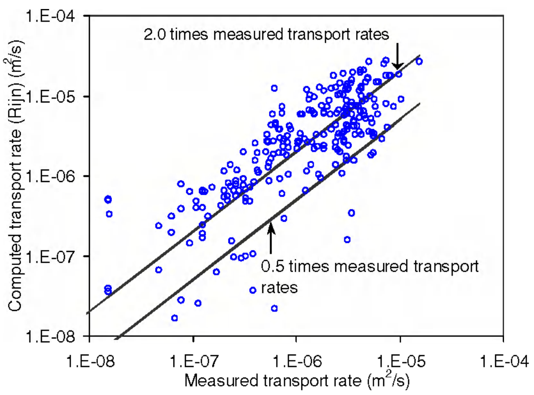

Figure 2. A comparison of the total transport rates predicted by the van Rijn model with the measured transport rates.

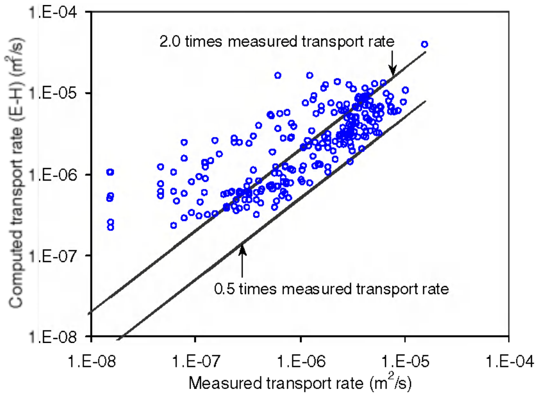

Figure 3. A comparison of the total transport rates predicted by the Engelund-Hansen model with the measured transport rates.

were mostly within these lines. Table 1 presents the superiority of the ANN model.

Conclusions

The predictive accuracy of the data-driven model built using an ANN was found to be better than that of the models of van Rijn and Engelund-Hansen. However, the dataset used was small and did not cover all transport ranges. Also the model was not tested with any field data. More research is needed to explore the effectiveness of a data-driven model in context to sediment transport.

Currently, a huge dataset comprising of flume as well as field data covering many transport and flow ranges is being used to build data-driven models for predicting transport rates.

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Environmental impact assessment study for the Common Meuse (MER Grensmaas 2003)

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Background

The Common Meuse Project is one of the most radical river management projects of modern history. Over an almost continuous length of 40 km, ecological rehabilitation projects, river widening measures and flood channels are planned to be realized in the coming 15 years (Fig. 1). The Common Meuse is the border between Belgium and the Netherlands. The objectives of this project are flood defence, nature rehabilitation and gravel mining. In this newly created ecological area with forests, brushwood and gravel islands, traditional species of animals and plants, which have vanished in the past century, are expected to return.

The Project Organization "De Maaswerken" assigned the Royal Haskoning and Meander Consultancy and Research combination for the Environmental Impact Assessment (EIA) Study 2003 (parts: 'River Management' and 'River Morphology'). The combination executed these studies, wrote the EIA Reports and participated in the presentation of the results to the citizens.

River Management Study

The River Management Study comprised the research of hydraulic effects of the intended river measures. Therefore a 2-dimensional modelling system (WAQUA) was applied (Fig. 2). The model covers 247 km of the Meuse River: from Eijsden (Belgian-Dutch border) to Keizersveer.

For this study six model variants, representing future scenarios, were composed (Autonomous Development, Preferred Alternative and four design variants) and approximately 200 hydraulic simulations (stationary discharges and dynamic flood waves) were carried out for different sets of boundary conditions.

The model results were used to assess the effects of the measures on water levels and flow velocities under different conditions (i.e. daily, bankfull, design and extreme conditions).

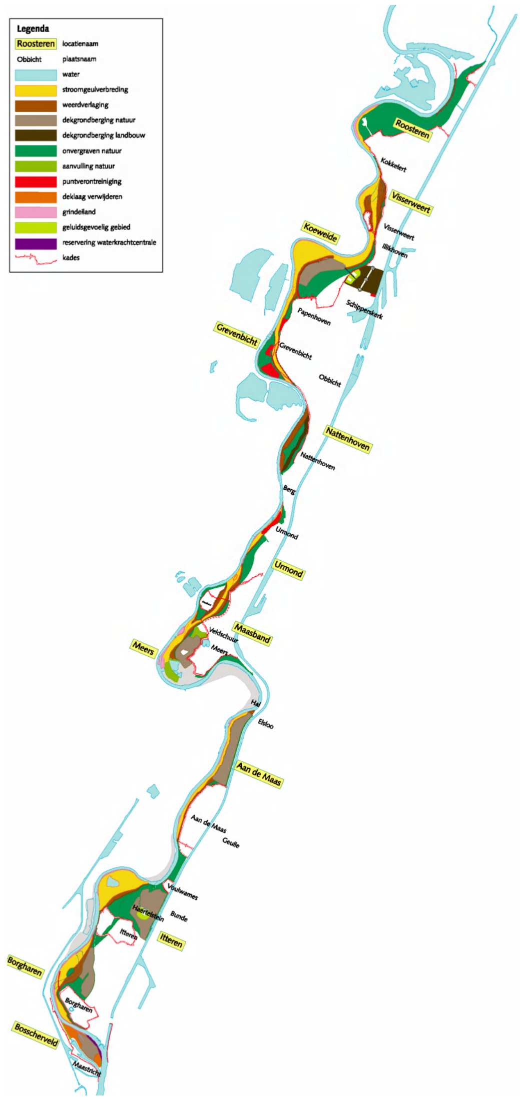

Figure 1. Overview of the project area (Preferred Alternative).

Locally the intended measures showed a water level reducing effect of more than a meter. The model results supported other parts of the EIA Study of the Common Meuse, such as Morphology, Ground Water, and Water Quality as well.

Morphological Study

Morphological desk study

The Morphological Study was split in two parts. The first part was a desk study, in which the short-term effects (5 to 10 years) of the Common Meuse Project on the river morphology were assessed by using the 2-dimensional computational results (WAQUA).

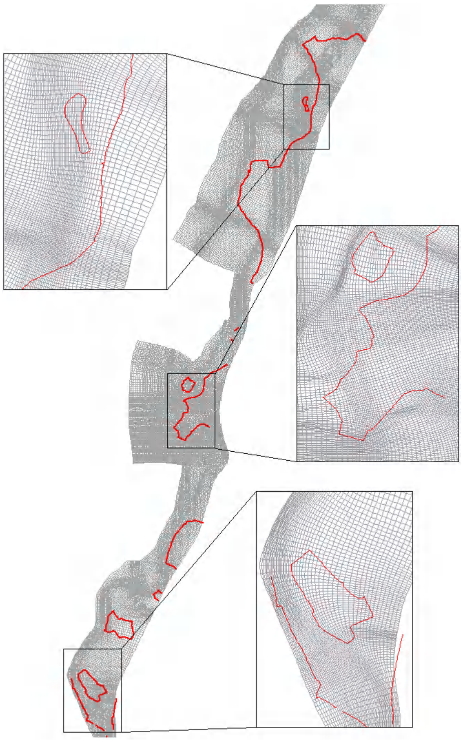

Figure 2. The computational grid (WAQUA) of the Meuse (embankments in red)

By analysing the actual and critical shear stresses (under different conditions) morphological tendencies were signalised. Important themes of study were bed stability, bank stability, the position of the river axis and morphodynamics in general. The bed and bank stability is a very important subject of analysis in the 'bottlenecks': the original (relatively) narrow river channel between two successive widened locations. An important aspect of the river morphology in the Common Meuse is the armouring process of the riverbed, caused by selective sediment transport. The riverbed sediment in this river is strongly graded. The results of this analysis supported the design of bed and bank defences; required lengths and size of the rock material could be estimated. Other subjects were the sequence of realisation of the works and the risk of silt precipitation in the stagnant zones.

Morphological modelling (SOBEK-graded)
The second part of the Morphological Study was supplementary to the first part, and dealt with long-term (up to 100 years) predictions of the riverbed development for different future scenarios. For this purpose the 1-dimensional hydraulic and morphological modelling system SOBEK-graded was applied. The program takes the gradation of the riverbed material as well as vertical differentiation of the bed material (in layers) into account. Both characteristics are relevant: the riverbed material consists of a mixture of sand and coarse gravel, and the geological profile in this area shows significant vertical differences. On several locations layers of coarse gravel cover layers of fine sand.

In total, six model variants were composed:

- Autonomous Development, for the prediction of the morphological developments without execution of the Common Meuse Project;
- Preferred Alternative, for the prediction of the morphological developments after execution of the Common Meuse Project;
- Two design variants, in which the depths of the widening measures and flood channels were designed 0,5 meter less and more with regard to the Preferred Alternative, respectively;
- Two historical reference situations: 1978 and 1987, used for the morphological calibration of the model, the extensively monitored time span of 1978-1995 was simulated for this purpose.

For the 100 years' simulations four discharge scenarios were considered (historical discharges, based on the hydrograph of 1911-1998; high discharges, based on the eighties; low discharges, based on the seventies; average discharges, based on the fifties). The sensitivity of the riverbed development for the discharge regime is significant.

The simulations for the Autonomous Development show a continuous riverbed erosion (Fig. 3).

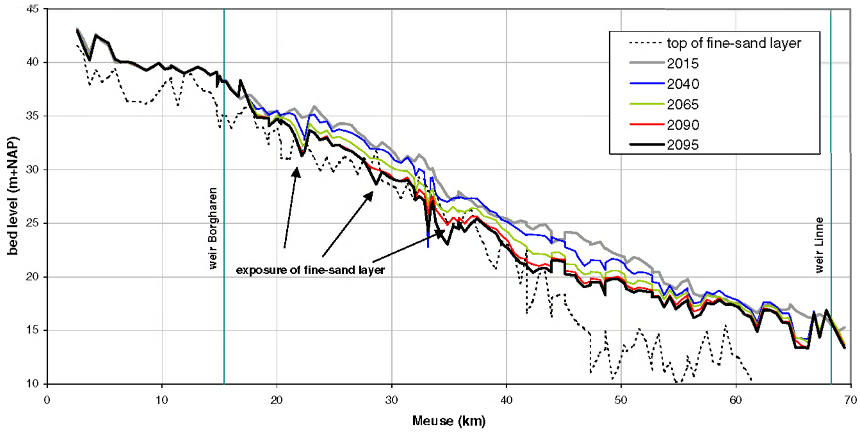

Figure 3. Riverbed development (Autonomous Development, historical discharge scenario).

At some point, the fine-sand layers will be reached, and the riverbed erosion will accelerate. The most important result of the study is the conclusion that beside several local erosion and sedimentation sites, the Common Meuse Project will stop this ongoing erosion and stabilize the global riverbed, as the reduced flow velocities in the widened river channel will interrupt the chain of passing sediment transport (Fig. 4).

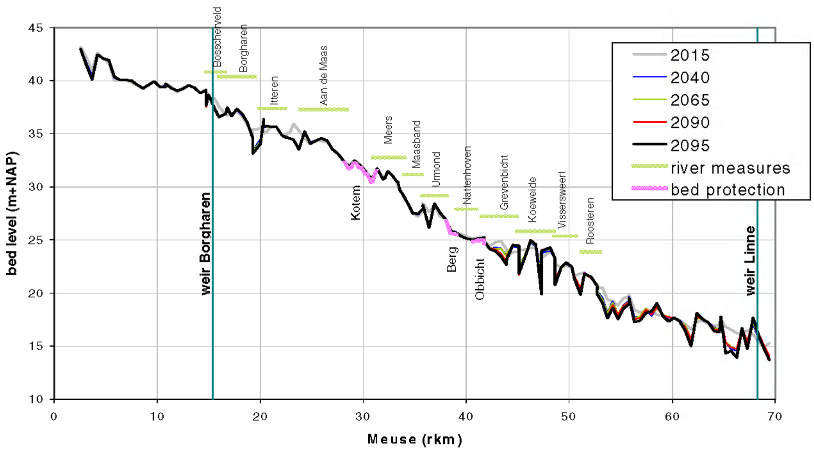

Figure 4. Riverbed development (Preferred Alternative, historical discharge scenario).

Vegetation dynamics of a meandering river (Allier, France)

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Introduction

New riverine nature management strategies focus on managing river stretches rather than individual floodplains. They combine nature and safety management. For safety management the discharge capacity of fixed rivers has to be maintained at a certain level. The floodplain vegetation relates to the discharge capacity through its hydraulic resistance. Process knowledge of vegetation patterns and their dynamics in a natural setting seemed necessary for the design of a good management strategy. The meandering process of a river creates a diversity of landscape elements in different stages of ecological succession. By erosion in the outside bend older succession stages are removed while at the same time new pioneer stages are formed on the point bar in the inside bend. In the research at hand the main research questions are:

- Is there a relation between vegetation dynamics and scale? Is vegetation type distribution stable on larger scale?
- How does the meandering process influence the vegetation distribution? What are rejuvenation frequencies?
- What is the age distribution of succession stages along a meandering river?

Material & Method

The Allier is a gravel river south of the city Moulins in the centre of France, Fig. 1.

Figure 1. Oblique aerial photograph showing the research area.

It has braided and meandering sections. The summer discharge is 20 - 50 m^3s^{-1} and peak discharge can be up to 1,000 m^3s^{-1}.

To be able to study the vegetation types on the river stretch scale (several floodplains) a GIS system was used. The use of aerial photographs made it possible to reconstruct the history of this part of the Allier.
The photo series covers the years 1954, 1960, 1967, 1978, 1985 and 2000. The photos are of scale 1:20,000. Products of the mapping process are maps as shown in Fig. 2 (year 2000 map). The legend on the right shows the mapped vegetation types.

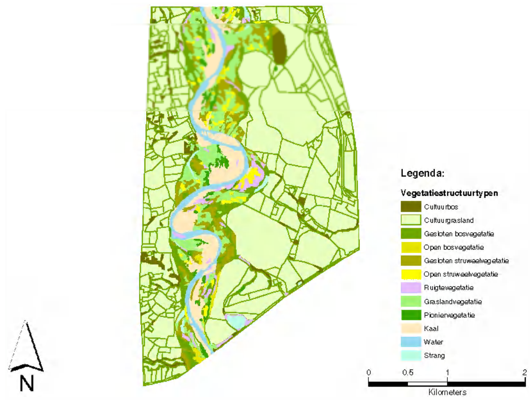

Figure 2. A produced map of year 2000.

Results

A map of floodplain age is created by overlaying in GIS the bare and water types of the different years, see Fig. 3. It shows the spatial distribution of stages of vegetation development, important for ecological diversity.

Changes seen in the landscape (Fig. 4) are quantified in change matrices.

Table 1 shows the matrix for the 1967-1978 transformation. In these matrices the rejuvenation can be read as the turnover in water & bare soil.

The surface area of vegetation types during the years is shown in Fig. 5. Especially the early succession stages grass and bare gravel are dynamic.

Sum of 67 - 78	Naar									
Van	Cultuur	Gesloten Bos	Gesloten Struweel	Grasland	Open Bos	Open Struweel	Pionier	Ruigte	Strang	Water & Kaal	Totaal
Cultuur (1023,3 ha.)	96,2	0,1	0,0	0,2	0,0	0,0	0,1	0,5	1,0	1,8	100
Gesloten Bos (46,7 ha.)	5,2	59,8	13,6	2,8	2,0	1,0	0,0	5,8	0,2	9,7	100
Gesloten Struweel (58,4 ha.	10,5	13,1	47,0	5,3	1,3	0,5	0,0	4,4	0,0	17,9	100
Grasland (170,5 ha.)	5,0	2,5	6,2	54,5	1,0	4,3	0,5	2,0	0,1	23,9	100
Open Bos (4,9 ha)	4,2	49,4	1,1	12,6	3,2	4,0	0,0	0,0	0,0	25,5	100
Open Struweel (21,9 ha.)	0,0	4,1	36,0	19,6	3,6	12,6	0,1	3,9	0,0	20,1	100
Pionier (14,3 ha.)	1,7	2,6	2,3	36,7	4,4	0,8	2,7	0,0	0,0	48,7	100
Ruigte (11,5 ha.)	41,1	10,1	11,4	10,7	0,3	11,1	0,2	3,0	0,0	12,0	100
Strang (1,4 ha.)	5,9	0,0	0,8	38,6	0,0	0,0	0,0	0,3	35,2	19,2	100
Water & Kaal (186,5 ha.)	0,3	1,7	2,7	20,1	0,3	0,5	3,6	5,1	2,5	63,2	100

Table 1. Example change matrix for the years 1967-1978. The turnover is given in percentage area per vegetation type. The absolute area is given between brackets in the first column.

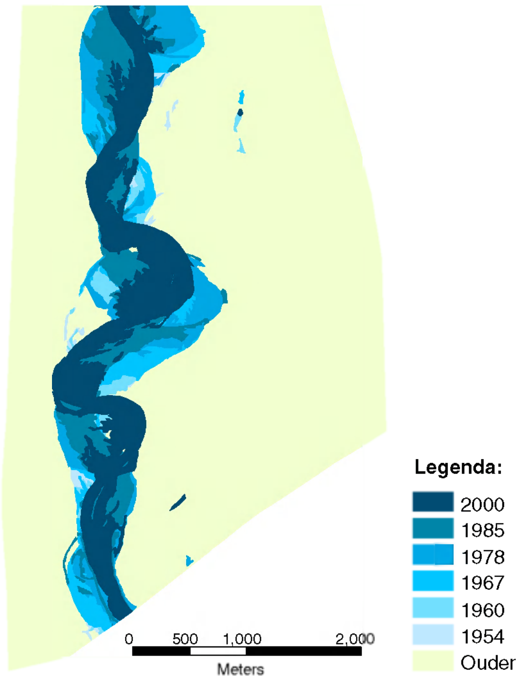

Figure 3. The age distribution of Allier floodplains.

Discussion & Conclusions

Along a natural river one will find patches of vegetation and side channels of various ages and in different stages of succession. Important is to notice that the spatial heterogeneity on the small scale may look like chaos, but seen on the larger scale the system is quite stable. Continuous succession and disturbance ensure that no place remains stable for long, although one will always find pioneer stages, full grown softwood forests or closed side channels on the river stretch scale. In the ideal situation, the overall vegetation composition (and hydraulic resistance) is constant or fluctuating between upper and lower boundaries, although it might be irregularly fluctuating on the floodplain scale. As a consequence, the scale on which management by rejuvenation will work is that of a river stretch because only then enough natural elements are present for a dynamic, stable and ecologically rich system.

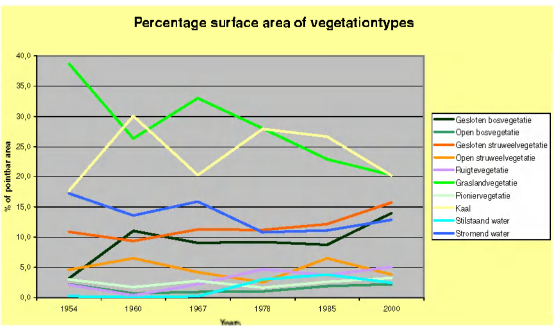

Figure 5. Percentage coverage of vegetation types of all the researched years.

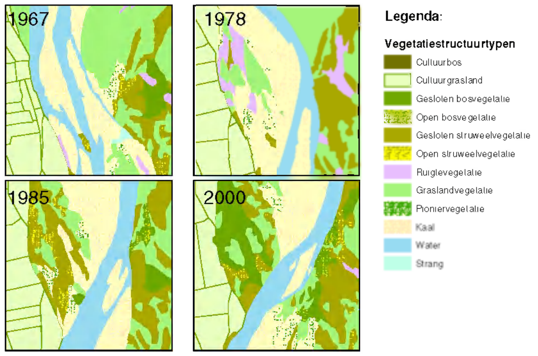

Figure 4. Detail of map sequence showing the development of one point bar.

Future research

The results presented here are preliminary. To obtain satisfying answers to the raised questions the data will be further analysed. An article will be prepared in spring 2004.

Acknowledgements

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fieldwork along the Allier river in 2002 and 2003!

Note

The Allier is researched by co-operating NCR institutes: M. Baptist (river modelling; Delft University of Technology) and J. van den Berg (river morphology; Utrecht University).

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Soil, hillslope and network structure as an opportunity for smart catchment scale hydrological models

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Introduction

It is now widely recognised that 'landscape properties' such as hillslope and catchment morphology and soil layer geometry and hydraulic properties are first order controls of the hillslope and catchment hydrological response. The spatial structure of these properties is not random in time or space, but is the result of processes like hillslope erosion and soil formation. We aim at understanding the spatio-temporal structure of hydrological relevant landscape properties by means of landscape evolution modelling. Two groups of properties can be recognised: 'geomorphological' parameters like slope gradient, hillslope width, soil cover thickness and the slope type distribution, and 'hydraulic' parameters such as hydraulic conductivity and effective porosity. Here we discuss only the first, geomorphological, group of parameters.

The Network Scale

The distribution of hillslope form types (divergent, straight, convergent) is controlled by the spatial structure of the channel network within a catchment. Here we investigate above distribution by making use of simulated 'artificial' channel networks that obey to some geomorphological rate laws. Within these networks, individual hillslope types can be mapped and their statistics calculated. The procedure works as follows:

- First, starting from an outlet node new branches are added from random directions, resulting in a random walk network (Fig. 1a). Under steady-state conditions, fluvial downcutting rate and tectonic uplift rate balance each other. By solving equations for these for 'graded' slope gradient, values for elevation can be assigned to each grid cell. The iterative addition of an additional constraint that flow from every grid cell is towards the steepest-descent neighbour results in a realistic topography and flow pattern (Fig. 1b). (This step is based on work published by Howard (1971)).
- The number and locations of channel branches entering or leaving grid nodes define the number and size of individual hillslopes (Fig. 1c).
- Mapping the hillslope types (Fig. 1d) helps in understanding the spatial patterns of these types. Although the overall distribution is rather uniform, different hillslope types are bound to certain positions. Because each hillslope type has a different hydrologic response, the catchment hydrograph is a composite of the individual hillslope hydrographs, weighted by their relative frequency. Initial hydrological modelling shows that the tail of the composite unit hydrographs is due to the contribution of convergent hillslopes. An implication of this is that low-flow conditions originate in convergent, near source topographic areas.

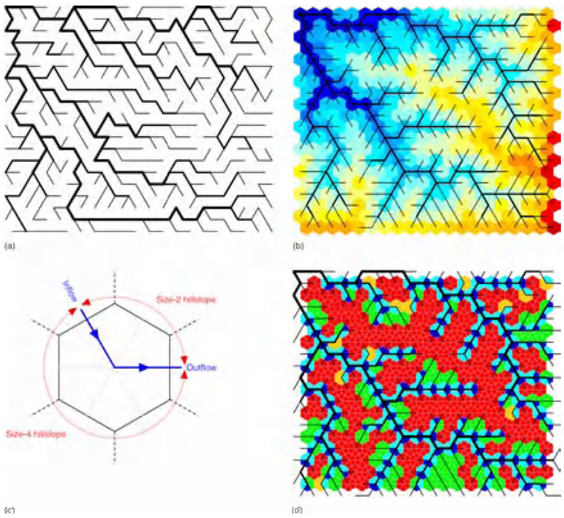

Figure 1. Procedure for mapping individual hillslope types.

The Hillslope Scale

On this scale, the hillslope morphology and the spatial distribution of soil thickness are investigated by means of landscape evolution modelling techniques, in combination with random-walk network techniques described above. The procedure operates as follows:

- A 'virgin'-landscape can be constructed by first crafting a random walk / steepest descent network (similar as for 'the network scale' above).
- Then this topography is smoothed by a long period of diffusive processes like soil creep and shallow mass wasting. These processes are modelled with a non-linear diffusion model: it is assumed that soil cover

is non-limiting. The resulting topography is shown in Fig. 2a. Next, soil formation rate is modelled as an exponential decrease with soil thickness. The resulting soil thickness map is shown in Fig. 2b. It is assumed here that the channel network contracts, and first order channels fill in. This step draws from published landscape evolution-modelling techniques such as published by Tucker & Slingerland (1997).

- For each hillslope, data on elevation, slope gradient and soil thickness can be collected. Here it is assumed that a channel head is present at 20 grid cells downhill of the lower-right corner of the map. (Fig. 2c). Hillslope statistics like collected above can serve as input for hydrological models such as the hillslope-storage Boussinesq model (see also the contribution by Hilberts in these proceedings).

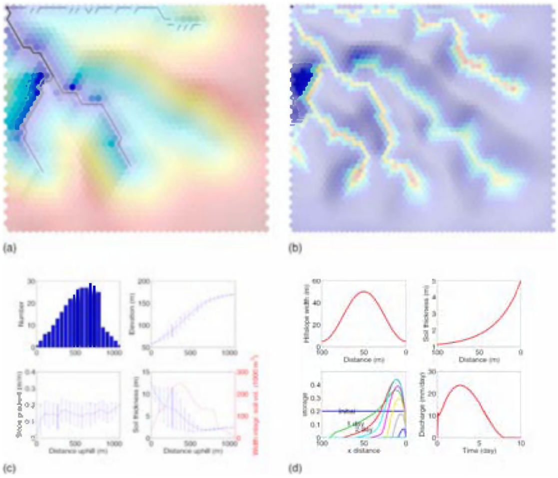

Figure 2. Procedure of landscape evolution modelling techniques.

Conclusion

The use of random-walk network and geomorphological landscape evolution models enable the study of the spatial distribution of hydrological relevant landscape properties. New generations of 'smart' semi-distributed hydrological models, such as the hydraulic groundwater theory based `hillslope-storage Boussinesq (hsB) model, (see Troch et al. (in press) and the contribution by Hilberts (in these proceedings) may exploit this understanding to parameterise the hydrological model.

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Integrated flood management strategies; A case study in the Lower Dong Nai – Sai Gon river system, Vietnam

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Introduction

The lower Dong Nai – Sai Gon river system is situated in the southwest of Vietnam and has the country's highest economic development rate. It houses Vietnam's largest population centre (Ho Chi Minh City) and has the largest concentration of industrial output. At the same time, the river basin continues to diversify its agricultural sector with products ranging from basic staples like rice and maize to raw materials for the local industry (Claudia et al., 2001). As a typical flat and low-lying transition area, it is flood prone and faces increasing damages as a result of re-occurring flood events, both from rivers as well as storm surges from the sea (Fig. 1).

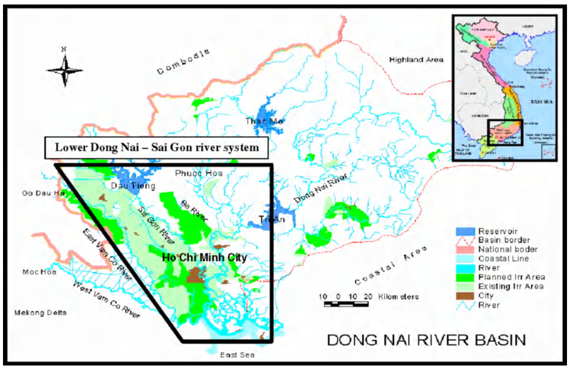

Figure 1. Vietnam and the Lower Dong Nai – Sai Gon river system.

In general, the existing flood defence structures are small and situated in a scattered order over the river basin (JICA, 1996). The dike systems are discontinuous and contain a relatively low safety standard (SIWRP, 2001). Two large reservoirs have been developed in the recent past (Dau Tieng and Tri An).

Year (freq.)	Damages			
	Houses (#)	Road (km)	Paddy crops (ha)	Cereals (ha)
1952 (1%)	7,598	13	31,270	120
1978 (10%)	1,834	20.5	8,110	203
2000 (25%)	1,100	32	6,500	100

Table 1. Historical flood damages (JICA, 1996 & SIWRP, 2001).

In the (recent) past the area experienced some exceptional floods, with return periods ranging from 1 – 25%, which brought about serious damages to private houses and properties, public facilities, agricultural crops and livestock (Table 1). During the flood season, the drainage possibilities of different rural and urban areas are severely affected.

Flood management strategies

In order to reduce flood damages and impacts, strategies have been developed with a 1-D hydrodynamic model (SOBEK-RURAL). Different (steady state) scenarios for future flood situations have been taken into account, considering both upstream runoff as well as tidal dynamics.

Flood management strategies have to comply with relevant aspects of social-economic, physical and ecological conditions in the lower Dong Nai – Sai Gon river system. Therefore, various starting points for different geographic areas have been defined (Fig. 2) (Petry, 2002):

- 'Keep the floods away from people';
- 'Keep people away from floods';
- 'Accept floods and clean up afterwards'.

After analysing flood risks, potential damages and losses for future flood situations (based on historic GIS data), flood management strategies have been derived, primarily based on the combination and complementarily of structural and non-structural measures, taking effectiveness and technical and socio-economic feasibility into consideration (Green et al., 2000).

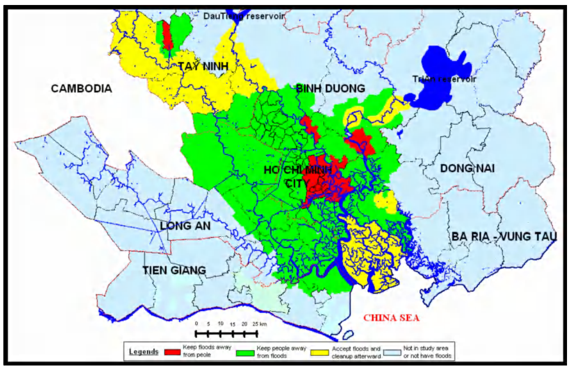

Figure 2. Spatial distribution of starting points for development of flood management strategies.

Non-structural approaches, as defined by ICID (1999), comprise activities, which are planned to eliminate or mitigate adverse effects of flooding without involving the construction of flow-modifying structures (i.e. land-use planning, preparedness and emergency and relief).

Results

In total eight different strategies have been defined, based on three conceptual approaches:

- Different principles of structural measures (discharge control, water level control and confinement);
- Compatibility between structural and non-structural measures, and;
- Spatial distribution and feasibility of various measures.

The developed strategies have been assessed and compared with a specific set of criteria, derived from studies like Hooijer et al. (2002) and Silva et al. (2001) (i.e. costs, excavation works, land-use, environmental impacts, implementation time, etc.) in order to determine a preferred strategy, which could be suitable for implementation.

The strategies can be roughly divided into three main categories: favourable, less favourable and non-favourable. The advise on favourable strategies is composed by taking existing environmental conditions (ecologically, socially and economically) of the study area into consideration. The 'storage & confinement' strategy (reservoirs, detention, dikes and embankments, and various non-structural measures) seems to be the most promising solution to mitigate floods in the lower Dong Nai – Sai Gon river system (Fig. 3).

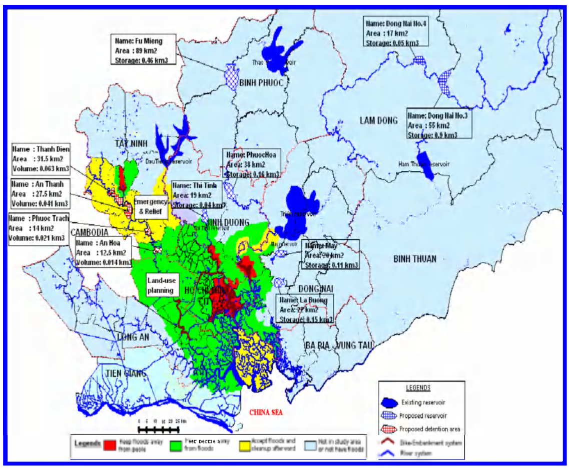

Figure 3. Spatial distribution of measures in the 'storage & confinement' strategy.

Discussion

The results indicate that the implementation of the 'storage & confinement' strategy will reduce peak water levels significantly as well as the consequences of flooding, hence potential losses and damages. Although a considerable reduction of flood impacts will be achieved, pre-established protection levels still are not fully met in many urban and economically important areas. Additional measures (e.g. drainage works, local dike and embankment systems) need to be studied and implemented as well.

As a result of lacking environmental system data, together with non-accurate hydrological data, the inter-relationships between land and water can be considered as the most important uncertainty of the study. Therefore, further (implementation) studies should consider the basin as a whole, not only in terms of the geographical and functional interdependencies involved, but also the inter-relationships between land and water as well as economic and human development.

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Integrated water resources management groupwork - case Mura river basin

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Abstract
The Mura groupwork is an integrating exercise at the end of the curriculum of the Water Management programme at UNESCO-IHE. The groupwork concentrates around the fictitious Mura river basin. Teams are selected based on creating multi-disciplinary teams that have to develop an Integrated Water Resources Management plan for this river basin. In four weeks the participants use their experience and acquired knowledge in developing this plan.

Introduction
The groupwork on the Mura river basin is a part of the curriculum of the Water Management (WM) programme at UNESCO-IHE Delft. After nine months of acquiring knowledge in many different fields, such as integrated water resource management, modelling, environmental planning, watershed management and water law and institutions, all aspects are addressed and integrated in this groupwork.

Objectives
The main objective of the groupwork is to apply experience and understanding, insight and skills gained in preceding modules to come up with environmentally and economically sustainable policy suggestions, strategic plan and practical solutions. Furthermore the participants have to learn to deal with and manage time, data and money constraints in planning. They have to learn how to work in a multi-disciplinary team and make optimal use of it, with recognizing and stimulating good leadership qualities in self and others.

The case
The Mura river basin is a fictitious river basin situated somewhere in the south-eastern Asia region in an equatorial island country called Asiatica (Fig. 1). The Mura river basin illustrates many of the severe problems typical for the region and climate in water resource management. The basin experiences severe problems such as floods, water quality problems (especially in the capital city Atra, due to lack of sanitation) and allocation

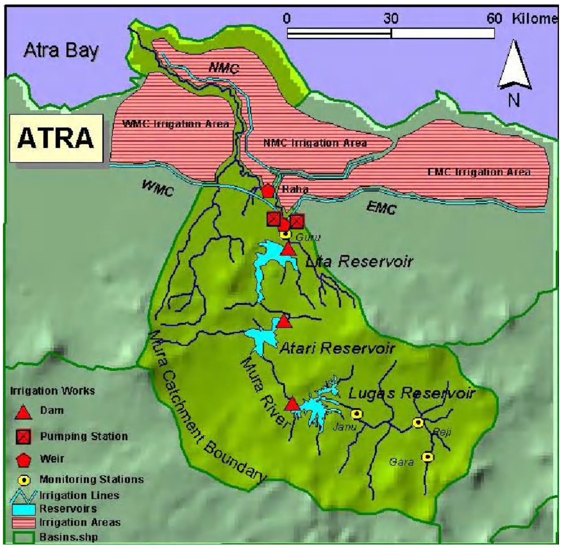

Figure 1. The Mura river basin.

problems between different water users, with the most important water using activities being domestic and industrial use, agriculture, hydropower, ecology, recreation and water to flush the canals in the city of Atra (Fig. 2).

Integrated water resources management is essential to provide the basin's inhabitants and surrounding areas with an economic and environmentally sustainable way forward.

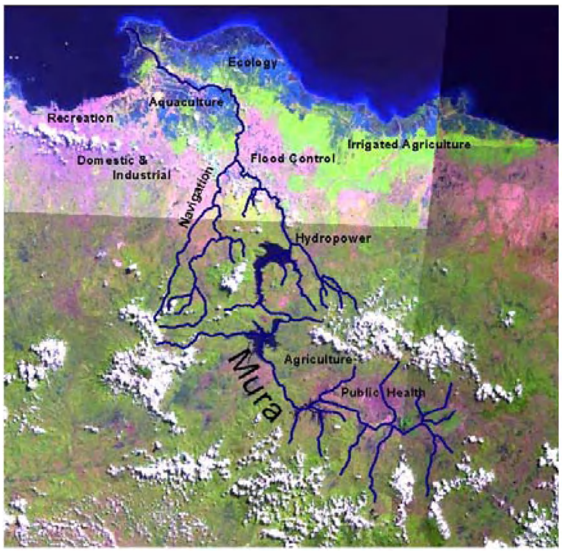

Figure 2. Problems in Mura river basin.

Set-up

The participants were divided into teams; the members of each team were selected based on background and affinity with the topics in the groupwork, so as to create multi-disciplinary teams. The teams represented competing consultancy companies that were invited to develop a 20-year Integrated Water Resources Management Plan for the Mura river basin by the government of Asiatica. The participants were provided with a lot of information and data on the river basin (see note) and its problems. They used this data to estimate the effects of their management plans and to come up with an environmentally and economically sustainable Integrated Water Resources Management Plan. Staff members of UNESCO-IHE acted as the government representatives who set-out the invitation for developing the IWRM-plan and who assessed the final plans. They also acted as expert consultants who helped to structure the process, assist the teams and provide additional information when necessary.

Groupwork 2003

In July 2003 three teams of 10 participants started with this groupwork, it took place in four sequential weeks, full time.

The first week the participants presented a problem analysis of the river basin and an inception report. At the end of the second week they presented their strategy for the river basin. The last two weeks were dedicated to developing the IWRM plan for the Mura river basin. At the end of the last week they presented and submitted the final report (see Fig. 3 for an example of a presentation). All groups presented their ideas and plans with a lot of enthusiasm, which resulted in successful completion of the groupwork.

Conclusions

The groupwork turned out to be a good integrating exercise at the end of the Water Management programme at UNESCO-IHE. The participants were encouraged to address and integrate all aspect of IWRM in developing an IWRM-plan for the Mura river basin. In the end the exercise was much appreciated by the participants.

Notes

Quantitative data adapted from WL I Delft Hydraulics (1986), Cisedane-Cimanuk Integrated Water Resources Development (BTA-155). Used with permission.

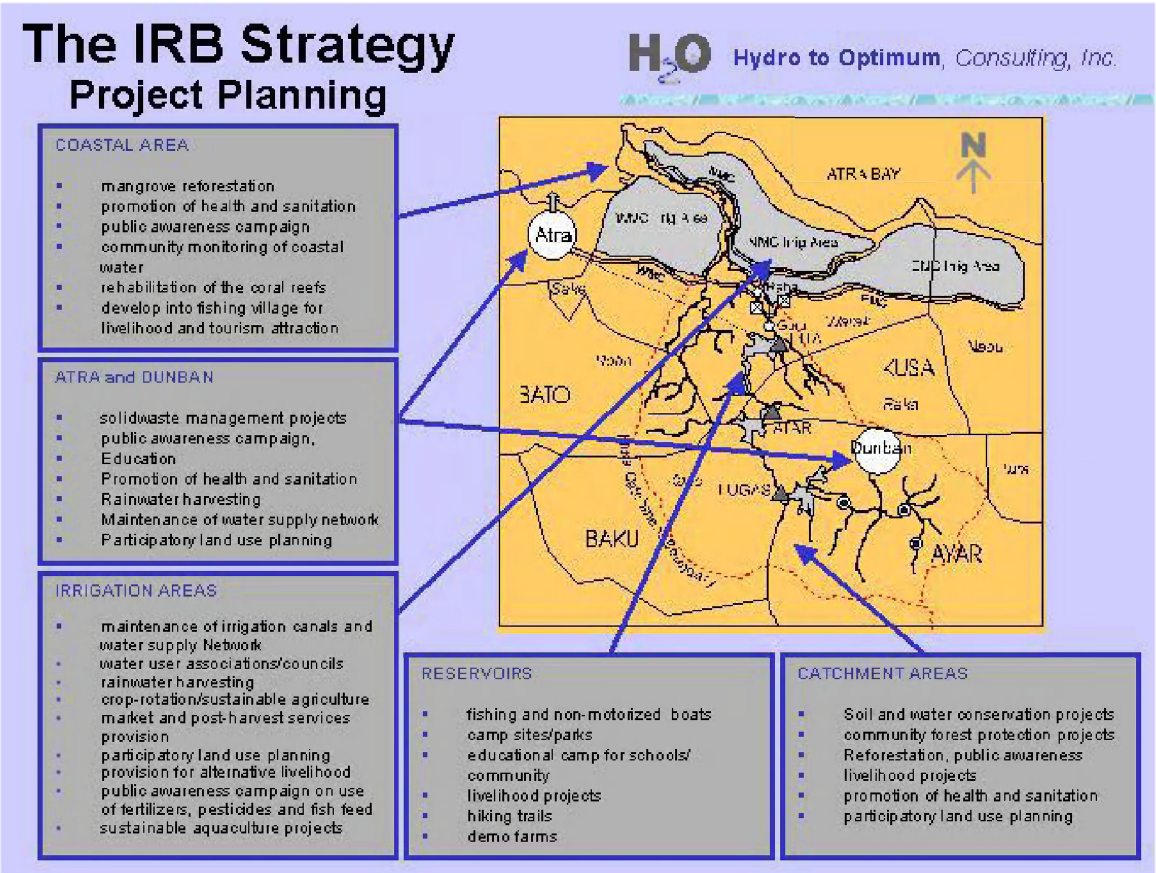

Figure 3. Integrated River Basin Strategy.

Effects of subsurface parameterisation on runoff generation in the Geer basin

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Abstract

A rainfall-runoff model has been developed for the Geer catchment Basin based on the Representative Elementary Watershed (REW) approach. To test the model, the sensitivity analysis has been carried out with respect to the effects of the subsurface parameterisation on the runoff generation processes. In addition, a new approach for representing the relation between topography and variable source area within a REW is proposed. Simulation results show that REW approach is appropriate for investigating rainfall runoff relation.

Introduction

The Representative Elementary Watershed (REW) approach has been introduced by Reggiani et al. (1998, 1999, 2000 & 2001) and fully described by Reggiani & Rientjes (2003). By this approach, a catchment is discretized into a number of sub-watersheds, called REWs, according to a specified Strahler order. Each REW consists of 5 model zones in which water flows are simulated based on a coupling procedure of mass conservation and momentum balance equations. Simulated flows are (1) unsaturated zone flow, (2) saturated zone flow, (3) saturation overland flow, (4) concentrated overland flow, and (5) channel flow, as shown in Fig. 1. The approach is classified as semi-distributed physically based.

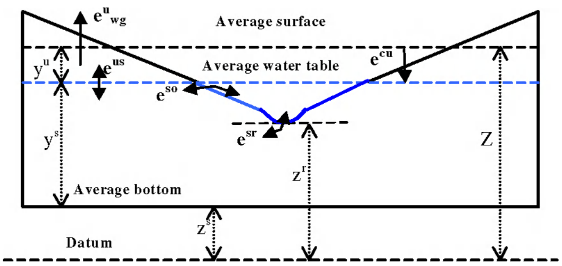

Figure 1. Schematised cross-sectional profile of a REW and the flow process.

The saturated zone plays a key role since the size of dynamically varying saturated overland flow source areas is function of the water table depth. Also groundwater flow across REW boundaries and interactions between the groundwater and river are simulated in this zone. On the source areas, rainfall and exfiltration water are directly transformed into runoff that largely determines the peaks of hydrographs. In the model applied here, the concentrated overland flow module has not yet been implemented. It only serves as an interface between atmospheric zone and unsaturated zone to capture rainfall and facilitate infiltration.

Based on the work by Zhang et al. (2002), some improvements are introduced to the model: the average bottom elevation of each REW is defined with respect to its own surface elevation; parameter values of saturated hydraulic conductivity and soil porosity in the upper and lower layer (K_{us}, K_{ss}, ε_u, ε_L), are dissimilar respectively. Especially, the representation of the saturated overland flow area fraction, ω_o is redefined so that the topography of REWs (or sub-catchments) can be incorporated. In this work, detailed numerical simulations are carried out to analyse the runoff behaviour with various model parameterisations. Also effects of different catchment discretisation on runoff processes are studied.

Parameterised model Equations

Infiltration: $e^{cu} = \min\left[\rho i \omega^u, \frac{\rho K_{su}\omega^u}{\Lambda_u}\left(\frac{1}{2}y^u + h_c(s^u)\right)\right]$ (1)

Evaporation: $e^u_{wg} = -e_p \rho \omega^u s^u$ (2)

Percolation: $e^{us} = \pm\beta^{us}\rho v^u_z \omega^u$ (3)

Seepage to river: $e^{sr} = \pm\frac{\rho K_{sr} l_r P_r}{\Lambda_r}(hr - hs)$ (4)

Exfiltration to surface: $e^{so} = \pm\frac{\rho K_{ss}\omega^o}{\Lambda_s \cos\gamma^o}(ho - hs)$ (5)

Groundwater flow: $e^{ij} = \pm\alpha^{ij}\rho g\left[\left(y^{si} + \varsigma^{si}\right) - \left(y^{sj} + \varsigma^{sj}\right)\right]$ (6)

Overland flow: $v = \frac{1}{n} J^{1/2}\left(y^o\right)^{2/3}$ (7)

Channel flow: $v = \left(\frac{8g}{f}\chi_r J \frac{m}{p}\right)^{1/2}$ (8)

REW geometry (area fraction of flow zones):

$$\omega^G + \omega^c \approx \omega^s \approx 1 \qquad (9)$$

$$\omega^u = 1 - \omega^G \qquad (10)$$

$$\omega^o = A_{sf}\left(\frac{y^s + z^s - z^r}{z_{surf} - z^r}\right)^{tg\alpha} \qquad (11)$$

Numerical simulations

Model simulations are carried out for a generic catchment based on the Geer basin topography. The basin is a sub-basin of the river Meuse in Belgium and covers about 490 km^2. It is characterized by a deep groundwater system where the aquifer extends beyond the surface boundaries of the catchment. Groundwater abstraction through pumping wells and drainage galleries are present in the basin and are simulated based on the available data. In the model subsurface properties are assumed to be uniformly distributed over the whole catchment.

At first, model sensitivity towards the model parameters is analysed. For this analysis 5 numerical simulations are performed, of which 4 cases are based on 2nd order stream network discretisation (73 REWs, Fig. 2) and 1 on 3rd order discretisation (17 REWs, Fig. 2).

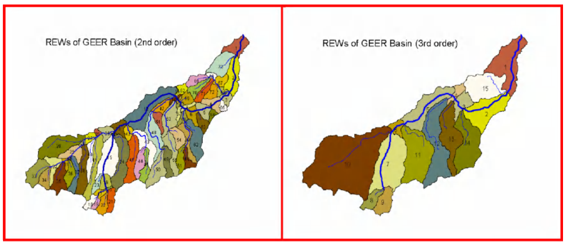

Figure 2. Discretisation of the Geer River basin.

To each simulation a 5-year constant effective rainfall series is set as the model forcing input. Parameter sets of the simulations for each case are listed in the Table 1. Results are presented in Fig. 3.

Case I	**ε=0.35, K_s=1.0m/d, 73REWs; ε and K_s same for U_{zone} and S_{zone}**
Case II	ε=0.35, K_s=2.0m/d, 73REWs; ε and K_s same for U_{zone} and S_{zone}
Case III	ε_U=0.45, ε_L=0.3, K_{su}=1.5m/d, K_{ss}=1.0m/d, 73REWs
Case IV	ε_U=0.45, ε_L=0.3, K_{su}=3.0m/d, K_{ss}=2.0m/d, 73REWs
Case V	ε_U=0.45, ε_L=0.3, K_{su}=1.5m/d, K_{ss}=1.0m/d, 17REWs

Table 1. Parameter sets for the sensitivity analysis.

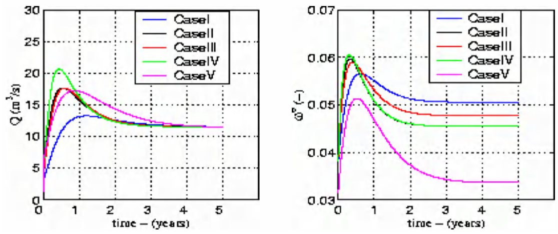

Figure 3. Sensitivity analysis for river discharges.

Secondly, model simulations are carried out with observed rainfall/evaporation time series covering the period 1993-1997. Results are presented in Fig. 4 and Fig. 5.

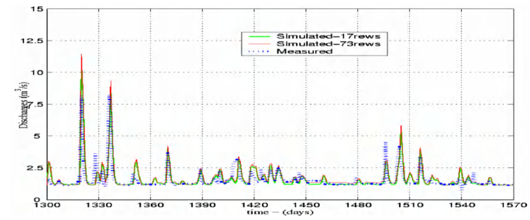

Figure 4. Comparison of simulated and measured discharges at outlet of Geer river.

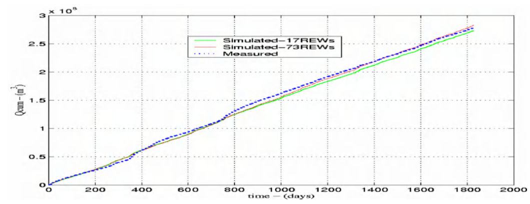

Figure 5. Cumulative discharges (1993-1997) at the outlet of the Geer river.

The model performance is evaluated by means of total water volume error, correlation coefficient (R), root mean square error (RMSE) and Nash-Sutcliffe efficiency (NSE) that are shown in Table 2.

	Water volume error (%)	**R**	**RMSE (m3/s)**	**NSE**
17 REWs	2.9	0.705	0.691	0.474
73 REWs	4.0	0.702	0.684	0.485

Table 2. Statistical analysis for the model performance.

Discussions

Results of sensitivity analysis (Fig. 3) show that the model is sensitive to subsurface parameters' variations. It is shown that the size of saturated overland flow areas (source areas) varies consistently subject to different subsurface parameterisation. The saturated overland flow runoff generation mechanism, however, is well represented. In view of the differences between the results for Case III and Case V, the effects of catchment discretisation on runoff generation can be observed:

- It is clearly shown (Fig.4) that rainfall runoff responses in the catchment are well simulated. In most of the simulation period, base flow is well simulated while some of the simulated peak discharges match the measured ones reasonably well. Lag time of peak discharges is generally well matched although some mismatches can be observed.
- From Fig. 5 and Table1, water volume errors indicate that the water balance was perfectly computed by the model. The model represents the Geer basin well even though NSE coefficient is not yet satisfactory. The model can reach similar performance indices applying two different catchment discretisation.

Conclusions

- The model is able to simulate the real world runoff production mechanisms and water balance behaviour of the catchment.
- The model requires fewer parameters and less input data compared to fully distributed, physically based models (see Rientjes, 1999) while yet the physics underlying watershed runoff dynamics is maintained.
- The REW approach is an appropriate approach for catchment-scale hydrological studies.

Acknowledgement

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River nutrient transport under various economic development scenarios – the transboundary Lake Peipsi/Chudskoe drainage basin

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The Lake Peipsi/Chudskoe drainage basin

Lake Peipsi is a shallow lowland lake on the border of Estonia and Russia, and in size the fifth largest lake of Europe (3,555 km^2). Its drainage basin (Fig. 1 and 2) is shared by Russia (67 %), Estonia (27 %) and Latvia (7 %).

Figure 1. Study area.

Figure 2. Landscape near Tartu.

Nutrient input and eutrophication problems

Although the lake is relatively undisturbed, it is vulnerable for eutrophication problems, because it is shallow and the ecological balance is easily disturbed by changes in nutrient input from the drainage basin combined with internal lake processes. Eutrophication causes algal blooms and decreases in fish stock (Fig. 3 and 4).

Figure 3. Local fishermen fishing on the ice (photo: P. Unt).

Figure 4. Lake Peipsi/Chudskoe suffering from Eutrophication (summer 2002).

What happens in the future? – definition of five scenarios

Within the next twenty years, the area is undergoing rapid economical changes that have influence on lake nutrient input. The EU Water Framework Directive (WFD) calls for an integrated catchment approach and information about past, present and future nutrient loads. This information helps mitigating high loads.

Five scenarios for future development were developed, on basis of the two variables

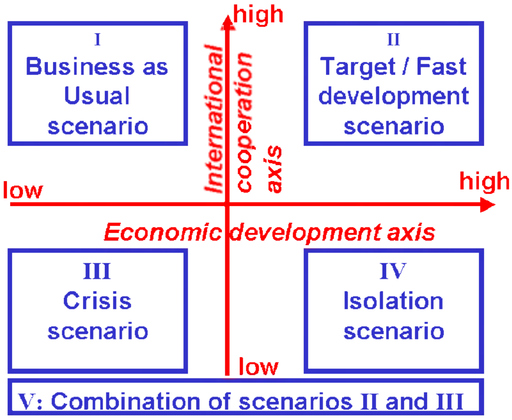


Figure 5. Scenario development: two axes and four scenarios plus 1.

economic growth and international cooperation in the region (Fig. 5).

Putting this information in a nutrient transport model

First, a large-scale GIS-based nutrient emissions and transport model (Fig. 6) was set up for the 1985 - 1999 period for which calibration data were available. After that, the model period was extended to include the future scenarios (until 2019). Economic development scenarios, usually consisting of qualitative storylines about expected changes, were translated into quantitative model input changes. Examples are changes in livestock and crop harvest, population amount, and wastewater treatment efficiency. Future Total Nitrogen (Ntot) and Total Phosphorus (Ptot) loads for the 2015 - 2019 period were calculated.

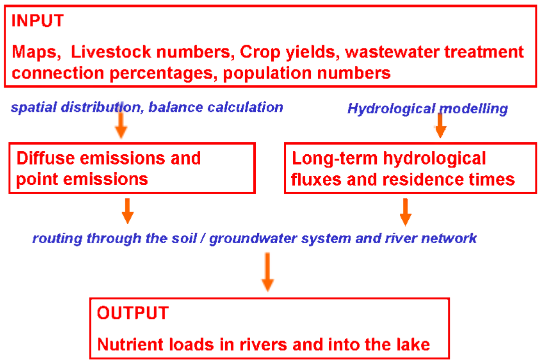


Figure 6. Nutrient emissions and transport model.

Future load predictions and management recommendations

Fig. 7 and 8 show the predicted Ntot and Ptot loads into the lake for the past and the five future scenarios. For Ntot, only the Target/Fast development scenario delivers a load comparable to the communist period. The other scenarios result in lower loads. For Ptot, loads are generally low in all scenarios. Fig. 9 (an example from the 1995-1999 period) indicates that the share of point sources in total loads is much higher for Ptot than for Ntot. This explains the different future load development for both compounds. Focussing on agriculture is the best way to mitigate Ntot loads, while a decrease of Ptot loads to the lake can be achieved by better waste water treatment.

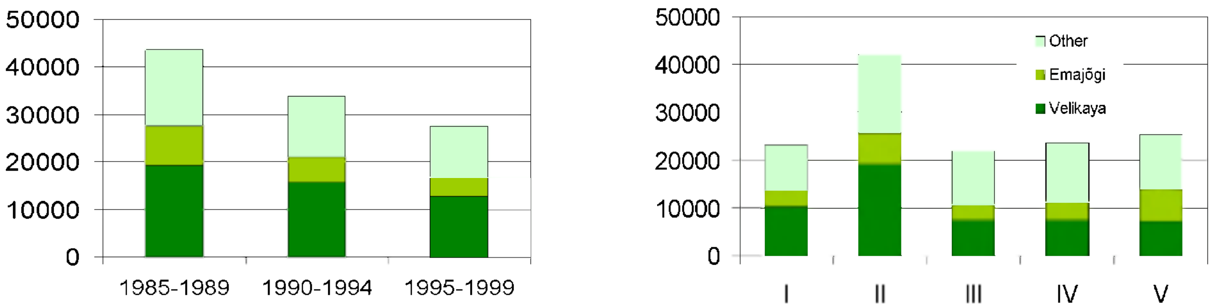


Figure 7. Simulated Ntot loads (T/yr) for 1985 - 1999 and five future scenarios.

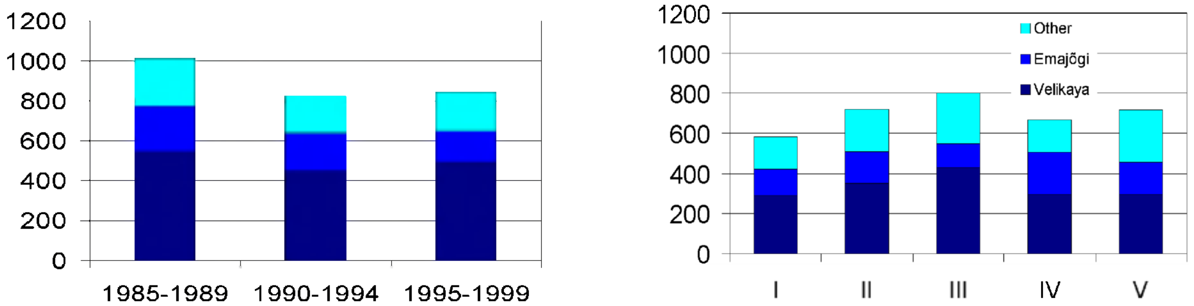
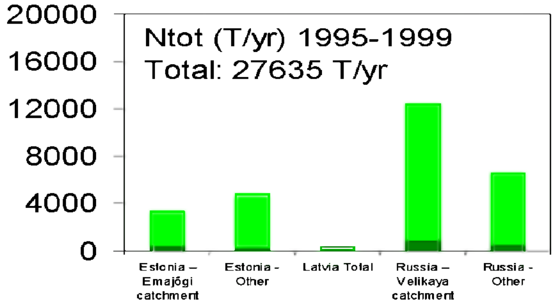


Figure 8. Simulated Ptot loads (T/yr) 1985-1999 and five future scenarios.



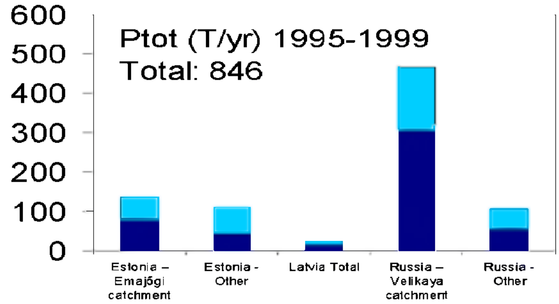


Figure 9. 1995 - 1999: Share of point/diffuse sources loads for various regions in the drainage basin. The dark colour is the point source contribution, the light colours represent diffuse sources.

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Reduction of siltation in harbours

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Introduction

Many river and lake harbours suffer from significant siltation, leading to frequent dredging activities to maintain the necessary water depth. Stricter legislation, classifying the sediments as chemical waste, raises the costs for the removal of these sediments enormously. In some cases this even leads to permanent closure of the smaller, recreational harbours. Besides the smaller scale harbours also the large commercial ports throughout the world suffer from siltation problems. These large economic consequences have initiated numerous studies on the processes of siltation and on measures to reduce siltation in various situations.

Siltation mechanisms

In order to determine the siltation rate in a harbour it is important to distinguish the processes that bring the sediment into the harbour. In general the sediment is transported in suspension and by exchange through the harbour entrance it is brought into the harbour where it is deposited because of relatively low flow velocities. Fig. 1 shows in a schematic overview which parameters are of importance and which exchange mechanisms can occur.

Detailed analysis of the different exchange processes has lead to the development of a number of silt reducing measures. Which exchange process is dominant is dependent on the water system. At the upstream part of the river and in lakes exchange through horizontal entrainment is almost always the most important mechanism.

Tidal effects and density currents generally do not occur in these situations. These proceedings describe the results of two case studies where a river situation without tidal effects and a lake system were studied to develop silt-reducing measures.

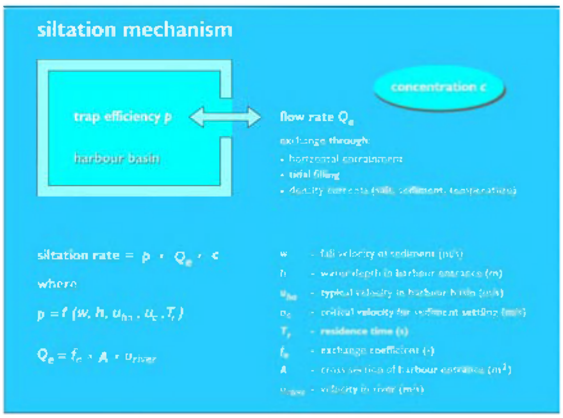

Figure 1. Schematic overview of important parameters and exchange mechanisms.

Rivers, a scale model approach

In the harbour of Roermond at the river Meuse horizontal entrainment through the mixing layer is the dominant mechanism. With measurements on the exchange of warm water in a scale model this mechanism was extensively studied leading to effective solutions for the reduction of siltation. Varying from simple measures that can be designed with a desk study to measures that require extensive scale model research.

In a river situation without tidal effects measures are focussed on reducing the horizontal exchange through:

1. Reduction of the cross section of the harbour;
2. Decrease in the strength of the mixing layer;
3. Modification of the configuration of the harbour entrance;
4. Diversion of the mixing layer from the harbour entrance.

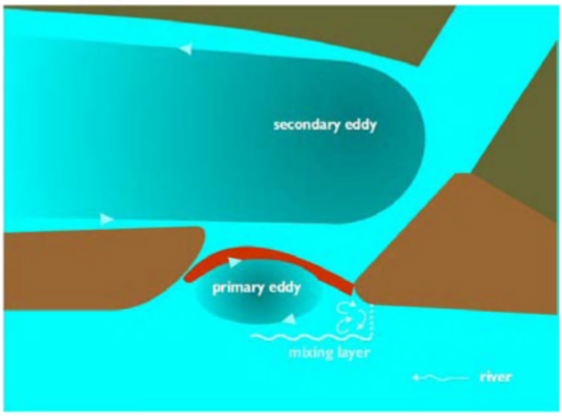

Figure 2. Schematic overview of scale model with measures.

The scale model study showed that the siltation in a harbour could be reduced up to 80% with a combination of a curved sill in the harbour entrance and a pile sheet at the upstream side of the entrance. Fig. 2 shows this combination of principles 1 and 2.

The pile sheet influences the mixing layer in front of the harbour in such a way that the gradient in flow velocity becomes smaller and the exchange of water is reduced. The sill reduces the cross section and, because of its shape, more or less isolates the primary eddy in the harbour entrance, thus reducing the strength of the secondary eddy and therefore the exchange. Diversion of the mixing layer by means of a Current Deflecting Wall also proved to be very effective. A Current Deflecting Wall has been built in the Köhlfleet harbour of Hamburg and measurements in the field have shown a reduction of the rate of siltation with 40%.

Lakes, a numerical model approach

The problem of siltation in lake systems has been studied by means of a three-dimensional numerical model (Delft3D) of the Loosdrecht Lakes. This model is well suited to describe transport processes of silt and the complex circulating flows in both horizontal and vertical direction that are caused by wind and waves.

The study focussed on the situation of Manten harbour in the south west corner of the lake. Fig. 3 shows a picture of Manten harbour where the exchange of silt through the harbour entrance is clearly visible. The study has shown that in lake systems the siltation is not dependent on the exchange between lake and harbour but only on the trap efficiency. So, accumulation of very fine organic sediments that are mixed well over the vertical only occurs in sheltered areas.

In a lake system measures to reduce siltation focus on the reduction of the trap efficiency in the harbour. This can be realised by using open constructions as much as possible to prevent the development of dead water zones. To minimize siltation in new harbours they should not be developed in corners or sheltered areas of a lake.

Figure 3. Manten harbour at Loosdrecht Lakes (courtesy: Mr. Veenendaal).

Morphological behaviour around bifurcation points of the Dutch Rhine branches

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Abstract
Bifurcation points are important for the diversion of water and sediment. In this study the morphological behaviour of two of the main bifurcation points in the Netherlands will be investigated. Research proposals have been set up and the first measurements took place. At the first coming peak discharge, the rest of the measurements will be performed.

Introduction
There are three main bifurcation points in the Rhine branches in the Netherlands. At these river bifurcations not only water is divided over the two branches, but also the sediment load in the water. The division of sediment is not necessarily equal to the water discharge.
The upstream sediment supply and composition influence local sedimentation patterns.
Little is known about the morphological behaviour around these bifurcation points, while at these points you could tune the water and sediment fluxes.
To understand the processes around bifurcations a measuring programme has been set up. Due to the fact that little is known about sediment division in the field there are also difficulties to calibrate morphological models.
In the Netherlands the three main bifurcation points are (Fig. 1):

- Pannerdensche kop (Boven Rijn, Pannerdensch kanaal, Waal);
- Merwede kop (Boven, Beneden en Nieuwe Merwede);
- IJsselkop (Pannerdensch kanaal, IJssel and Nederrijn).

In the 90's research has been performed around the Pannerdensche Kop. At this moment two research proposals have been set up for the Merwede Kop (Bolwidt & ten Brinke, 2000) and the IJsselkop (Bolwidt & Jesse, 2002).

This research is performed under authority of the Directorates Eastern Netherlands (DON) and Southern-Holland (DZH) of Rijkswaterstaat, in cooperation with University of Utrecht, TNO-NITG and MEDUSA.

Figure 1. The IJsselkop bifurcation during low discharges, on the left the Nederrijn, on the right the IJssel, August 2003 (Photo: Bert Boekhoven).

Methods
For both locations an integral approach is made with measurements on:

Subsoil:
Goal: to determine the structure and composition of the subsoil. Besides the location of coarse and fine material, the resulting database gives information of the thickness of the active layer. This layer has been in motion during past high discharges.
With: Vibrocore (grain size) and Seismic system (subsoil layers)

Sediment transport:
Goal: To determine the amount and composition of sediment load. Division over the bifurcation is taken into account.
With: Delft Nile Sampler DNS (Bed load transport) and "Akoestisch Zand Transport Meter" AZTM (Suspended transport)

Bed forms:
Goal: To determine the spatial and temporal variation in bed load transport and grain size of the top layer. Measurements are directed at river dunes, which develop at high discharges.
With: Multibeam (bed level) and MEDUSA (grain size top layer) from a travelling ship.

Water level and discharge:

Goal: To understand the driving force behind the morphological processes you need to have detailed information on discharge and water levels at all branches around the bifurcations.

With: ADCP and water level recorders.

Different conditions-different approach

Most morphological changes of the riverbed will manifest during high discharges. Therefore most measurements will be done during this relative short period. Due to local circumstances, there will be differences in hydrological and grain size and therefore each bifurcation will have a different additional approach.

Merwede Kop

For the Merwede bifurcation point the tidal effect is influencing the morphological behaviour, which makes the situation complex. At the beginning of a discharge peak, 13-hours measurements will be performed to determine the effect of the tide at the sediment transport.

IJsselkop

Due to the damming of the Nederrijn at low discharges the IJssel gets a higher discharge. The effect on the morphological behaviour will be investigated at low discharges.

Results till now

Last year (2002) the measurements of the subsoil around the IJsselkop have been performed by TNO-NITG (Gruijters et al., 2003), as well as one set of multibeam measurements to determine the dune patterns in this area at high discharges.
In fall of this year (2003) the low discharge measurements will be performed.
Around the Merwedes, so far a test campaign has been made to give an impression of the effect of the tides. At the end of the project all the different parts of the studies will be integrated in one report.
The university of Utrecht has written a PhD proposal, in which the result of these measurements will be used to understand the process of downstream fining (Frings, in prep).

Conclusions and future research

At the first coming discharge peak the measurements will start to determine the morphological behaviour during different discharges. In the end it will result in better understanding of the water and sediment behaviour around these two bifurcation points. Together with the knowledge of the Pannerdensche kop, the behaviour of the Dutch Rhine river system can be better understood in its present function, and predictions can be made about the consequences of interventions in the river system.

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Which processes determine the downstream fining of bed sediment in the Dutch Rhine branches?

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Abstract
The impact of abrasion, selective transport and sediment exchange processes on the downstream fining of bed sediments in the Dutch Rhine branches is evaluated. Abrasion has probably a small influence near the German border, but is negligible in the downstream part of the Rhine branches. Selective transport is assumed to be the primary downstream fining mechanism. The degree of selective transport is probably enhanced by vertical and horizontal sorting processes at the riverbed and by the presence of suspended load transport. Among the sediment exchange processes, bed degradation is assumed to have the largest influence on downstream fining. At a smaller scale, the sediment distribution at river bifurcations is important. Floodplain sedimentation and dredging probably have only a minor influence.

Introduction
Many rivers are characterized by a downstream decrease in bed grain size. The processes causing this downstream fining trend have extensively been studied in gravel bed rivers. Downstream fining processes in sand bed rivers and sand-gravel bed rivers have received much less attention.
The aim of the ongoing research is to identify the primary causes of downstream fining in the lower reach of the river Rhine, which is a sand-gravel bed river near the German border and a sand bed river near its mouth (Fig. 1).

Three possible influences on downstream fining are considered: abrasion, selective transport and sediment exchange processes.

Figure 1. Fine bed sediments exposed alongside the river IJssel during the low-flow period of august 2003.

Abrasion
Abrasion, the mechanical breakdown of individual grains is usually assumed to be negligible in sand bed rivers, because of the low shear stress, the small grain size, the high degree of grain roundness and the virtual absence of non-durable grains (e.g. Kuenen, 1956). For the largest part of the Dutch Rhine branches, therefore, the downstream fining of bed sediment cannot be explained by abrasion. It is possible, however, that abrasion has a small, but significant influence on the downstream fining trend in the Rhine branches near the German border. In this area the riverbed consists of a sand-gravel mixture and Bradley (1970) observed that sand grains in sand-gravel mixtures are splitted and crushed by the impact of gravel grains. Kodama (1994) also observed that the abrasion rate of fine grains increased in the presence of coarse grains.

Selective transport: suspension and sorting processes
While gravel bed rivers are dominated by bed load transport, sand-gravel bed rivers and sand bed rivers also have a considerable suspended load transport. This division between bed load transport and suspended load transport has a major influence on downstream fining. This is because coarse grains are only taken into suspension at very high bed shear stresses. Therefore the composition of the fast moving suspended load layer is much finer than the composition of the slowly moving bed load layer. As a result fine grains are preferentially transported downstream. Selective transport, however, not only results from the division between bed load transport and suspended load transport. The bed load transport and suspended load transport itself are also size-selective, contributing significantly to the downstream fining trend. The size-selectivity of the bed load transport is strongly determined by vertical and horizontal sorting processes at the riverbed. Two important vertical sorting processes are dune sorting (Kleinhans, 2002) and armouring (Parker & Klingeman, 1982). Dune sorting concentrates coarse grains in deep bed layers (Fig. 2), which are only mobile at high

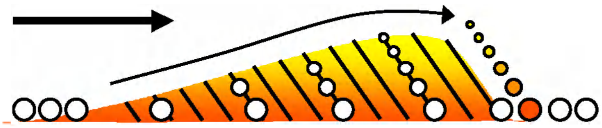

Figure 2. Vertical sorting by river dunes (after Kleinhans, 2002).

discharges. This decreases the mobility of the coarse grains and increases the degree of selective transport. Armouring has the opposite effect: coarse grains are concentrated at the bed surface where they are easily entrained, thus decreasing the mobility difference between coarse and fine grains. Horizontal sorting processes may lead to the development of coarse and fine patches on the bed surface. It is assumed that within those patches grains of all sizes are nearly equally mobile, but because fine patches move faster than coarse patches, the overall bed transport will be size-selective (Paola & Seal, 1995). The size-selectivity of the suspended load transport is the result of the large settling velocity of the large suspended grains. Therefore they are only present in the lowermost part of the suspended load layer, while fine grains are present throughout the suspended load layer. Because the flow velocity in the lower part of the suspended load layer is relatively low, the average velocity of coarse suspended grains is smaller than the average velocity of fine suspended grains, implying selective transport (Deigaard, 1980).

Sediment exchange processes

The systematic downstream fining trend caused by abrasion and selective transport can be disturbed by the supply of material with a different grain size into the river, or by the size-selective withdrawal of material from the river. In the case of the river Rhine four possibly important processes have been identified: floodplain sedimentation, dredging, bed degradation and sediment distribution at river bifurcations.
Floodplain sedimentation and dredging lead to an extraction of fine material from the riverbed. This has a diminishing influence on the downstream fining rate. The influence is assumed to be relatively small because of the small amounts of sediment involved.
Bed degradation involves a supply of material of different origin into the river. Taking into account the large bed level decrease that took place in the Rhine branches during the last century, this must have had a significant influence on the bed grain size.
The influence of river bifurcations, like the IJsselkop and the Merwedekop, on the downstream fining trend is also very large. In the meander bend upstream of a river bifurcation the sediment load becomes sorted horizontally through the process of bend sorting. Fine grains are concentrated in the inner bend, coarse grains in the outer bend. Therefore a river branch splitting from the main channel in the outer bend will receive a coarser sediment load than the river branch splitting from the main channel in the inner bend. The downstream fining trend thus will differ between the two branches.

Conclusion

Selective transport is considered to be the primary cause of downstream fining in the Dutch Rhine branches. The degree of selective transport may be enhanced by vertical and horizontal sorting processes at the riverbed and by the presence of suspended load transport. Apart from selective transport, also the continuous bed degradation in the Dutch Rhine branches has probably exerted a large influence on the present bed grain size. At a lower scale the sediment distribution at river bifurcations may be important.
The exact influence of the several processes mentioned in this paper on the downstream fining of bed sediment in the Dutch Rhine branches is still unclear. This will be the subject of study in the next three years.

Acknowledgements

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IJSSELKOP: modelling of 3D grain size distributions, one step closer to reality

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Abstract

In 2001 the Netherlands Institute of Applied Geo-sciences TNO studied the subsoil at the bifurcation Pannerdensche Kop (Gruijters et. al., 2001), aiming at the construction of a 3D grain size distribution model of the top 5 m of the riverbed. This model is used as input for morphological models to predict the morphological stability of the bifurcation and the long-term sediment transport. From October 2002 until October 2003 a similar study was performed at the bifurcation IJsselkop and the river IJssel up to 10 km downstream of the bifurcation (Gruijters et. al., 2003). Both projects, which were funded by RIZA, used vibrocore drillings and seismic surveys to construct a model of the geological layers in the subsoil. For the IJsselkop bifurcation a different sampling scheme was used. This scheme resulted in an improved understanding of the short-range variation in grain size distributions, resulting in considerably less smoothing of the data after interpolation. Also a new technique was developed which estimates a full 'synthetic' grain size distribution (GSD) from the parameters, which are estimated for every sample in the vibrocore (silt content, gravel content and sand median). The combination of these data with the measured GSD strongly enhances the spatial variation in the interpolation result, and prevents sand (or gravel) layers that were not sieved and are bounded by gravel (or sand) layers from disappearing.

Introduction

The Pannerdensche Kop project (Gruijters et. al., 2001) showed that the sampling scheme used was not suitable to detect the spatial variation in GSD on a scale of 10 - 200 m. Furthermore the interpolation method smoothed the actual variation in GSD considerably. For the IJsselkop project (Gruijters et. al., 2003) again a combination of vibrocore borings, measured GSD and high resolution seismics was used to construct a three dimensional database of the subsoil (resolution 25 x 25 x 0.2 m) containing detailed grain size information.

Materials and methods

For the IJsselkop project 125 vibrocore borings were carried out. These borings were placed at 400 m intervals along 3 lines, a line in the centre of the river and two lines near the borders. The first vibrocore at the centre line is placed 200 m downstream of the first two virocores located at the left and right border. At three locations in the centre line, five vibro-cores are placed at 10, 25, 50, 100 and 200 m. At TNO-NITG the vibrocore samples were photographed. All lithological layers visible in the vibrocore drillings were described in detail (Bosch, 2000), including estimations of silt and gravel content, and the median sand grain size. In total 1796 layers were described, from 625 layers samples were taken to measure the GSD by sieving. Both the descriptions as the photos were combined with the seismic data to construct a 3D model of the geological layers in the subsoil at the IJsselkop (Fig. 1).

Because sieving all the layers is to expensive, a selection of 5 samples for every vibrocore was made, leaving an average of 10 samples per boring not selected. Therefore a method was developed to calculate a GSD using the estimated parameters from the vibrocore descriptions.

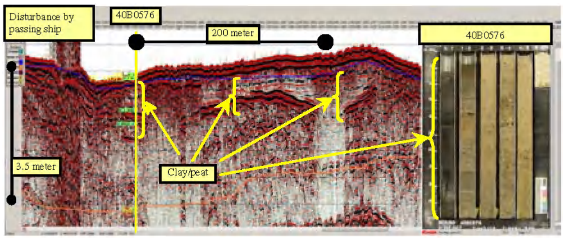

Figure 1. Combination of the seismic data and vibro-core data (nr. 40B0576). The clay peat layer in the first meter of the vibrocore results in a clear reflector in the seismic data (yellow brackets). The blue line indicates the top of the active layer (i.e. sand/gravel that is transported in dunes during high discharges), the thin red line is the top of the Kreftenheye Formation.

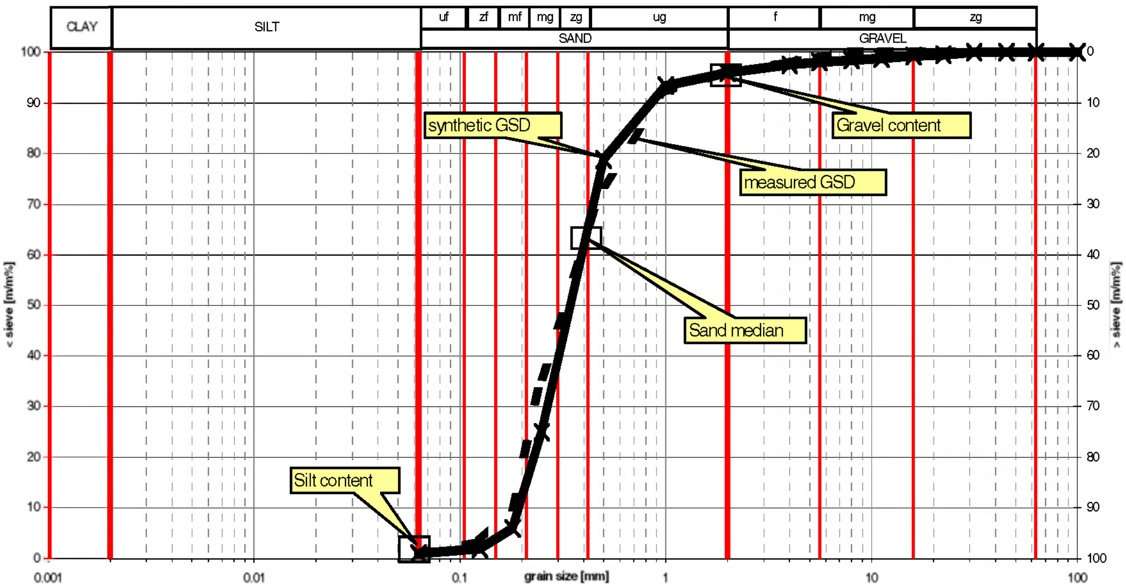

Figure 2. Construction of synthetic GSD from measured silt content, sand median and gravel content for a sand sample.

At first, each measured GSD was matched by a synthetic GSD using an ATAN function and three measured parameters (silt content, gravel content and sand median). The ATAN function was corrected for each fraction to accommodate the less symmetric shape of the measured GSD (Fig. 2). Secondly this corrected ATAN function was used to calculate a full GSD from the estimated silt, gravel content and sand median for the 1,171 samples that were not sieved.
The estimated silt content and sand median differ systematically from the measured ones. Therefore, before using the estimated parameters to calculate a synthetic GSD, a second correction was applied.

Results

Using the new sampling scheme, both the short-range (up to 250 m) as the long-range (up to 1,700 m) variability could be determined. Both variograms were combined for the interpolation, resulting in a relative nugget of 10%. In combination with a well-chosen search neighbourhood within the range of the detected spatial correlation, unrealistic averaging of the grain size data was prevented.

Both the measured GSD and synthetic GSD were used in a 3D Kriging interpolation (ISATIS, 2002 & EDS, 2003) to create a 3D model of the first 5 m of the subsoil at the IJsselkop. At each grid cell of 25 x 25 x 0.2 m a full GSD was calculated. The effect of using the synthetic GSD is illustrated in Fig. 3.

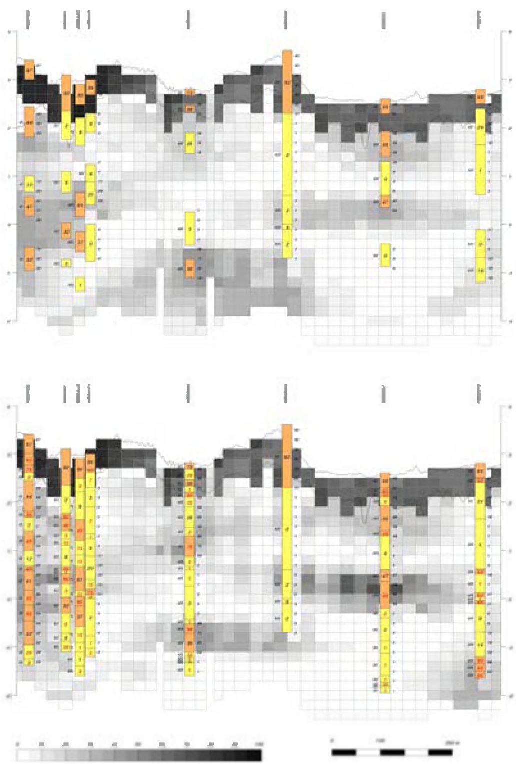

Figure 3. Results of the 3D interpolation of the fraction > 2 mm, without (above) and with (below) synthetic GSD. Using the synthetic GSD clearly results in a more differentiated model with more explicit changes in lithology.

Conclusions

From the IJsselkop study the following conclusions arise:

- Expert judgement on the selection of variogram-parameters and the search

neighbourhood will prevent unrealistic averaging in Kriging;
- The use of three groups of 5 vibrocores at short distances in the centre line facilitate the determination of the short range spatial variability in GDS;
- Estimated silt content, sand median and gravel content, can be used for calculating a synthetic GSD. However, empirical fitting of the applied ATAN function is necessary.
- Using synthetic GSD results in a more differentiated model with more explicit changes in lithology. It prevents sand (and gravel) layers that are not sieved and are bounded by gravel (or sand) layers to disappear after interpolation.

The translation from estimated grain size parameters from soil descriptions to full GSD can be used for similar sediments at other locations. Taking a limited number of sieved GSD to fine-tune the needed corrections of the ATAN function will lower the necessary laboratory budget.

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Eurasian rivers in flood: application of the mixed distribution theory to runoff extremes

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Introduction

The theory of mixed distributions for frequency analysis can be applied when there is reason to believe that the assumption of homogeneity of the data series is not valid. In hydrology this can be the case for annual extreme rainfall events or annual extreme runoff events. The reason for inhomogeneity can be that the mechanisms causing the extremes are different. As a result the occurrences should not be treated as if they were part of the total population, as they belong to different populations.

Method and results

To apply the theory of mixed distributions the occurrences are grouped in sub-sets according to the mechanisms causing the extremes. For each of the sub-sets the statistical distribution is obtained. The probability of exceedance for the mixed distribution writes:

$$P_{mixed}(x > X) = P(x > X \mid S_1) * P(S_1) + P(x > X \mid S_2) * P(S_2) + ... + P(x > X \mid S_n) * P(S_n)$$

Where:

$P_{mixed}(x > X)$ = Probability of exceedance according to the mixed distribution

$P(x > X \mid S_n)$ = Conditional probability of exceedance according to the sub-set

$P(S_n)$ = The probability of having an extreme from a certain subset

Many Eurasian rivers show a clear distinction between spring and summer runoff extremes. These extremes can be linked to the obvious different mechanisms of snowmelt in spring causing floods and rain events causing floods in summer. However, for several stations distinction into two sub-sets in this way resulted in an unsatisfactory fit of the frequency distribution. A strong deviation from a straight line of the sub-set of summer extremes gave rise to the idea that the summer extremes might have been caused by different mechanisms. In particular the high summer values seem to belong to a different sub-set. Physically a different rain causing mechanism, such as cyclones or typhoons could explain this effect.

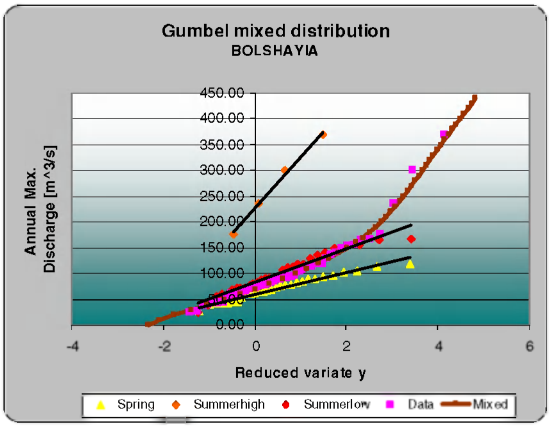
Although the real cause of the distinction in ‘summer high’ and ‘summer low’ extremes remains subject for investigations, distinction in these two sub-sets was bluntly applied.
The sub-sets were separated from the point were an inflection in the frequency distribution occurs. Despite the high degree of objectivity in defining the two sub-sets for summer extremes the results are extremely remarkable.

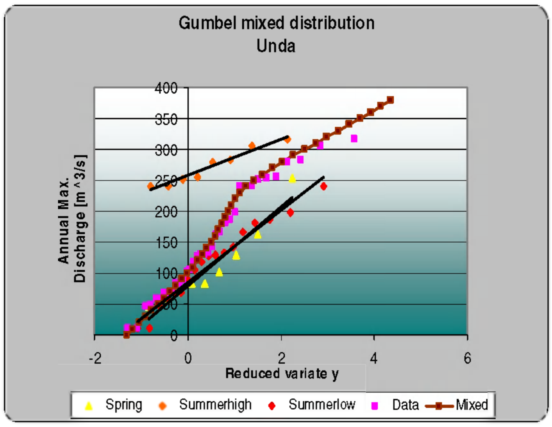
This procedure was applied in different regions in the Far East of the Eurasian territory for series with a clear distinction in spring and summer extremes, i.e. Siberia, the upper Amur basin and near the Japanese sea coast. All these series showed inflection points in the summer subset when not split up. This eventually led to the definition of three sub-sets for all the series.

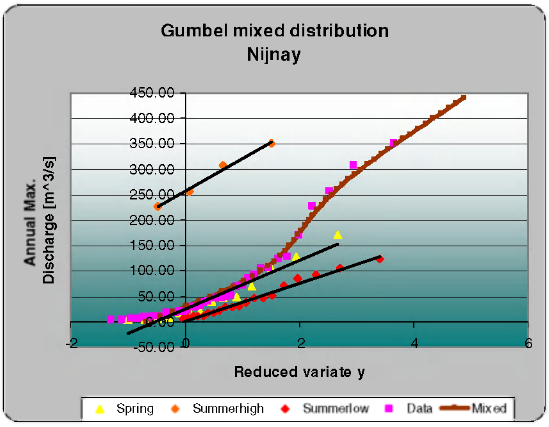
Conclusions

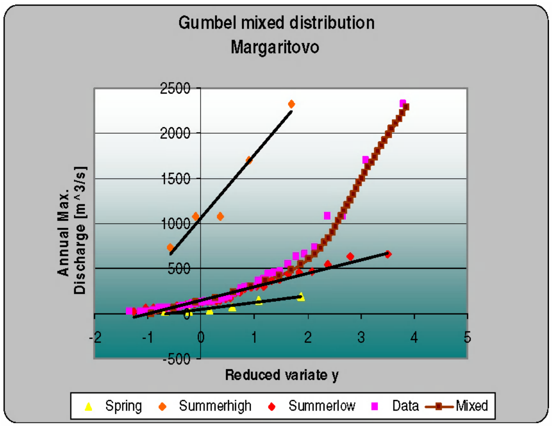
The analysis was carried out to investigate the potential of the mixed distribution theory in modelling the frequency distribution of runoff extremes. So far this turned out to be fruitful. At present a more comprehensive investigation on a larger territory is carried out.
Nevertheless, based on the location of the observation points of the series analysed so far, it can be concluded that the applicability of the method is not bounded to a particular region only, as it successfully applies to different regions.
Finally some conclusions on the usefulness of applying the mixed distribution theory can be made. The mixed distribution theory shows that frequency distributions not necessarily need to plot as a straight line on distribution paper when composed of sub-sets of frequency distributions. When the sub-sets of frequency distributions can be satisfactorily defined this will improve the fit of the flood peak distributions and particularly the prediction of magnitude of rare flood events.

In addition application of the theory of mixed distributions provides the opportunity to better analyse the effect of climate change on flood frequency distributions, as it is known that climate change effect the different flood causing mechanisms in a different way.









Geological modelling: how reliable are input parameters?

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Abstract
The main goal of the research presented here is to quantify the reliability of grain size data used in modelling of the subsoil.
Preliminary results are given regarding the uncertainties of the used data, i.e. the grading curves and the used grain size parameters.
Data used to quantify these uncertainties has already been used in modelling of the subsoil (for example the IJsselkop project, carried out for RIZA) or has been obtained as part of an internal NITG project.
Parameters studied include lithology, D50 (sand median) and differences in grain size between laser diffraction techniques and sieve analysis.
The results show that uncertainties in estimating grain size parameters cannot be neglected.

Introduction
In geological modelling, geostatistics and geological knowledge are used to combine 1D and 2D measurements to a 3D frame of the different (geological) layers in the subsoil. Within these layers different parameters may be estimated. The reliability of the measurements used in a geological model is crucial for the overall reliability of the constructed model. For morphological models, insight in the variation of the grain size distribution within a layer is dominant.
The main goal of the current research is to quantify the reliability of the used grain size data. The Netherlands Institute of Applied Geosciences-TNO carries out the above outlined research. For this study data is used from morphological studies at the Pannerdensche Kop, Bovenrijn-Niederrhein and IJsselkop, as well as data gathered by TNO-NITG.

Data analysis
Analysed material mainly consists of fine to coarse river sediment with a low grading factor.
Three kinds of analysis have been performed:

- Lithology analysis: lithology estimated (extracted from DINO[1]) vs. lithology measured (sieves as well as laser diffraction, 1,581 samples);
- D50 sand analysis: D50_sand estimated vs. D50_sand measured (only performed on sand samples, 1,190 samples);
- Laser diffraction techniques vs. sieve analysis: comparison of fractions and D50_sand (124 samples, resulting in 248 analysis).

Results
Lithology analysis
In 13% of the samples the estimated lithology deviates from the lithology measured.

- 80% of the incorrect estimated sand samples are gravel samples with 50-70% sand admixture;
- 50% of the incorrect estimated gravel samples are sand samples with 15-30% gravel admixture;
- Adding a buffer of 10% around the 30% gravel limit (< 30% = sand, > 30% = gravel) explains only 8.3% of the total number of incorrectly classified samples.

	DINO-estimations		
Data based on grain size analysis	Clay / Loam	Sand	Gravel
Clay / Loam	0.1	0.06	-
Sand	0.06	46.6	7.8
Gravel	0.06	4.7	40.6

Table 1. Estimations of lithology and grain size analysis of the same samples (in % of 1,581 samples). In red, samples estimated as sand, which are gravel (4.7%), and vice versa (7.8%).

D50 sand analysis
- 48% of the sand samples have the same D50 class estimated and measured;
- 44% of the samples have been underestimated compared to grain size analysis of which 35% is by one D50 class;
- 8% of the samples have been overestimated compared to grain size analysis.

[1] DINO: "Databank Informatie Nederlandse Ondergrond", database containing all layer descriptions made by describers TNO-NITG.

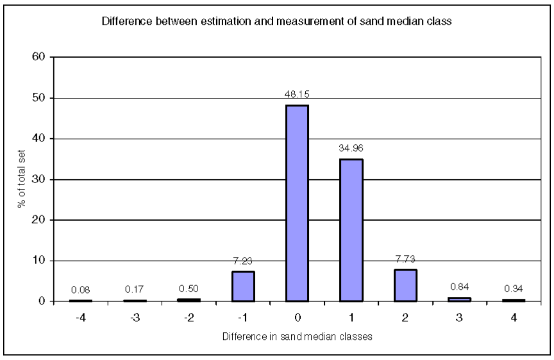

Figure 1. Differences between estimation of sand median class by describers TNO-NITG (from DINO) and grain size analysis of sand median class. X axis is expressed as total difference in sand median classes. For example: estimated median class: very fine sand, measured median class: very coarse sand, total difference in median classes is 3. With:

-2/-1	estimated sand median class (from DINO) coarser than measured sand median class
0	no difference
1/2/3/4	measured sand median class (from DINO) coarser than estimated sand median class

Laser diffraction techniques vs. sieve analysis

- Laser diffraction techniques and sieve analyses give slightly different grain size analyses. Coarse fractions (500 – 2,000 µm) are larger with laser analysis, fractions < 500 µm are smaller, compared to sieve analysis.
- $D50_{Malvern}$ is on average 56 µm coarser than $D50_{sieve}$. There is good correlation between the two, with R^2 = 0.86.
- Samples analysed with the Malvern (up to 2 mm) of which the rest of the sample is sieved (from 2 mm up to 180 mm) cannot be connected without showing a clear break at the connection point (2 mm). This 'break' is more clear with coarse samples (gravel samples). The 'break' is inherent to the differences between the sieve method and the Malvern, the latter uses laser diffraction techniques from which the grain size is deduced.

Conclusions

- Lithology estimations made by TNO-NITG describers are good and can thus be used in modelling of the subsoil. Incorrect estimations (only 13% of the samples) can be explained by the percentage of admixtures and difficulties in estimating these correctly.
- D50 sand is difficult to estimate, estimation results in 35% of the samples in an underestimation by one sand median class compared to measurements.
- Laser diffraction techniques and sieve analyses give slightly different grain size analyses. Coarse fractions (500 - 2000 µm) are larger with laser analysis, fractions < 500 µm are smaller, compared to sieve analysis.
- $D50_{Malvern}$ is on average 56 µm coarser than $D50_{sieve}$. There is good correlation between the two, with R^2 = 0.86.
- Samples analysed with the Malvern (up to 2 mm) of which the rest of the sample is sieved (from 2 mm up to 180 mm) cannot be connected without showing a clear break at the connection point (2 mm).

The results and conclusions outlined above should always be kept in mind when estimations of grain size parameters are used in an underground model.

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Delft – FEWS: Flood Early Warning System

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Introduction

The growing sensitivity of decision-makers with respect to potential damage caused by inundation, calls upon increasingly sophisticated and accurate techniques to predict such type of risk. A flood early warning system provides information on the current state of the water system within a polder, a river catchment or an estuary and forecasts the flood flow and water levels at specified locations for a range of lead times within a certain accuracy band. The main philosophy behind the development of Delft-FEWS is the design of the system as an open platform, which allows potential end-users to incorporate their own, already tested and validated prediction tools, such as routing routines or hydrological models, into the FEWS systems.

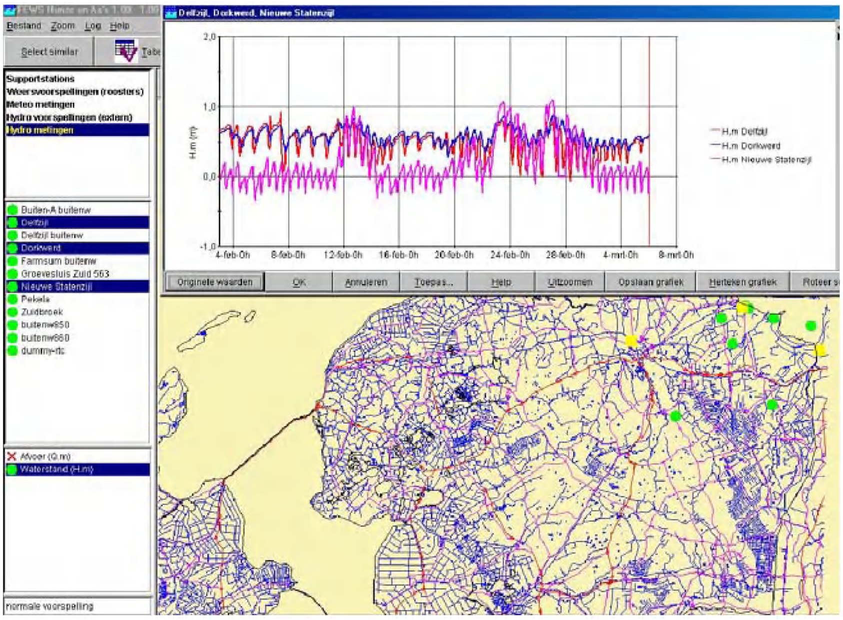

Figure 1. User interface.

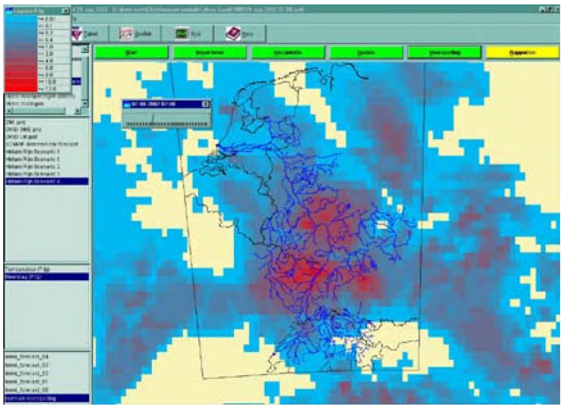

Figure 2. Radar.

What is Delft - FEWS?

- User interface around hydrological and hydraulic models
- Runs model forecasts
- Data integration, validation and transfer can be automated to a desired level defined by the user
- Uses grid based weather predictions like HIRLAM
- Serial or spatial interpolation using various interpolation methods
- Runs the models in two steps, in the first, the models are initialised and data assimilation techniques are used to improve model performance. In the second step the models are run for the forecast period.

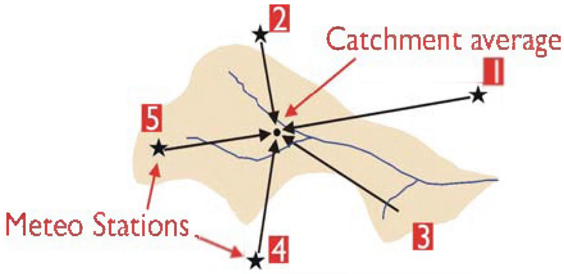

Figure 3. Catch-average.

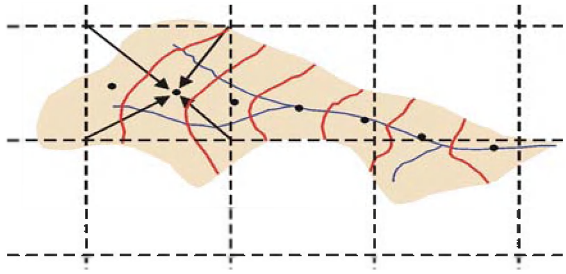

Figure 4. Catch-zones.

- Allows the user to analyse previous forecasts (also called hindcasting) and builds up a database with statistics of forecast accuracy for quality management
- Sends warnings to end users (by fax or internet)

Application

- FEWS for the complete Rhine basin of Rhine, operational for RIZA and FOGW (Federal Office for Water and Geology, Switzerland).
- For the Environment Agency in Great Britain, Delft-FEWS is being developed for the main part of England.

Figure 5. Delft-FEWS in Great Britain, regions currently being developed (red) and regions in preparations (blue).

- FEWS Sudan, FEWS Pakistan.
- FEWS was used for the investigation of the possible consequences of the 2002 Elbe flood on the Rhine basin in case the storms where to occur there
- Determination of the design discharges of the Rhine basin
- FEWS Regional, WS Hunze en Aa's acts as a demo case to show the usefulness of FEWS as a decision support tool in the Netherlands

Development and research

- Improved data assimilation techniques (Kalman Filtering) and methods for model optimisation.
- Methods for determining the aggregated uncertainties of meteorological forecasts and hydrological forecasts will be investigated.
- Automated model calibration
- The use of weather RADAR images

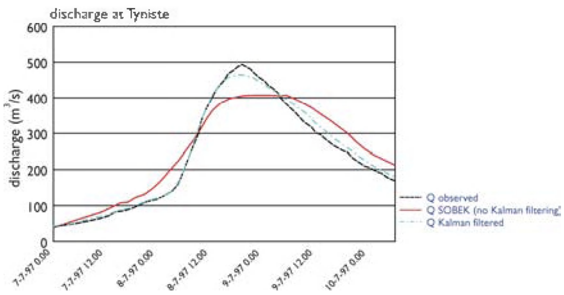

Figure 6. The Kalman Filtering algorithm as applied to the Orlice (tributary of river Elbe) is seen to lead to adequate predictions.

Influence of non-linearity in the storage-discharge relationship on discharge droughts

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During drought, most stream flow is derived from stored sources, primarily groundwater. In many catchments the relation between groundwater storage and discharge is non-linear, for example because the aquifer is unsaturated, because of variations in the conductivity of the aquifer or because of decreasing drainage density as a result of decreasing groundwater levels. This non-linearity increases the persistence and severity of droughts according to Eltahir & Yeh (1999). In this paper it is examined whether and how non-linearity in the storage-discharge relationship increases drought duration and severity.

The influence of non-linearity was examined by simulating long time series (10 * 1000 years) of outflow from reservoirs with increasing non-linearity. As input to the non-linear reservoirs recharge was simulated for two catchments: the sub-humid Pang catchment (UK) and the semi-arid Upper-Guadiana catchment (Spain). For the Pang catchment, first 38 years of observed precipitation and evapotranspiration was resampled to 10 * 1000 years using Nearest Neighbour resampling. Subsequently, recharge was calculated using a simple bucket-type model. For a more elaborate description see Peters (2003). For the Upper-Guadiana catchment first 58 years of recharge was simulated with a spatially distributed model and that was subsequently resampled to 10 * 1000 years.

The groundwater discharge is not simulated for these specific catchments, but for a range of reservoirs with different storage characteristics. Each reservoir is characterised by a reservoir coefficient j, which is expressed in days. Here only the results for a reservoir coefficient of 80~d will be presented. For a more full discussion see Peters (2003). For the simulation of the non-linear reservoirs the method developed by van de Griend et al. (2002) was used. The relation between the storage S and the discharge q is given by:

$$S = j(q)q$$

For each time step de reservoir coefficient j is recalculated as a function of the current discharge q. Using this formulation, van de Griend et al. (2002) derived the following recursive solution:

$$q(t+\Delta t) = e^{-\beta\Delta t} q(t) + \left(\beta - \beta^2 \frac{\Delta t}{2}\right) \int_t^{t+\Delta t} R(r)\mathrm{d}r$$

where t is time (d), R is the recharge (mm/d), $\beta = \frac{1}{j(q)b}$ and b is a parameter determining the non-linearity ($0 < b \leq 1$, where b = 1 is the linear case).

From the time series of groundwater recharge and discharge, droughts were derived using the threshold level approach, which means that a drought is defined as an excursion below a constant, predefined threshold. This is illustrated in Fig. 1.

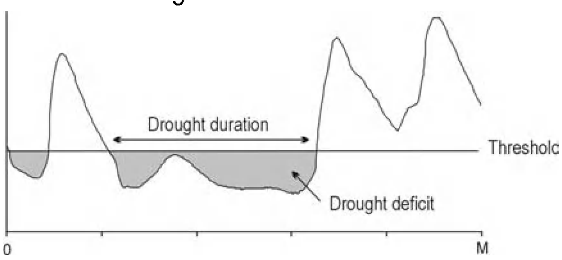

Figure 1. Definition of drought deficit and duration using the threshold level approach.

Fig. 2 shows the frequency distribution of the droughts using Weibull plotting positions for the recharge from the two catchments. From comparing the drought duration for the linear and non-linear reservoir (Fig. 2c and 2d), it is clear that the drought duration (and thus the persistence of droughts) did indeed increase under all circumstances. The drought severity, however, did not uniformly increase. For the recharge from the Pang catchment the drought deficit in fact decreased as a result of non-linearity for droughts with a return period lower than 20 years.

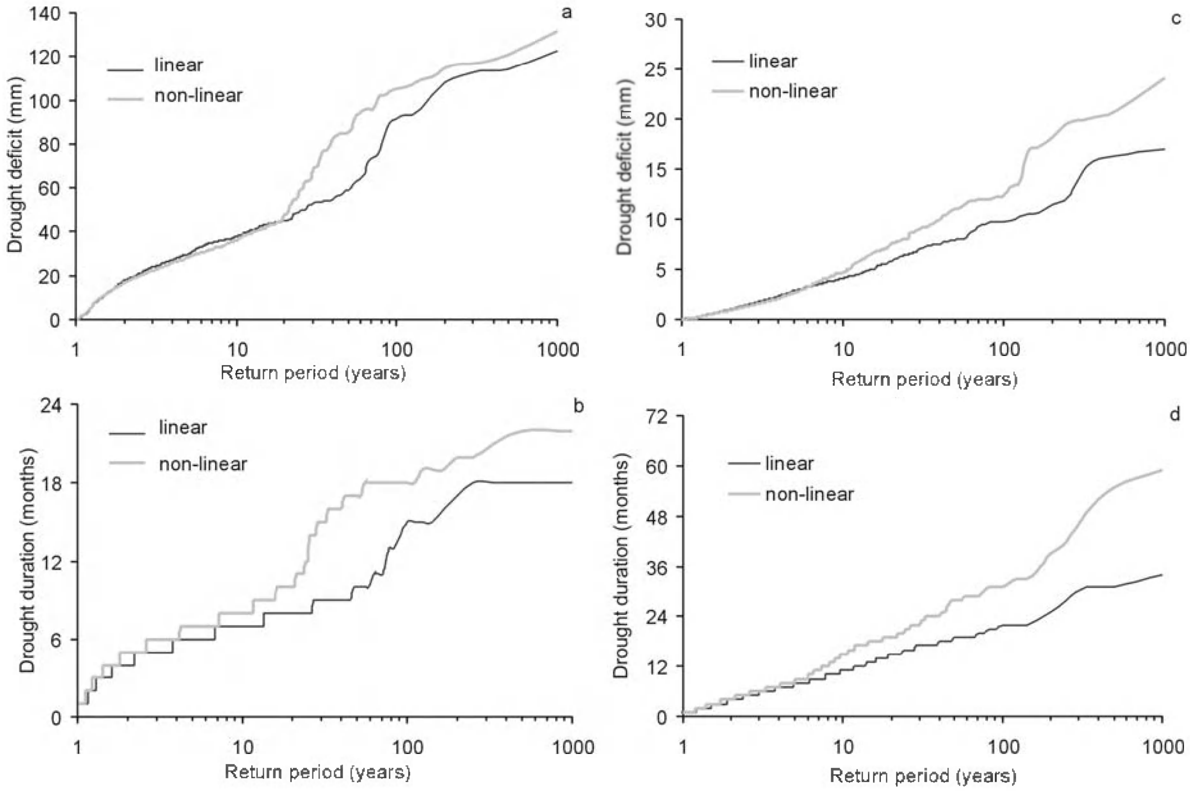

Figure 2. a) Drought deficit for the Pang catchment, b) drought duration for the Pang catchment, c) drought deficit for the Upper-Guadiana catchment and d) drought duration for the Upper-Guadiana catchment. All reservoirs have a reservoir coefficient or equivalent reservoir coefficient of 80 d.

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Spatial distribution of heavy metals in floodplains

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Abstract
In the Netherlands, the floodplains are being reconstructed to cope with the future higher discharges. By doing so, the patterns of sediment deposition change. Since these sediments are contaminated with heavy metals, we studied the patterns of sediment deposition and the spatial distribution of heavy metals in Dutch floodplains along the River Rhine.
The most important factors for sediment deposition are: 1) distance to the river and 2) the topography within the floodplain. Concerning the distance to the river, mainly sand is deposited within a distance of 100 meters from the river. Therefore, the heavy metal concentrations within these 100 meters are relatively low. There is no significant difference between different inundation periods. Regarding the influence of topography, the cadmium and copper concentrations of the higher and the lower parts of the floodplain are different: in the higher parts the cadmium and copper concentrations are lower than in the lower parts.

Introduction
In the framework of the policy document “Ruimte voor de rivier”, several floodplains along the Rhine River will be reconstructed. This reconstruction will affect sediment deposition on these floodplains. The assessment of changes in sediment deposition is important, since the sediment attaches heavy metals. Due to biological uptake, heavy metals accumulate in floodplain vegetation, spread through the food chain, thereby causing a risk for the entire ecosystem. To be able to map this ecosystem risk, we studied the spatial distribution of sediment-bound heavy metal deposition on Dutch floodplains during inundation periods.

Material and methods
Sediment deposition was measured with sediment traps (Fig. 1) in several floodplains (i.e., near Brummen, Zwolle, Amerongen, Neerijnen en Druten) along the River Rhine. The amount of heavy metals found in the sediment traps is determined and used in geographical and statistical analyses, like correlation and cluster analyses.

Figure 1. Sediment trap in floodplain.

Results
The most important factors for sediment deposition seem to be: 1) distance to the river and 2) floodplain topography. Within a distance of 100 meters from the river, sediment is deposited that contains a concentration of cadmium and copper of respectively at most 3.8 and 39 mg/kg dry weight (Fig. 2). Behind these 100 meters sediment is deposited with cadmium and copper concentrations above respectively 3.8 and 39 mg/kg.

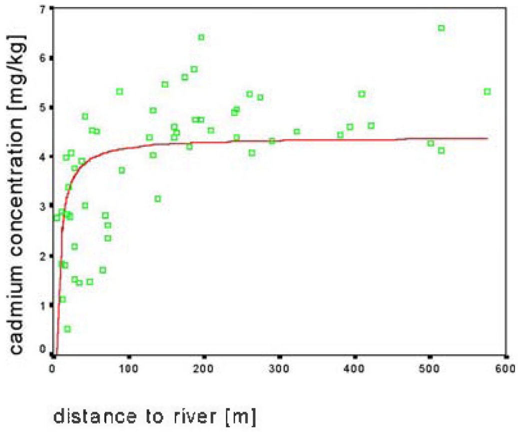

Figure 2. Relationship between distance to the river in the floodplain and the cadmium concentration of the sediment for all investigated floodplains and different inundation periods in 2001 and 2002.

Because we used different inundation periods, we checked for a possible influence of the inundation periods on the relationship between contamination and distance-to-river. Fig. 3 shows three inundation periods in the Afferdensche en Deestsche Waarden. Only a small part of the floodplain was inundated in

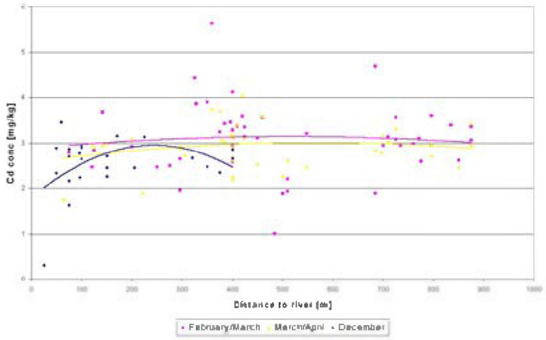

Figure 3. Cadmium concentration of the sediment against distance to the river in the Afferdensche en Deestsche Waarden for three inundation periods in 2001 and 2002.

December. There seems to be no significant difference in heavy metal concentrations between inundation periods.

Regarding the influence of topography, the cadmium and copper concentrations of the upper and the lower parts of the floodplain are significantly different (p = 0.000). In the lower parts the cadmium and copper concentrations are higher than approximately 4 and 40 mg/kg dry weight; in the upper parts the concentrations are lower (Fig. 4).

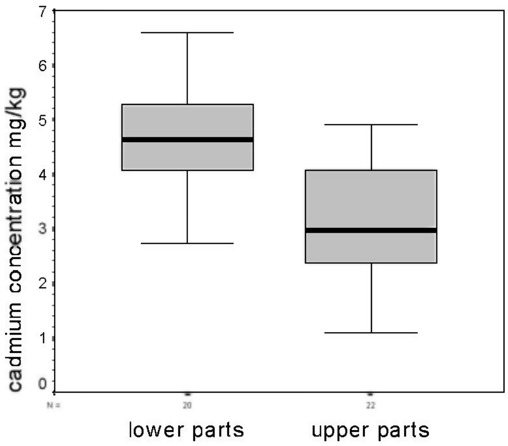

Figure 4. The cadmium concentrations in the lower and upper parts of the floodplains.

Discussion

Within the first 100 meters from the river the flow velocity is high so mainly sand is deposited in the floodplain. Heavy metals are mainly bound to clay, less to sand. This explains the lower concentrations of cadmium and copper near the river. In depressions the water remains longer, which gives the small clay particles time to settle. This leads to a higher heavy metal concentration in the lower parts than in the upper parts.

Data-driven modelling for flood-related problems

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Traditionally flood management is based on behaviour-driven, or physically based (simulation) models following the equations describing the behaviour of water bodies. Since recently models built on the basis of large amounts of collected data are gaining popularity. This modelling approach we will call data-driven modelling; it borrows methods from various areas related to computational intelligence - machine learning, data mining, soft computing etc. The well-known model of this kind is a linear regression model. A non-linear model that is becoming popular is an artificial neural network (ANN). Hydroinformatics section at UNESCO-IHE in Delft is applying data-driven methods in a number of civil engineering problems, including flood-related problems. An approach that is being mainly used now is that a hierarchical 'mixture' of models is built, each responsible for particular hydro meteorological conditions and 'specialised' in predicting low or high flows. Fig. 1 and 2 show the application of the M5 model tree method in prediction of runoff of the Huai River in China. The input variables included a number of past measurements of rainfall and runoff and prediction was made for 1 day ahead.

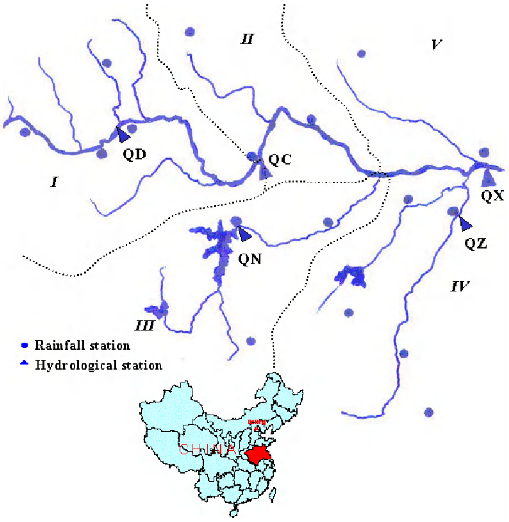

Figure 1. Huai River area (I, II, III, IV, V represent 5 sub-catchment areas).

Fig. 3 shows the increased performance of a specialised model for high flows (which in its turn includes a hierarchy of several specialised models).

The list of such applications includes: using decision trees in classifying flood conditions and water levels in the coastal zone depending on the hydro meteorological data, using artificial neural networks (ANN) and fuzzy rule-based systems for building controllers for real-time control of Dutch regional water systems, using ANNs and M5 model trees in rainfall-runoff modelling and flood prediction, using chaos theory in predicting water levels in the coastal zone, etc.

A number of research results and practical applications were developed in the framework of the Delft Cluster project 'Data mining and data-driven modelling'.

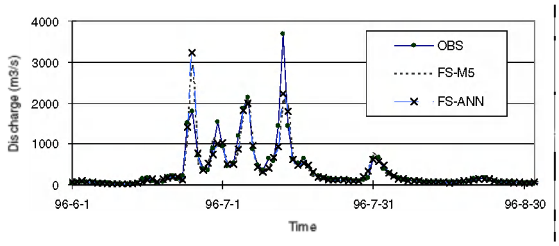

Figure 2. M5 and ANN models trained on the flood season data (testing, fragment).

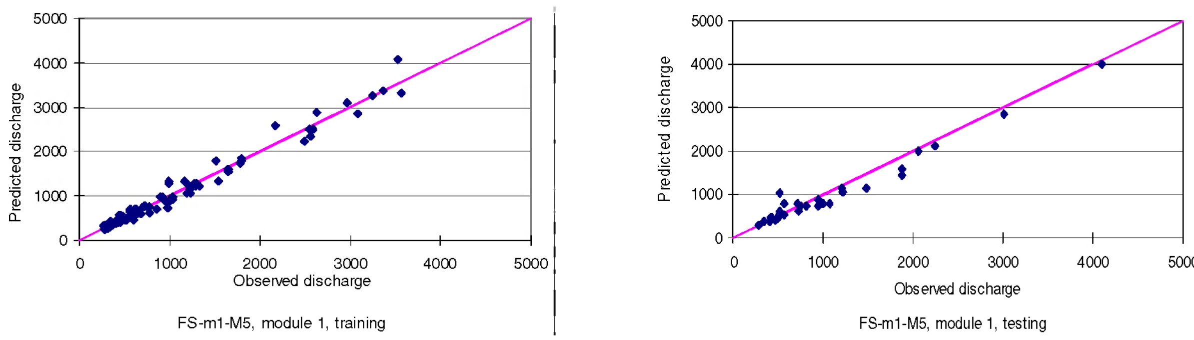

Figure 3. Performance of the data-driven model (M5) trained only on the high-flows data during the flood season (samples with $QX_{t-1} > 1000$ m^3/s). An increase of accuracy can be observed.

Symposium 'Data mining and data driven modelling: neural, fuzzy and other methods in solving civil engineering problems' organised in April 2002 in IHE-Delft showed the growing interest of practitioners to the novel methods of flood modelling. The latest experiences make it possible to conclude that the data-driven methods could effectively complement physically based simulation models. More information can be found on http://datamining.ihe.nl.

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Modelling sediment dispersion over floodplains using a particle tracking method

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Abstract
To monitor the dispersion of polluted sediments over the Dutch floodplains, we have developed a sediment-dispersion model in which we use a particle tracking method – the so-called 'Method of Characteristics' – to overcome numerical dispersion. This raster-based model uses input data such as initial suspended sediment concentrations, water levels, flow velocities and diffusion coefficients. To check the model results, we took water samples on a floodplain along the Waal River during its inundation in Spring 2002. We compared the model results with the measurements and it turned out that the model predicts the suspended sediment concentrations well in large parts of the floodplain.

Introduction
Scenario studies often use sedimentation models to study the deposition patterns of sediment-associated pollutants on floodplains. However, since these models are often raster-based and work on a coarse grid scale, numerical dispersion can lead to erroneous results. A particle tracking method – which works at the point scale – can overcome numerical dispersion. Konikow & Bredehoeft (1978) have developed the Method of Characteristics (MoC), a particle tracking method to simulate solute transport in groundwater. We modified this concept to be applicable for surface water and implemented it in PCRaster (Wesseling et al. 1996).

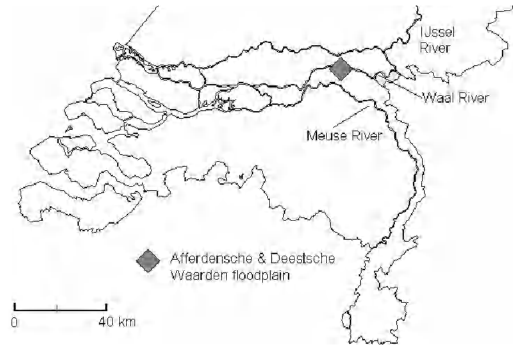

Figure 1. Location of the study area, the Afferdensche and Deetsche Waarden near Druten.

The purpose of this study was to determine the performance of the modified MoC model in the study area along the upper Waal River (Fig. 1). The RIZA hydrodynamic model WAQUA provided the input data – such as water levels, x- and y- flow velocities – for the sediment dispersion model. In addition, we used empirical formulae to derive the longitudinal and transversal dispersion coefficients. Finally, to check the model output we gathered field data.

Materials and Methods
The Afferdensche and Deestsche Waarden (ADW)floodplain is located along the Waal River, some 25 km downstream of Nijmegen (Fig. 1). Here we carried out our field measurements and we applied our model to this area. During the inundation period from late February to mid-March 2002 we measured suspended sediment concentrations (SSCs) at three times. Next, we derived all model parameters, such as water height, flow velocities and dispersivities, for the average river discharge between February 26 and March 2 (7,000 $m^3 s^{-1}$ at Lobith) from the hydrodynamic model WAQUA and empirical formulae.

Results
Looking at the measurements, we found a general decrease in SSC from the upstream entrances to the downstream part of the floodplain. The model, however, indicated a north-south gradient in SSCs with high values in the north western part of the floodplain and low values in the southern part (Fig. 2).

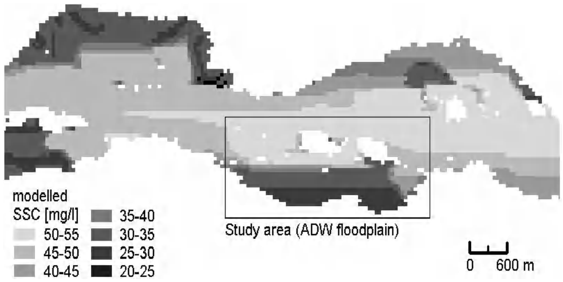

Figure 2. Modelled suspended sediment concentrations in the model area. The box denotes the same area as shown in Figure 3.

Discussion and conclusions

We determined the performance of the sediment dispersion model for the study area and found a good agreement between measured and modelled results in large parts of the study area (Fig. 3). At the locations in the north-western part of the study area, however, we found a large difference: in that area the model predicts the SSC to be 16 to 21 mg l^{-1} higher than the measurements indicate. This systematic difference points at an error in the modelled influx of sediment through the inlet in the central north of the floodplain (Fig. 3).

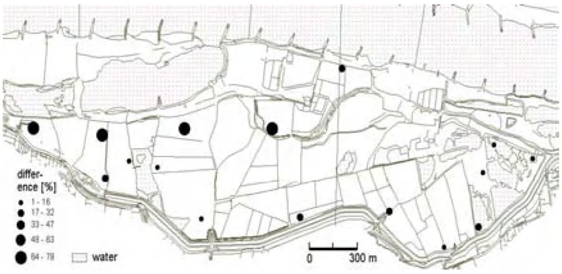

Figure 3. The percentage difference between observed and predicted suspended sediment concentrations.

In conclusion, the above evaluation of model performance shows that the model well predicts the pattern of suspended sediment concentration of most of the ADW floodplain. Besides, it shows that the model is sensitive for the water level and flow field. We believe the erroneous predictions in the northwest will disappear when we use a more detailed digital elevation model. All in all, the implementation of the Method of Characteristics in a 2D model was successful and can aid in a better prediction of the dispersion of polluted sediments over floodplains.

Acknowledgements

We are greatly indebted to Menno Straatsma for taking the water samples with his kayak. We also acknowledge the support from Ton Visser and Gertjan Zwolsman (RIZA-WST in Dordrecht), who carried out the WAQUA calculations and provided the necessary literature, respectively. Besides, we thank Ed Hull for his comments on the draft versions of the paper.

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The hillslope-storage Boussinesq model for variable bedrock slope

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Abstract
The recently introduced hillslope-storage Boussinesq (hsB) model is cast in a generalized formulation enabling the model to handle a locally varying bedrock slope. This generalization extends the analysis of hydrological behaviour to hillslopes of arbitrary geometrical shape, including hillslopes having curved profile shapes. The generalized hsB model performance for a free drainage scenario is evaluated by comparison to a full three-dimensional Richards equation (RE) based model. In addition, comparison of both models to a storage based kinematic wave (KW) model enables us to assess the relative importance of diffusion processes for different hillslope shapes, and to analyse the influence of profile curvature on storage and flow patterns specifically.

Model development
The mass balance equation for describing subsurface flow along a unit-width hillslope reads:

$$\frac{\partial}{\partial t}(fh) = -\frac{\partial q}{\partial x} + N \qquad (1)$$

where h = h(x,t) is the elevation of the groundwater table measured perpendicular to the underlying impermeable layer, f is drainable porosity, x is distance to the outlet measured parallel to the impermeable layer, q = q(x,t) is subsurface flux along the hillslope bedrock, t is time, and N is a source term. This equation can be generalized by mapping the three-dimensional hillslope shape onto a one-dimensional soil pore space (Fan & Bras, 1998):

$$S(x,t) = fw(x)h(x,t) \qquad (2)$$

where S(x,t) is the actual storage, w(x) is the hillslope width, and h(x,t) is the water table height averaged over the width of the hillslope. Moreover we define subsurface flux as (Boussinesq, 1877]):

$$q = -kh\left(\frac{\partial h}{\partial x}\cos i(x) + \sin i(x)\right) \qquad (3)$$

where k is the saturated hydraulic conductivity, i(x) is the local bedrock slope at x. Upon combination of Eqs. 1, 2, and 3, we obtain a generalized hsB equation that can handle spatially variable bedrock slope:

$$f\frac{\partial S}{\partial t} = \frac{\partial}{\partial x}\left(\frac{kS}{f}\cos i(x)\frac{\partial (S/w)}{\partial x}\right) + \frac{\partial}{\partial x}\left(kS\sin i(x)\right) + fNw \qquad (4)$$

Experiment set-up
We have applied the generalized hsB model, the KW model as described by (Troch et al., 2002), and the RE models as described by (Paniconi & Wood, 1993) to a set of nine characteristic hillslopes (see Fig. 1).

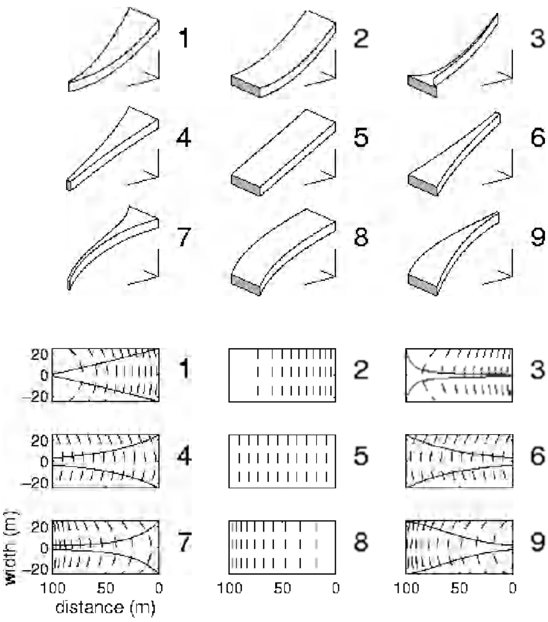

Figure 1. Nine characteristic hillslopes.

The nine characteristic hillslopes consist of three divergent, three straight and three convergent hillslopes with profile curvature varying from convex to straight to concave. For 5 and 30% slopes free drainage experiments are inter-compared, starting from 40% saturation. In order to generalize the results a dimensional analysis is conducted. A dimensionless representation will give us scaled model results. We define the following dimensionless variables:

$$\tau = \frac{tki}{fL}, \chi = 1 - \frac{x}{L}, \phi = \frac{Qcum(t)}{V}, \sigma = \frac{h(x,t)}{d}$$

where L is hillslope length, $Q_{cum(t)}$ is cumulative flow up to time t, V is the initial volume of water stored in the hillslope, and d is soil depth. The dimensionless variables define (in order) kinematic time, flow distance as a fraction of the total flow path, dimensionless flow, and dimensionless storage.

Results and conclusion

Fig. 2a, 2b, and 2c show the dimensionless storage patterns for the 5% bedrock slope simulations.

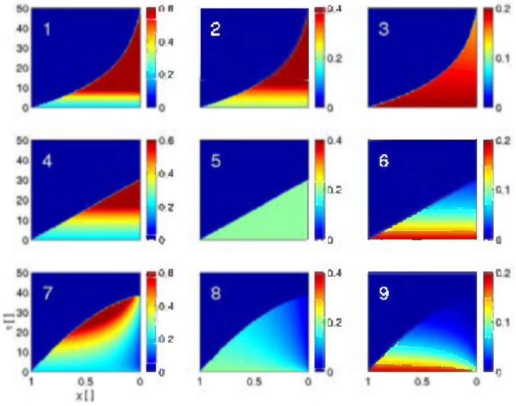

Figure 2a. hsB 5% storage.

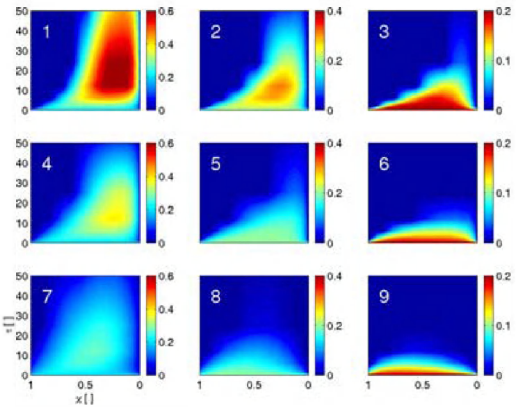

Figure 2b. RE 5% storage.

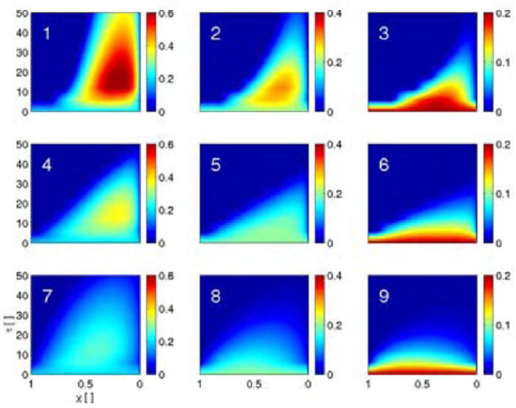

Figure 2c. KW 5%/30% storage.

Fig. 3a and 3b show the storage patterns for the 30% bedrock slope case.

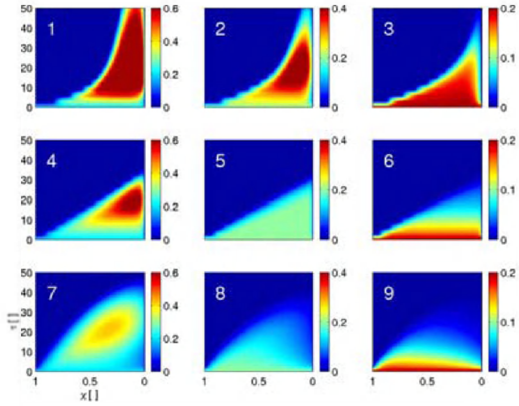

Figure 3a. hsB 30% storage.

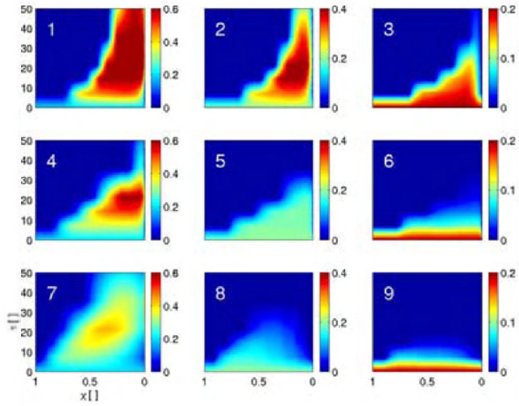

Figure 3b. RE 30% storage.

Fig. 4 displays the dimensionless hydrographs for all hillslopes (k = 1 m/h, 0.22 ≤ f ≤ 0.3).

In this work we have generalized the hsB model to variable bedrock slope and we have conducted an intercomparison of a RE model, taken as a benchmark, with the hsB, and a KW model, in order to investigate within which settings the application of the KW and hsB model is valid.

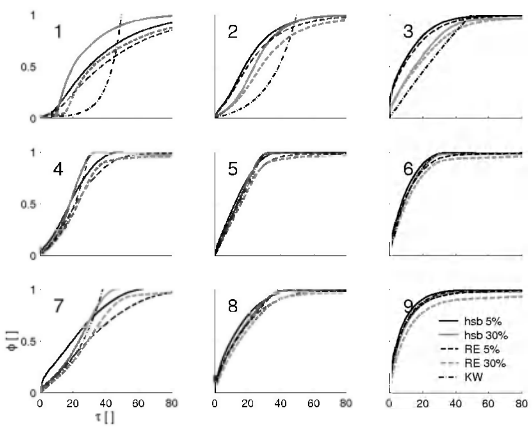

Figure 4. Hydrographs 5%/30%, all models.

Generally one can conclude that (1) the hsB results show a good match with the RE results. (2) In relation to the validity of applying a KW model it is limited to simulation settings in which hydraulic diffusion has a marginal impact on storage. (3) The RE hydrographs appear to have a slight delay compared to the hsB results. This may be explained by the capillarity effects of the soil.

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NWO and Water

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NWO: the organisation

The Netherlands Organisation for Scientific Research (NWO) promotes fundamental and applied research of high quality. An international orientation has high priority. The means to perform this mission are M€ 400 per year from the Ministry of Education, Culture and Science and about M€ 50 per year additional funds from other ministries and enterprises. Via several funding schemes NWO finances over 4,300 positions in scientific research, both at universities and at NWO institutes.

NWO has a variety of funding schemes.
A line of personal grants exists for young talented postdocs up to well-established postdocs with budgets from k€ 200 up to k€ 1,250 ("Vernieuwingsimpuls"). On top of this, annually four Spinoza-prises (M€ 1.5) are awarded to internationally renowned scientists. The research councils fund open programmes and a wide range of dedicated programmes, aimed at research on specific themes. NWO participates in many thematic European research programmes, in particular in the recent so-called EUROCORES, which are coordinated by the European Science Foundation. Moreover, NWO has funding schemes for investments, for centre subsidies and for travel, workshops, and international coordination.

The mode of operation of NWO is characterised by three layers of appraisal of research proposals, which are submitted for funding. At the first level proposals are reviewed by independent peers, for ALW usually scientists from abroad. The reviews can be commented by the applicants of the proposals. The next level is the judgment and prioritising of proposals by the programme committee, which is composed of senior Dutch scientists. Decisions on funding are made by the Research Councils, Boards, or Steering Committees in case of co-funding by external parties. By approximation, about 4,000 – 5,000 external referees are annually involved in the review process and more than 1,000 (mostly Dutch) scientists are involved in committees, boards and councils.

The funding by NWO is mainly organised according to clusters of disciplines in Research Councils ("Gebiedsbesturen"). In addition two foundations exists for research in a variety of disciplines: WOTRO for research in tropical and developing countries and NCF for supercomputing.
Besides, NWO administers a couple of research institutes: on physics (four institutes), sea research (NIOZ), space research and earth observation (SRON) and astronomy (ASTRON). In addition, NWO hosts coordinating offices for managing external funds for research on Genomics, Biopartner, ICT, and the European office for EDCTP (clinical trials of medication in Africa).

The NWO strategy

In the Strategic Plan 2002-2005 of NWO seven interdisciplinary themes were presented, one of them called 'System Earth'. This theme acts as an umbrella over a number of issues related to the large-scale human influences on earth systems, generally indicated as Global Change. This covers a wide variety of research, e.g., on climate change, on development of hydrogen energy systems, on policy mechanisms under the Kyoto-protocol, on the use of tropical coastal zones, and on water management in The Netherlands.

In particular the Research Council on Earth an Life Sciences has identified strategic themes on Global Change: biodiversity, the coupled bio-geosphere, climate variability, continent-ocean boundaries, water and coastal zones, bio- and geo-informatics and monitoring. Some of these themes are shared with WOTRO and the Council on Exact Sciences (EW). In addition, several external parties join in relevant funding programmes. In particular the Ministry VROM has committed funding for a series of issues related with climate change, which are covered by different programmes.
In the near future, the following relevant programmes are open for proposals (see Table).

Funding	Programme	Deadline
ALW, EW, *VROM	Climate variability (incl. C-cycle)	6-1-04
ALW, *NERC (UK), *NRF (Norway)	RAPID Climate Change	15-12-03
ALW, WOTRO, *VROM	Water	2-2-04
ALW, *BuZa, *LNV, *VROM	Netherlands Polar Programme	15-10-04
ALW, *V&W, *VROM	Earth Observation	17-11-03
MaGW, ALW, *VROM	Vulnerability, Adaptation, Mitigation	spring 2004

*: external funders

The NWO-programme WATER: rationale, themes and sub themes

The Water programme is a joint venture of ALW and WOTRO. The programme has a wide, multidisciplinary scope, but the central rationale is in global change and in particular climate change in relation with water. The first call for M€ 3 closes 02-02-2004. A second call for M€ 2 will be opened by the end of 2004.

The Water programme document names three themes and several sub-themes:

- Water and the earth system:
  - The water cycle
  - Atmospheric water
  - Surface water
  - Soil and ground water
  - Terrestrial ecosystems and hydrology
- Global change and aquatic ecosystems:
  - Water quality and harmful algal blooms
  - Aquatic food webs and biodiversity
  - Waterborne diseases
- Water and society:
  - Water scarcity, governance and contestation
  - Water productivity, regenerative capacity and livelihoods around water uncertainty
  - Water management, networks and control of floods and water supply

Within the context of global change and in particular climate change, the scientific challenges of the programme relate to common threads through all aspects:

- Diversity, heterogeneity, variability;
- Non-linearity, thresholds, boundaries;
- Vulnerability, resilience and adaptation (in The Netherlands, Europe and in developing countries).

For information on the Water-programme: www.nwo.nl/alw and e-mail alw@nwo.nl.

Five years NCR, review and preview

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Abstract
Five years ago NCR was founded by nine Dutch research institutes to build a joint knowledge base on rivers and to promote co-operation between the most important scientific institutes in the field of river studies in the Netherlands. This co-operation was also meant to strengthen the national and international position of Dutch scientific research and education. In these five years, NCR succeeded in filling in its platform function through e.g. the organisation of the so-called yearly NCR-days and building a strong international image through amongst others the leadership of the INTERREG-IIC IRMA-SPONGE program.

Introduction
The Netherlands Centre for River Studies (NCR), a co-operation of the major developers and users of expertise in the Netherlands in the area of rivers, was founded on October 8, 1998. So, this year, we are celebrating our first lustrum.
The extent of the research challenges for the coming decades necessitates co-operation on national and international levels: one single research institute cannot perform the interdisciplinary research needed nowadays on its own, especially where the institutional structure in a country more or less follows methodological lines. In the case of river research in the Netherlands, some institutes focus on field monitoring, some on field campaigns, some on numerical modelling and laboratory experiments, some on behaviour analysis, and some on uncertainty analyses. Co-operation between the various institutes, making use of the specific expertise and infrastructure of each institute, is therefore essential. And this is exactly what has been done in the Netherlands with the establishment of NCR in October 1998.

NCR partners
The NCR partners of the first hour were:
- TUD (Delft University of Technology),
- UU (Utrecht University),
- KUN (University of Nijmegen),
- UT (University of Twente),
- UNESCO-IHE,
- RIZA (Institute for Inland Water Management and Waste Water Treatment),
- ALTERRA (Dutch centre of expertise on rural areas, two separate institutes at that time, now merged into one) and
- WL | Delft Hydraulics.

In 2000 they were joined by TNO-NITG (Netherlands Institute of Applied Geoscience) and at the beginning of 2003 by WU-CWK (Wageningen University, Centre for Water and Climate).

NCR Functions
NCR has two key functions:
- 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; examples are the yearly NCR-days and the different workshops NCR organises;
- research-orientated and educational co-operation: in which a real commitment of the partners is reflected.

Figure 1. Signing of NCR co-operation agreement on October 8, 1998.

Main results of first 5 years

Platform function

Five specific parts of the platform function of NCR can be distinguished:

1. The NCR thematic days for young researchers and the NCR professional orientation
2. The co-organising role of various International Conferences and Symposia
3. The NCR Internet site www.ncr-web.org
4. The NCR publications series, and of course
5. The NCR-days.

The thematic days and professional orientation have been explained at the NCR-days of 2002 by Reinier de Nooij and can be found in the proceedings of these days (NCR publication 20-2003).
One of the meetings NCR helped to organise is the Symposium of Lowland River Rehabilitation, the results of which were summarised by Tom Buijse during these NCR-days. In the coming period NCR will also play a role in the organisation of the 7th INTERCOL International Wetlands Conference (July 2004), the 3rd International Symposium on Flood Defence (May 2005) and the 8th International Fluvial Sedimentology Conference (August 2005).
Information on these meetings can be found on the NCR Internet site. This site has been developed since 2000. It gives general information on NCR and its partners and it has the possibility for NCR researchers to insert their own information on the site. We would like the researchers to use this possibility more often. At the moment the site is visited 50 times a day (as an average on a working day), but only 40% is from the Netherlands, so most probably only 50% (25 hits a day) are serious visitors.

The NCR publication series started in 2000 too. Until now the series consists of 23 publications. In the years 2000, 2002 and 2003 three publications were published; 2001 showed an outburst of 14 publications, due to the final reporting of the various IRMA-SPONGE subprojects.

The NCR-days officially also started in 2000. But already in 1997 and 1998 so called pre-NCR-days were organized in Lunteren and Delft, where ongoing (university) research was presented and in 1999 NCR organised a workshop with presentations from non-university partners, which was reported in the NCR publication series (NCR 02-2000).
The NCR-days from 2000 onwards, meant for young researchers to present their ongoing river studies on two consecutive days, in order to maximise the exchange of ideas and experiences between the participants and to provide the researchers a sounding board for their study approach and preliminary results, proved to be very successful. The participation increased from some 80 to 105 (2003) and even 125 (2002), with very enthusiastic feed back from the participants. Of course the proceedings of these days are also incorporated in the NCR publication series.
To celebrate our first lustrum the NCR-days Presentation and Poster Awards were established.

Research co-operation

The research function of NCR was summarised in Dutch in the "NCR Programma" in 2000 and in 'Summary of NCR Programme, version 2001 – 2002' in 2001.
It is worth mentioning that NCR is not a funding facility. The partners have committed themselves to put at least the equivalent of some € 100.000 each year into the co-operation, but the real added value of NCR lies in putting together projects that are financed within different research frameworks. Many of these frameworks provide 'shared cost financing' (e.g. EU framework programme, Delft Cluster), meaning that only part of the total costs of the project is funded. Other frameworks (e.g. NWO) only provide financing for University research personnel or instruments. NCR, being a research co-operation without research funds of its own, provides the platform to bring these frameworks together.
Senior researchers of the NCR-partners provide the capacity to analyse the possibilities, to draft the proposals and to supervise the research.

In 2002 the following research themes were adopted:

- Living (in harmony) with the River ("(Over)leven met de rivier")
- Dynamic River Management (Cyclic Rejuvenation)
- Genesis of Floods, which is closely linked with the Hydrological Triangle (see page 19), and last but not least
- The Morphological Triangle (see proceedings NCR-days 2002).

A very important part in the NCR-role as far as research is concerned is the building of a strong international image through international research co-operation. This aim of NCR received a boost by the invitation to lead the EU sponsored (INTERREG-IIC) IRMA-SPONGE research program. This program ended in 2002. It was reviewed as very good and successful. The most important results were published in the NCR publication series.

Future activities

In the coming period the NCR Programming Committee will focus on the updating of the NCR program along the lines of the themes mentioned above. Important funding sources for this program will be, apart from the own resources of the NCR partners, the Dutch BSIK program (Delft Cluster, Living with Water etc.), the Dutch NWO/ALW Water and LOICZ programs and the 6th framework programme of the EU (Global Change).
For instance as a follow up of the IRMA-SPONGE program already two EU sponsored projects, 'Freude am Fluss' and 'FLOODsite' are in the contract negotiation stage.

'Freude am Fluss' (INTERREG-IIIB) will be a tri-national, multi-disciplinary, public/private project that looks beyond public's 'immediate reactions' (NIMBY): it explores the deeper visions of the public concerning living along rivers with their floods, seeks for the benefits (economic, social and cultural) of co-designing solutions (of maximizing Freude am Fluss) and will provide attractive examples of concrete designs and plans for measures mitigating risk and maximizing pleasure.
Co-ordinator is KUN. It has 12 partners from 3 countries (NL, D, F). NCR partners are KUN, Delft Hydraulics, RIZA (RWS-DON and -DWW). Project duration is 5 years, the total project budget is approximately 7.7 Mio€ and the EU contribution approximately 3.8 Mio€.

'FLOODsite' (FP6 Global Change) will be an Integrated Project with 36 partner institutes. Co-ordinator is HRWallingford, NCR plays a co-co-ordinator role. NCR partners involved are Delft Hydraulics, TUD, UT, WU and UNESCO-IHE. KUN, Alterra and possibly TNO-NITG will participate through subcontracting. RIZA has a seat in the Application and Implementation Board. Project duration will be 5 years, the total budget 14.133 Mio€ with an EC contribution of 9.68 Mio€.

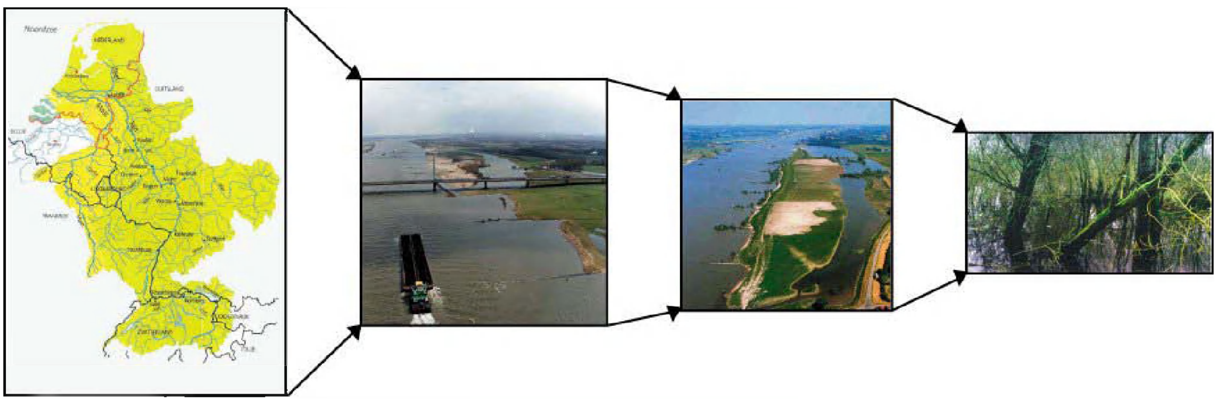
'FLOODsite' aims to provide an integrated framework for flood risk management from operational to planning time horizons (50 years and beyond) in:

- Sustainable pre-flood measures (infrastructure provision, planning and vulnerability reduction)
- Flood event management (early warning, evacuation and emergency response)
- Post-event activities (review and regeneration).

'FLOODsite' is subdivided in seven themes.

Conclusions

After five years of NCR we may conclude that NCR succeeded in its aim to provide an open platform for all people interested in scientific research and communication on River issues and to promote co-operation between the most important scientific institutes in the field of river studies in the Netherlands (and abroad).
The NCR-days prove to be very successful. Thanks to the successful IRMA-SPONGE program the international image of NCR is strong. It provides NCR with a major role in future EU projects like the FP6 Integrated Project 'FLOODsite'.



Scope of NCR: river basin river branch floodplain ecotope

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NCR Publications series

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