Interactive Flood Management and Landscape planning in River Systems:

development of a Decision Support System and analysis of retention options along the Lower Rhine river

Executive Summary

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Abstract

A generic Decision Support System was developed that supports the planning and assessment of river landscapes using two alternate approaches. In the "top-down" approach, plans are developed conceptually on a large inter-reach scale and subsequently defined in more detail on a local scale. Alternatively, in the "bottom-up" approach, detailed plans for local river floodplains may not only be analysed on the detailed local scale, but also in conjunction with adjacent plans and ultimately as part of the plans developed on an inter-reach scale.
Besides 1D and 2D computational modules for hydraulic and ecological impact assessment the decision support system also contains an information management system that provides easy access to relevant documentation as well as a database based system containing results of analyses previously carried out.
Special attention was given to the integration of hydrodynamic modelling with ecological and habitat analysis, network evaluation and landscape evaluation.
Besides the DSS development, the objective of the project is also to analyse options for retention ponds along the Lower Rhine River. All effects of such options will be addressed at (pre-) feasibility level (not detailed design). DSS-LR is a tool that may be very helpful in landscape planning and river restoration. It is, however, not the ultimate solution but will often be used in combination with common sense and, depending on the project, with other software tools.

1 Background

1.1 Spatial planning and water management

In 1993 and 1995, high floods threatened the area behind the dikes of the Lower Rhine branches and the Muese. Although about 250.000 people were evacuated, and the financial damage was considerably, the dikes held, and no losses of lives occurred. However, it became clear that in the near future, some serious measures had to be taken to prevent this kind of situation. Many people became aware of the fact that the area of the Lower Rhine in Germany and the Netherlands might not be as safe as everybody thought. This set the stage for a number of decisions and actions by regional and national governments, but other developments are relevant as well.

Figure 1: Dikes under threat

Already in 1992, the World Wildlife Fund (WWF) issued a report 'Natural Rivers', in which a prominent place was reserved for the discussion about an ecological restoration of the river area. Measures that were suggested involved the construction of secondary channels and clay-excavation to achieve river banks with a more natural character and favourable conditions for floodplain forest development. It should be emphasised that this was one of the first studies that proposed an integral approach to the problem of re-styling a river landscape: Safety was as always the prime directive, but ecological restoration, shipping, drinking water, agriculture, all those aspects got attention.

During the early nineties awareness on the impacts of the climate change on river flows increased. As a result, the design discharge was re-evaluated (The design discharge is the discharge that, according to statistics, occurs on average once every 1250 years. In turn, this design discharge determines the design water level, which is then used to deduce the height of the dikes). Based the new insights the design discharge was expected to increase and hence a new round of dike reinforcement would be necessary. From a social point of view this was hardly acceptable, and while it is also an unsustainable solution for the longer term. Furthermore, policy makers saw themselves confronted with many of initiatives in the floodplains (mainly with a recreational character) which influenced the water level at high discharge conditions.

Faced with all these aspects, emphasised by the floods of 1993 and 1995, water managers and spatial planners expressed a need for an instrument to answer questions related to spatial planning in combination with the safe management of higher discharges through the Lower Rhine area.

1.2 Decision Support Systems

In the last decade, mathematical models, databases, expert systems and geographical information systems all have been applied as separate tools in the research and management of water resources. A Decision Support System (DSS) aims to integrate these tools and thereby provide an adequate scientific description of water systems for the comparison of different strategies and measures. A DSS is an important tool to:

- integrate research efforts in different scientific disciplines and translate the results to the management level.
- increase understanding at the management level of the relations between users of a water system and the system itself.
- provide different authorities with a common framework for the analysis and comparison of management decisions.
- facilitate the comparison of many different management options and measures.
- repeat the decision making process after additional or different information has become available.

Figure 2: Tools supporting decisions

Flexibility is an important point of concern during the development of the DSS. The DSS must on the one hand suit the needs of the river manager for (long-term) policy development and, on the other hand, support interactive development of flood protection measures and landscape planning. Within the DSS accepted methodologies for alternative development and evaluation are formalised and are automatically consistent for various scale levels. The user is guided through an integral and multidisciplinary evaluation process in order to facilitate a well balanced and sustainable development of a river system.

The diversity in needs of the end users of the DSS results in a challenging list of requirements to support the various phases of the planning process:

- identification and development of strategies (the conceptual level);
- screening of alternatives consisting of plans and measures (the policy level);
- interactive design and screening of detailed plans for flood management and landscape planning (the design level).

The need for technical support, background information and analyses concerning flood management and landscape planning in river systems is continuously increasing. Access to information, improvement of communication with stakeholders, and an integrated and multidisciplinary approach become essential in decision making processes. Therefore in 1997 a start has been made with the development of a generic Decision Support System (DSS) for interactive flood management and landscape planning. This instrument is seen as a promising tool in the decision making process in the mentioned field for river systems in the Netherlands and abroad.

1.3 Retention Ponds

There are many different types of river measures and landscape planning projects along the river Rhine branches in the Netherlands. There are two types of measures that potentially reduce flood stages:

- measures that locally influence flood levels (for example by means of enlarging the river cross section); and
- measures that reduce peak discharges and thereby reduce flood stages over the entire river length downstream the location of the measure (for example by means of retention ponds, in which temporarily water is stored).

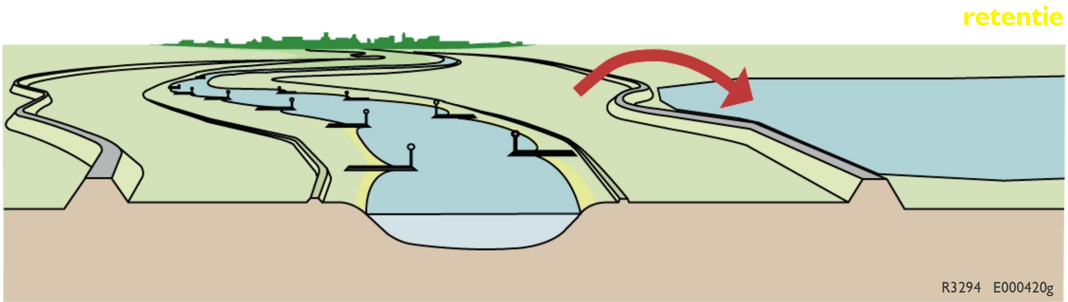


Figure 3: Concept of detention is to absorb the peak of the flood

Since retention ponds, when used effectively, reduce peak discharges of the Rhine River retention ponds are quite promising measures that, when applied on the Lower Rhine river can be of great benefit to both Germany and the Netherlands. It is therefor very interesting to study the different implementation options and possible benefits of retention ponds along the Dutch Rhine branches.

2 Objectives

The main goal of this project was to develop and apply a generic Decision Support System that supports the approach of river landscape planning using two alternate approaches. In the “top-down” approach plans are developed conceptually on a large inter-reach scale and subsequently defined in more detail on a local scale. Alternatively in the “bottom-up” approach detailed plans for local river floodplains may not only be analysed on the detailed local scale, but also in conjunction with adjacent plans and ultimately as part of the plans developed on an inter-reach scale.

Besides 1D and 2D computational modules for hydraulic and ecological impact assessment the decision support system was also intended to provide an information management system that would give the user easy access to relevant documentation as well as a database based expert system containing results of analyses previously carried out. This database had to support queries and multi-criteria analysis to help select and rank plans on desired attributes.

Special attention was given to the integration of hydrodynamic modelling with ecological and habitat analysis, network evaluation and landscape evaluation.

Developments should be made in close contact with the end users in order to ensure the usability of the tool.

Besides the DSS development, the objective of the project is also to analyse options for retention ponds along the Lower Rhine River. All effects of such options will be addressed at (pre-) feasibility level (not detailed design).

3 Approach

Within the project the following activities or themes were distinguished (comprising various combinations of design, research, modelling and communication):

3.1 Definition Study.

In close contact with water managers in the Netherlands the needs regarding the functionality of a decision support system were identified and discussed. Basis was the IVR-DSS that had been developed between 1994-1997. This led to the functional design of the DSS for the Dutch river area.

3.2 DSS prototype development.

A prototype DSS was developed containing the modules: documentary information system, systematic planning of measures, integral evaluation of alternatives concerning flood protection and ecology (policy level of the DSS, one-dimensional approach).

3.3 1st release of DSS.

The DSS was further developed containing the previously mentioned modules in a more elaborated expert system, an interactive design module for development of flood plain plans (fully GIS based),and integral evaluation of flood plain plans (design level of DSS, two dimensional approach). This system was an instrument to be used for the integral exploration of landscaping projects of the Rhine branches, and it has been applied successfully in several stages of re-styling projects.
In the first step of the development of the system, a GIS-related database which contains the spatial boundaries of the plans for the

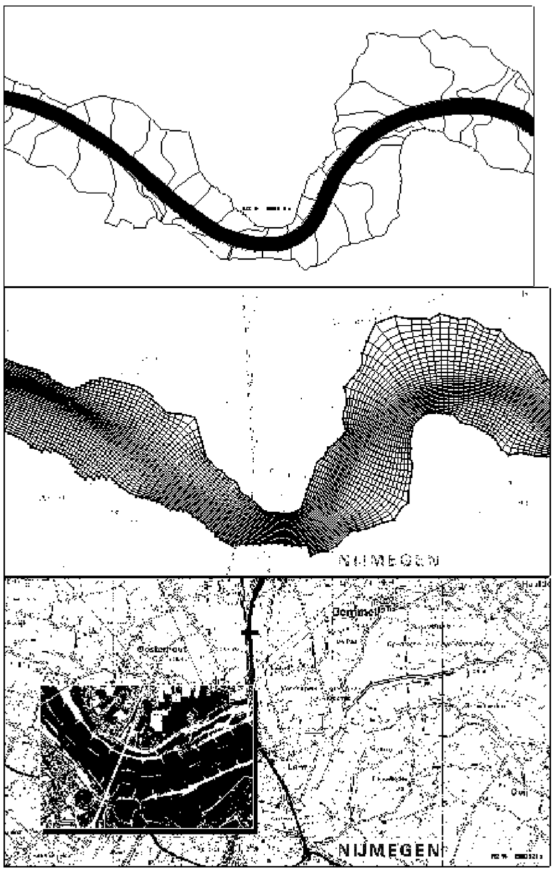


Figure 4: 1D and 2D models are developed

floodplains has been constructed. Then, using standard GIS-applications, the essential features of the plans (location, area, etc.) are isolated and are used to characterise the plans. Finally, the characterisation for each plan, or set of plans (which is then called a landscaping variant) is translated into a schematisation which acts as input for hydraulical, morphological or other river-related model calculations. A pre-processor takes care of this process. A so called 'click-chart' (a map of the area of interest, in which the individual floodplains and the associated plans can be activated and de-activated) can be used to construct simple landscaping variants, which can then be tested for the various effects.
Using simple post-processing facilities, the various effects on river functions (water level, discharge, etc) of the measures can be visualised. Other effects of a landscaping variant (costs, minerals, amount of clay excavation, etc.) are presented in effect-tables. They are calculated by simple relations derived from the data in the central database.

3.4 Analysis of retention options in The Netherlands

Using the DSS the effect of a limited number of retention options in the Netherlands were analysed to assess their impact on the water levels during floods.

3.5 User evaluation.

The DSS system developed so far has been applied to an number of problems and areas in different projects, where the actual application would vary depending on the actual problem definition and areal characteristics:

- IVB-DOS This project performed an integrated reconnaissance of the delta area of the Rhine and Meuse rivers.
- IVM This project aims at an integrated reconnaissance of the Meuse River area in The Netherlands
- IVR This project aims at an integrated reconnaissance of the Rhine River area in The Netherlands
- RvR Room for Rhine branches, same as previous with special attention to options to accommodate higher floods.

Figure 5: Interaction with users enhances the DSS

The experiences gained with these projects offer an excellent opportunity to evaluate the performance of the DSS and the requirements of the DSS as a generic tool for interactive river management and landscape planning. In this theme experienced users, developers and potential users are given the opportunity to provide input to the functional design of the further improvements to the DSS. Triggers in this respect are experiences with existing applications, requirements for retention options and extension of the area to include Germany, as well as expectations regarding plans and issues in the future. The activities in this theme are:

- Formation of the user group (including other IRMA-Sponge projects)
- 1st workshop with demonstrations of the different DSS applications and initiation of the evaluation process.
- Collection of ideas, suggestions and comments. Based on the input of the user group a draft functional design will be made.
- 2nd workshop of the user group to achieve consensus regarding the functional design of the improved DSS.

3.6 DSS improvement.

Based on the functional design, the DSS system will be improved so that it will fulfil the needs of the users in a better way. The activities in this theme can be divided into several topics:

- Improved interactive use of the DSS. This relates to the way data, projects, knowledge or measures are entered or designed in the DSS, and the way the DSS provides output to the user. Conceptually the DSS should allow the user to stay close to the normal landscape planning and strategy design approach as possible, and allow the user to use and enter information in terms that the user is familiar with. In view of the international character of the project, it was decided to make the GUI's multilingual.
- Improved robustness of the DSS. The step by step development of the DSS and additions of modules has not always led to optimally robustness of the system as a whole. This activity is aimed at improving the system and reducing the dependence of certain versions or types of software. Also an improved data structure may be required in this topic.
- Linking SOBEK and Delft FLS off-line. In SOBEK-rivers a functionality is present to simulate retention basins as an area with an entry and outflow structure. Delft FLS was coupled off-line to simulate one area in 2d .
- Additional functionality through additional modules or additional functionality of existing modules. One possible activity under this topic could be the addition of DELFT-FLS to simulate the flooding of retention basins in more detail, another the addition of the LARCH ecosystem module. Some important improvements will be made in the LEDESS rivers module.
  - Improving the planning procedure. Planning measures to prevent flooding or changing land-use will be made more sophisticated due the process of planning by landscape planners. Dealing with landscape quality plays an important role in the planning process. Examples of landscape quality are historical sites, rare habitats, archeological sites or other valuable areas in the landscape that need protection in one or another way. But also polluted areas or economic highlights can be considered as landscape qualities planners have to deal with. Interactive planning and cyclic planning of measures and targets are updated and improved using planning concepts and better software tools for planning measures and targets.
  - Abiotic suitability for measures and targets is extended and based on recent research in floodplains. In this case targets can be defined as future land use or management like hard wood forest or natural grasslands.
  - In the DSS of that moment the link between hydraulic models and LEDESS was limited. The interaction between the hydraulic models in the DSS and the LEDESS model was improved. The 5 time steps (0 – 100 years) used for succession of the vegetation and habitats of animals do effect changes in hydraulic roughness for non-dynamic systems now. In the new version a more dynamic interaction between vegetation development and hydraulic roughness was developed.

Figure 6: Recognising areas of natural value

- At two different landscape scales (branch scale and flood plain scale) data was classified (ecotopes and landscape quality) according to expected planning scenarios, policy decision and rivers system knowledge. A method was developed for automated classification of data. Classifications were adjusted to the other parts of the DSS. As a result of this phase different maps with ecotopes and landscape quality can be generated. Also the new data input for the LEDESS model was made available.
- The LARCH model is a population-dynamic DSS developed for calculation of spatial connectivity in meta-population. In the DSS population dynamics of key species was originally not calculated. Therefore the LARCH model was linked to the LEDESS model. Patches with habitat suitability in the LEDESS model will be input in the LARCH model. In this case the LARCH-scan model is used in which population connectivity for some model species can be calculated. Because both models used their own habitat classification and habitat parameters the most important step in linking was redefining the classification and parameters and calibration of the interaction between both models.

Figure 7: Developing room for the River

- The linking of SOBEK and LEDESS in a dynamic way (e.g. every 5 year in a calculation) was developed. To link the models dynamically, after every nth step of SOBEK , LEDESS should be called. A new hydraulic roughness is determined for SOBEK and SOBEK will continue.

3.7 Analysis of retention on the Lower Rhine

Using the improved DSS system an application is developed for the Rhine reaches between Cologne (Koln) in Germany and the middle of The Netherlands (Gorinchem, Schoonhoven, Kampen) which allows the evaluation of retention options.

The application of the DSS to a certain area requires the development of applications of the individual modules or components to include the data and schematisation of the area considered. The application of the DSS to the Lower Rhine area with special consideration to the evaluation of retention options therefor requires the following activities:

- Sobek (1-D) schematisation for the combined reaches Andernach-Lobith and Lobith-Gorinchem. This activity included the collection of necessary data.
- LEDESS and Larch application to the area concerned, including data collection. In the LEDESS-rivers knowledge tables describe the relation between measures or targets and different types of land use, landscape quality and nature development. These knowledge tables do not cover

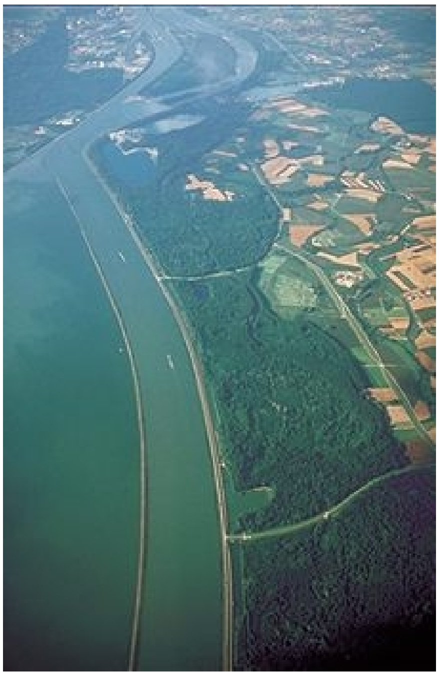


Figure 8: The Altenheim retention area

the whole river area as suggested. Extension of these knowledge tables was required and regional knowledge tables were necessary for the different river branches or regions.

- Addition of specific area related measures or options to the knowledge database.
- Schematisation of the retention basins in Delft-FLS.

Promising measures, especially regarding retention areas were identified to be analysed using the developed application. The assessment criteria were carefully determined. How to evaluate the benefits or effects of retention is not straightforward. The identified promising measures were entered into simulation runs, and the runs are assessed using the developed assessment criteria.

4 Achievements

Between 1997 and 2001 a generic Decision Support System (DSS) for interactive flood management and landscape planning has been developed. During the development of this DSS flexibility was an important point of concern. The DSS must on the one hand suit the needs of the river manager for (long-term) policy development and, on the other hand, support interactive development of flood protection measures and landscape planning.

The diversity in needs of the end users of the DSS has resulted in a set-up of the system that supports various phases of the planning process:

- identification and development of strategies (the conceptual level);
- screening of alternatives consisting of plans and measures (the policy level);
- interactive design and screening of detailed plans for flood management and landscape planning (the design level).

This chapter gives a description of the DSS Large Rivers that emerged from this project. The project is characterised by many intermediate products and versions. This illustrates the developments carried out in an iterative manner in close co-corporation with the end users. The description of the development achievements are divided into two parts: the developments in the project Room for the River Rhine (RvR) aimed at developing a tool for the Netherlands, and the developments in the DSS-Large Rivers project that aimed at making a generic tool for interactive design and planning process, with ecological and habitat analysis, network evaluation and landscape evaluation.

4.1 Developments for the RvR project

With the RvR DSS various types of measures can be analysed, such as the construction of 'parallel channels', the relocation of embankments and measures promoting the development of certain ecosystems. In these DSS's mathematical models play a central role in impact assessment. Water quantity simulations with the hydrodynamic model SOBEK provide insight in the impacts on safety and navigation. In a DSS impacts of strategies can be presented in score-cards, graphs and thematic maps.

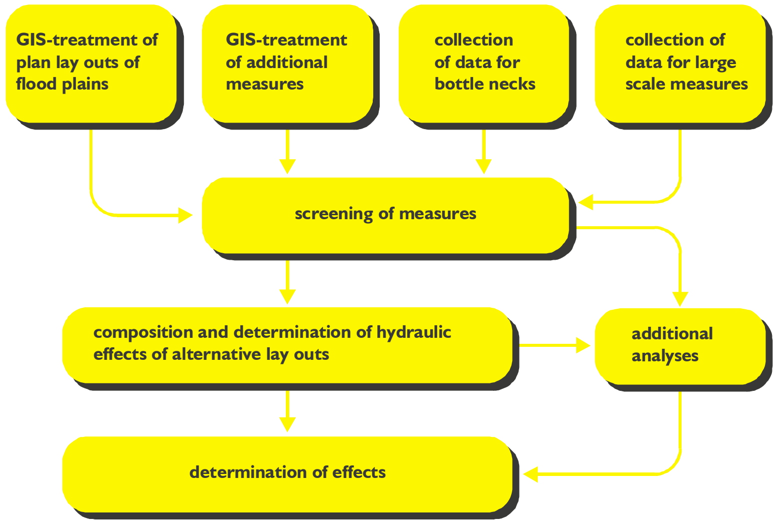


Figure 9: Structure of the study "Room for the river Rhine

The RvR DSS was primarily focussed on the Rhine branches, especially on the effects of rise in water levels. The strategies followed in the DSS had to solve the main problem: flood protection of the dike-protected areas in the Rhine river region.

Up to this point, the RvR project has primarily consisted of exploratory and policy advisory activities The central question was if – in anticipation of a higher design river discharge – it is possible to manage the current level of safety against flooding in the river areas by employing techniques for widening and deepening the river without subsequent dike reinforcement.
In February 2000, the results of the aforementioned studies have been offered to Ms. De Vries, the Dutch Minister of Transport, Public Works and Water Management. The results were accompanied by three alternative variants, each one being capable of transporting the increased discharge of 16.000 m3/s by Lobith. They differed in approach: One variant emphasised nature development, one emphasised wet-nature (And hence, more excavation) and one took into account the exclusion of floodplains with a high cultural or landscape value (the so-called 'do-not-touch'-area's)..
Furthermore, some preliminary results for an even higher discharge of 18.000 m3/s were shown, anticipating on the climate change in 2050 or 2100. It then turned out that with only measures between the dikes, the waster levels could not be reduced sufficiently. Retention and green rivers, combined with a different division of the water over the branches of the river, is necessary.
These scenario's are now being evaluated. In the near future, a choice for a certain scenario, or combination of scenario's has to be denoted, and all the existing plans, and forthcoming plans have to be tested against this scenario. As this will be done in more detail, both with respect to the spatial scale (several floodplains instead of complete branches) as to ecological and social-economical aspects, it is likely that the DSS-large rivers (especially the 2D-part) will take an important role in this evaluation.
Moreover, the increase of the discharge to 18.000 m3/s, was only addressed shortly in the study Room for the river Rhine. A closer look towards this problem is now being executed in the so-called Resilience study. How flexible are the Rhine branches (including the lower river area) to take care of an increase of 20 % of the discharge. The time-schedule didn't allow for the use of the DSS, for the development was not ready by that time.
Shortly after the completion of the studies Room for the river Rhine and Integrated Exploration of the Lower River Region, the Minister also ordered that a similar study should start for the river Meuse. This seems logical, because the greater rivers is the Netherlands

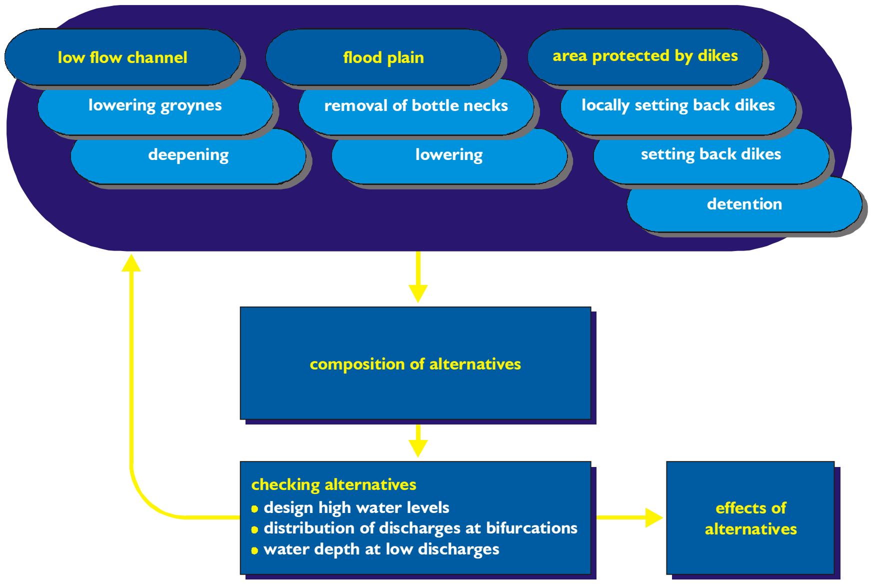


Figure 10: Combination of measures, hydraulic testing of alternatives and determination of the effects of alternatives

(Rhine branches and Meuse) are closely connected and cannot be treated as isolated rivers. For the Meuse, a preliminary study (focussing on river-engineering aspects rather then ecological and social-economic, although the are not completely neglected) has been carried out in the years 1999-2001. Starting point was an increase of 10 % of the discharge of 3800 m3/s for the Meuse. This study will bring knowledge around the Meuse on the same level as the resilience study does for the Rhine Branches and the lower river area. Hence, by the end of 2002, there will be one area covering study for all greater rivers in the Netherlands. Especially for the Meuse, the DSS-large rivers plays an very important role. It is the basic tool with which the measures are sketched and the effects of the measures are calculated.

4.2 Developments for the DSS Large Rivers project

After the completion of the IVR-DSS (integral exploration of the Rhine branches DSS) and its application in the project Room for Rivers (RvR), the RIZA and RWS-DON departments of the Ministry of Public Works in the Netherlands expressed their wishes to improve and extend the current DSS. In the new DSS also the experiences with the LWI-DSS (Land, water and Information DSS) should be included. This resulted in the application of the DSS-Large Rivers. The main improvement is the implementation of the 2D design flow as currently realised by using the programs BASELINE (2D design in GIS environment) and WAQUA (2D computation of hydrodynamics).

The two-dimensional modelling components have been added to the DSS Large Rivers to better support the design and elaboration of detailed plans for flood plain management. The DSS is therefore totally integrated in the ArcView GIS system, in which the multi-dimensional plans are designed. The designs can now be evaluated by one- and two-dimensional models for water flow and ecology, receptively SOBEK and LEDESS-1D, and WAQUA and LEDESS-2D.

For the assessment of ecological and agricultural impact the LEDESS-1D model is used. The LEDESS-2D model determines the impacts on terrestrial and aquatic ecology, whereas WAQUA is used to evaluate impacts on currents and water levels.

The intention was that this DSS would be developed with the Rapid Application Development approach. Hence, in an early stage the end users should be included in the design process.

Therefore, as a first activity, several workshops were organised with possible end users as participants. Among them were river-scientists, DSS-developers, policymakers and GIS-specialists. These people were interviewed with the aim to make an inventory of the user-requirements of the DSS. The following questions were posed:

- What are, according to you, the key-tasks of a DSS
- What is (on the short term) the minimum functionality of a DSS, such that your organisation will use it. And what is the functionality on the long term.
- What is NOT necessary to incorporate in a DSS
- What are the requirements *within* your organisation to operate and maintain a DSS

As a spin-off, attempts were made to formulate functionality in possible modules.

The interviews have led to a number of opinions, where the intended work-flow of the DSS is the key-issue. The opinions have been translated into components which in principle, may be part of the DSS. Furthermore, several aspects which could be analysed with the DSS have been mentioned. In the table below the components and aspects are presented:

Components	*Aspects*
Interactive design (GIS based)	**Soil**
Creating a calculation grid	**Morphology**
Calculate (1D and 2D)	**Ecology**
Analysis (Iterative)	**River-engineering**
Presentation (Maps, numbers, range)	**Nature**
Maintenance (Monitoring)	**Culture-historical**
User levels (project managers, technicians, scientists)	**Costs**
Information (chart-database, organisation, data)	

An important issue which came out of the interviews has to do with the properties. Functionality as well as modularity are guided by the properties of the system. The interviews have led to the following (not extensive) list of properties:

- System-properties
- Modular design
- User friendly
- Connection with already existing and used software
- Client-server applications
- Workflow properties
- Design and testing should be possible (and consistent) on different scale levels
- Demand for fast iterative process and abilities for performing quick scans
- Result and presentation properties
- At least as good as current procedures
- Denotation of a uncertainty range
- Abiotic results should be simulated more accurate then the other results
- Chart-based presentation

Apart from these properties, two other important points should be mentioned. The instrument should:

- Formalise existing procedures on the base of uniform and accepted methods and data from and towards the DSS
- Support current workflow and current decision process

Especially the last point (combined with the already mentioned connection with existing software) is essential for the creation of enough support amongst the people in the field, such that the DSS will really be used on the floor.

Evaluation of these properties, aspects and components has led to a description of functionality that the DSS should possess. The most important components are listed below.

- GIS-environment is essential
- Enable a global (hence often 1D) analysis (both in design and calculation; lengthscale of several kilometres), as well as a more detailed design (limited to a single floodplain, lengthscale several hundred meters)
- Interactive design (the already mentioned cycle of vision, measures, and testing against the vision), preferable direct sketch on a GIS-map
- Enable comparison of different case, with respect to a (adjustable) table of relevant effects

Finally, it is worth mentioning that among the interviewed a quit sceptic attitude towards DSS-s in general exists. The main reason is that a lot of people see a DSS as a black box which produces facts and figures; the user doesn't really have sight or control over the way these facts and figures are produced. Therefore, a lot of people have indicated that they want the system to produce uncertainty ranges, rather that for instance just a water level in the river, or the sedimentation in kg/m2.

With the DSS-LR it will be possible to carry out studies like the RvR-study as well as studies for detailed design and organisation of riverbanks.

Main functions of DSS Large Rivers

The main functions of the DSS-LR are:

- to make information on the study area accessible,
- to define projects and combinations of projects (variants),
- to execute calculations on effects,
- to analyse results and to produce reports to present effects of measures.

The DSS Large Rivers instrument has a User Interface (UI) from which the different functions of the DSS can be easily carried out. This UI has changed dramatically compared with the RvR DSS, there is a complete integration with GIS systems and spatial information is included in the system in a more interactive way.

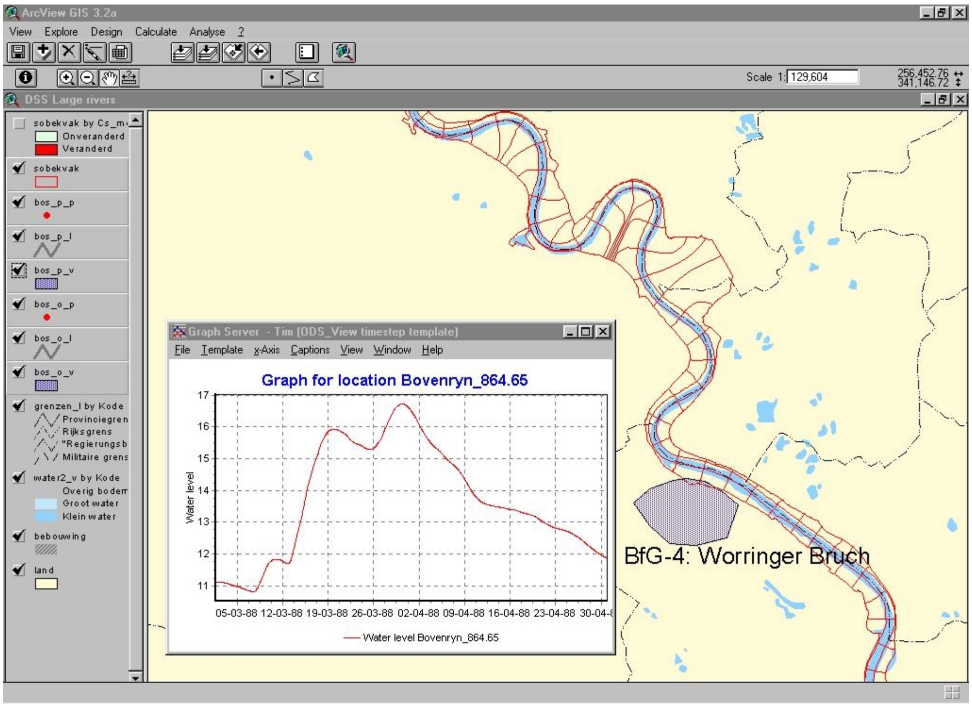


Figure 11: Overview of the DSS Large Rivers

Available information in the system

One of the most important components of a DSS is its well structured information system. This information can be information stored in the database while initiating the DSS, the Documentary Information system (DIS), but also the information stored while using the DSS, the Expert System (ES).

The DIS provides easy access to information either by location (selected on a map) or function of the river system, such as safety, navigation, etc.. Assisted by the DIS the user may carry out a quick scan of local and regional plans before a new initiative for river flood plain management is formulated. The Documentary Information system is used to enter and retrieve any data related to the project area, in various formats like Microsoft Word, Excel and images.

The Expert System contains the results of previous analyses carried out with the DSS. As such it provides a knowledge base on promising measures and strategies to achieve certain objectives of river flood plain management. The Expert System also assists the user in developing insight in the quantitative and qualitative impacts of measures in the river system. It provides suggestions through which type of measures the objectives - desired impacts - of river and flood plain management may be realised. In practice this means that within the DSS Large rivers data is exchanged between the information system and the calculation system. Each time the DSS is used its database will be fed with generated information from results of applied alternatives. Next time the user will formulate new alternatives more information will be available.

The information system is map-based and allows the user to use geographical information which is stored in a central GIS database. With the information system, results can be presented in aggregated data, graphs, tables and maps.

The main structure of the DSS-LR is based on 4 steps which can be taken:

1. explore
2. design/define
3. compute
4. analyse

These 4 steps can be taken iteratively if necessary, depending on the results of the computations. Figure 13 shows the steps, and the modules which form the steps.

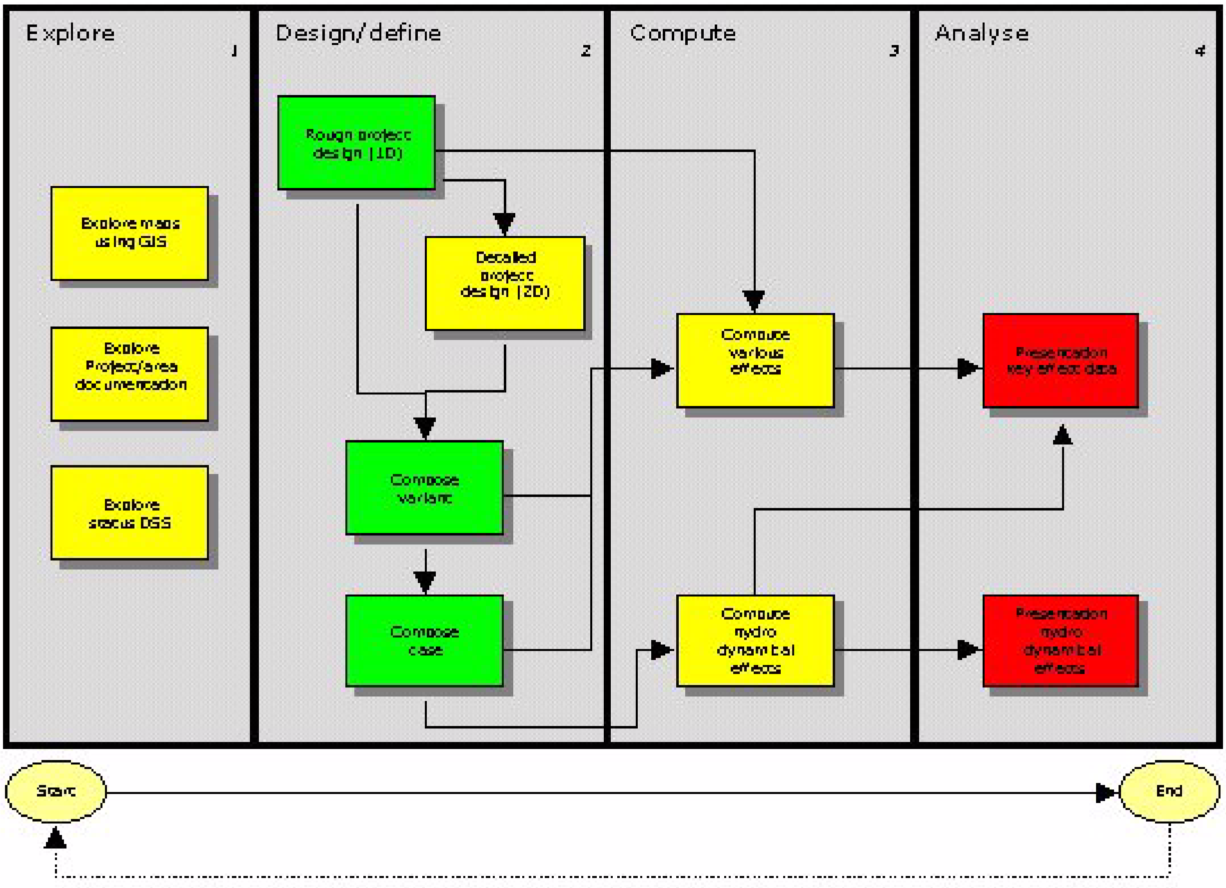


Figure 12: Structure of the DSS

Define projects and combinations of projects

The DSS allows the user to develop plans on different scales by interactive use of a design module. There is a draft design mode and also a detailed design mode. During interactive spatial design of plans the user can use the drawing facilities of the GIS. To facilitate the process of spatial designing, background maps can be used. The user can define areas with a high potential for natural development or sensitive areas where it is not wise to apply measures.

The basis of each design is the description of a project. A project is defined by a location of one or more measures, which are described by their parameters (like dredging depth in case of the lowering of a river flood plain). A variant consists of one or more projects. Composing a variant is done by selecting a number of projects, which are displayed on the map at their proper locations.

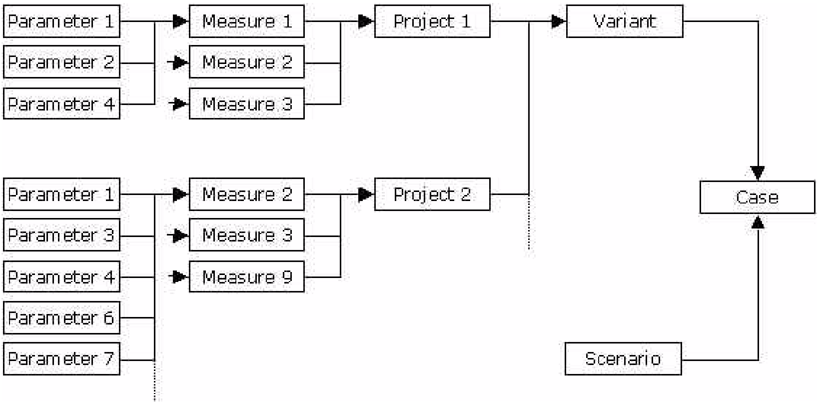


Figure 13: Relationship between measures, projects, variants, scenarios and cases

Scenarios describe possible future developments related to the river system, which are not influenced by the management of the river system within the study area. An example of a scenario variable may well be the increase of the river discharges due to climate change.

The combination of a variant and a scenario describes a case. It is possible to add a description and a selection of overall, not site related measures. The figure below shows the relationship between projects, variants and cases.

Measures available for evaluation in the DSS

A lowland river is has some typical components, a navigation channel, groynes, embankments, flood plains and dikes.

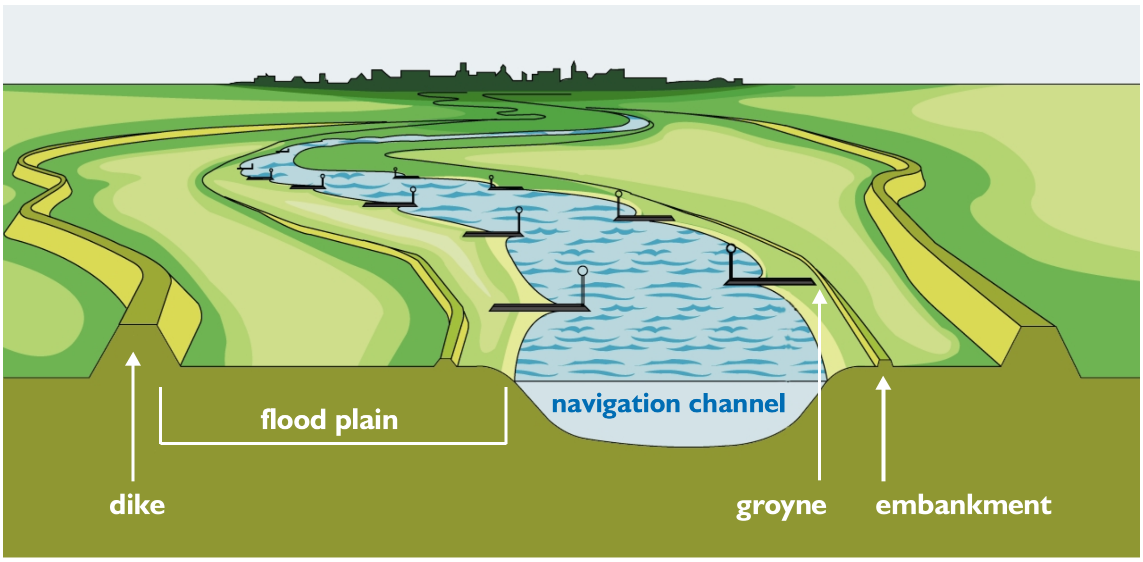


Figure 14: Typical components of a lowland river

Due to climate change and a different perception of risk the design discharge of many river systems tend to become higher. Without further measures, this also means higher design water levels. The underneath figure gives an overview of possible measures that could be taken to change the design of river systems in order to prevent a rise in design water levels.

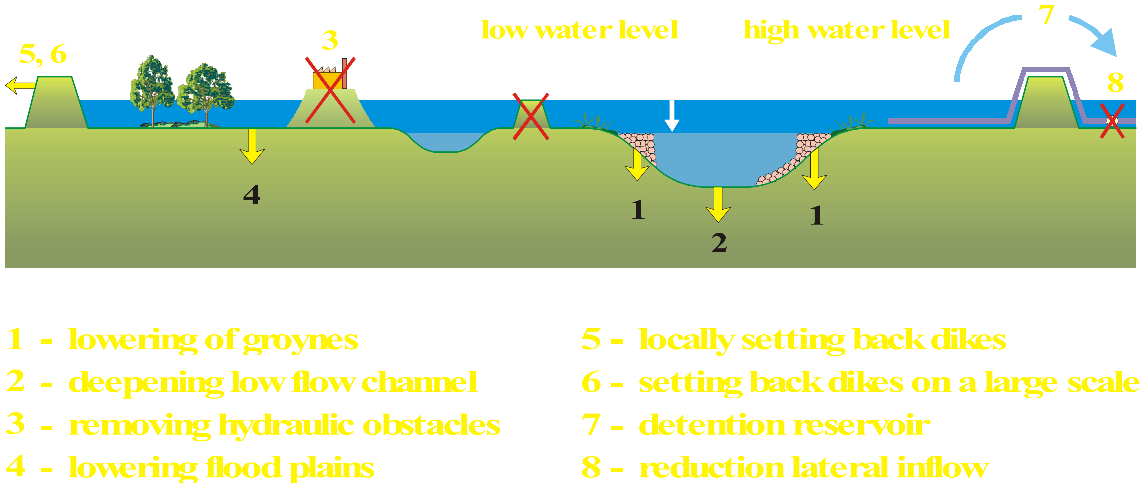


Figure 15: Types of measures implemented in the DSS

The DSS-Large Rivers offers a structured analysis procedure to analyse the effects of the measures in the river, as well as on river engineering effects, ecological effects and costs.

In order to assess the hydrological impacts, measures are translated into changes in the geometry of the riverbed or roughness values in the hydraulic model. Regarding measures that involve changes in vegetation, there is a feedback mechanism possible where it is checked whether the hydraulic circumstances induced by the measure are compatible with the desired vegetation.

Costs are determined based on the civil works involved, especially the volume of moved material; the acquisition of land (or reimbursement of induced damage), and additional operation and maintenance costs.

Figure 16 provides an illustration of the types of measures involved. A total number of 30 measures have been implemented.

After the measures have been defined for all the projects concerned, the DSS takes care of the transformation of the measures of the new plan into model input for the different models.

Execute calculations on effects

In the DSS mathematical models play a central role in impact assessment. The mathematical models provide insight in the impacts on many aspects. These impacts are expressed in effect of the case on the river environment. With the determination of effects a distinction is made between the hydrodynamic and morphologic effects, and the other effects. The effects of a case can be determined for the following aspects:

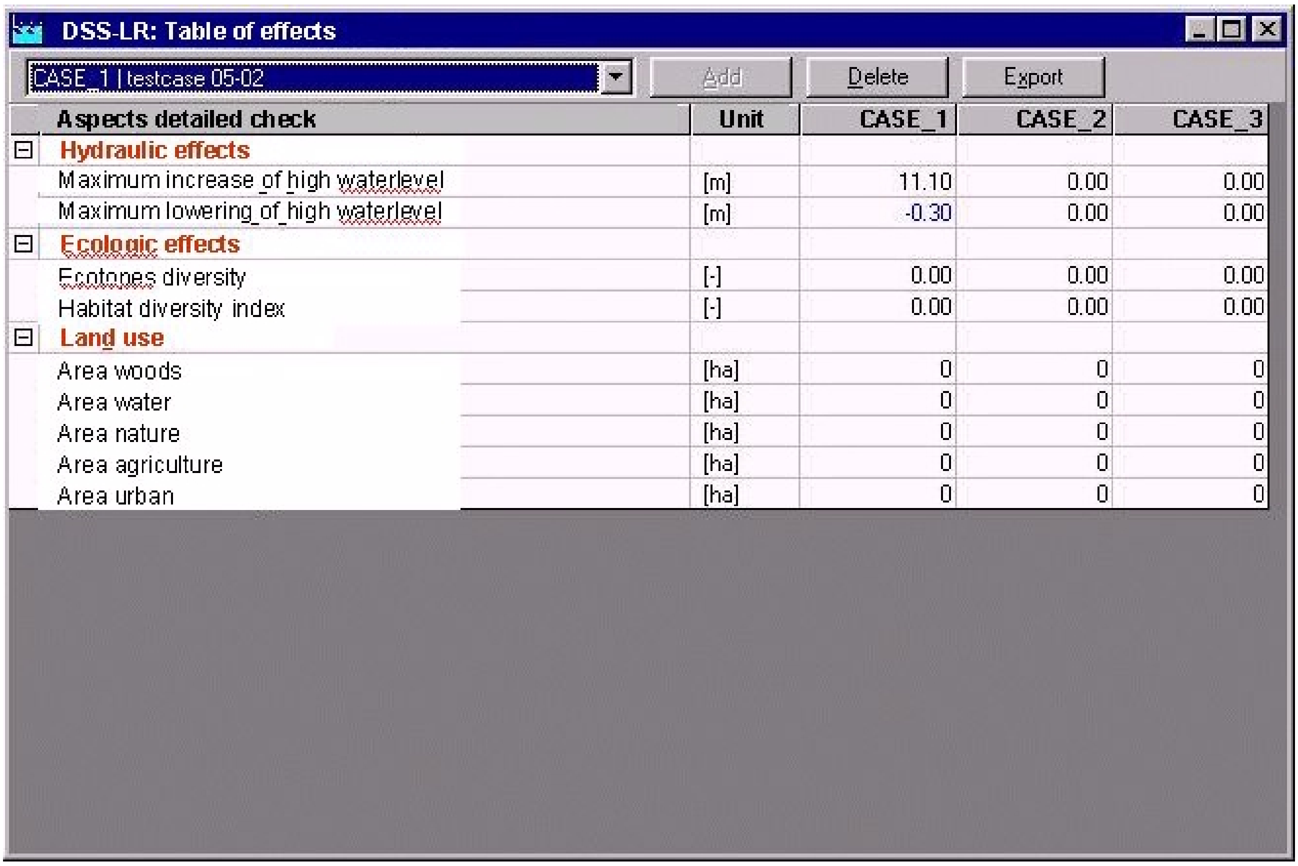
- Increase of water levels
- Costs;
- Values of the landscape quality;
- Prediction of the distribution of ecotopes;
- Distribution of a number of indicator species (fauna);
- Navigability; and,
- Sedimentation of the fairway.

For a number of aspects the determination of the effect depends on the result of the hydrodynamic and the morphologic computation. Other effects can also be calculated independently.

The effects are expressed in aggregated values, which are displayed in the table of effects. In the DSS-LR the ecological module LEDESS is used to determine the resulting distribution of the ecotopes and the species. The starting point of the calculations is the adaptation of the geometry and the roughness of the cross sections in the input file to describe the selected measures. To determine the roughness values, the user-defined target ecotope is used. It is also possible to select an autonomous development in stead of a target ecotope.

After the calculation of hydrodynamics and morphology, it is possible to carry out a new analysis of the ecology, which takes into account the changes of habitat factors like frequency and duration of inundation. A different aspect of the ecological module is the possibility to calculate not only a predicted final situation, but also to describe the hydrodynamic effects of the ecological development by computing the water levels for a number of development stages and taking their effects on the habitat factors into account in the next time step.

An example of the effects table with aggregated data for 2D-hydrodynamics is shown in figure 16.



Aspects detailed check	Unit	CASE_1	CASE_2	CASE_3
Hydraulic effects				
Maximum increase of high waterlevel	[m]	11.10	0.00	0.00
Maximum lowering of high waterlevel	[m]	-0.30	0.00	0.00
Ecologic effects				
Ecotopes diversity	[-]	0.00	0.00	0.00
Habitat diversity index	[-]	0.00	0.00	0.00
Land use				
Area woods	[ha]	0	0	0
Area water	[ha]	0	0	0
Area nature	[ha]	0	0	0
Area agriculture	[ha]	0	0	0
Area urban	[ha]	0	0	0

Figure 16: DSS table of effects

Analysis of results and reporting of effects of measures

Planning for river and flood plain management is a continuous and dynamic process. There will always be the need to adjust a policy to changing circumstances. The use of a DSS formalises to some degree the planning process for river and flood plain management. The knowledge of a team of experts is condensed to a large extend into models and procedures. Through integration of multi-criteria evaluation procedures with river models a system is created with which water resources planners are able to systematically and quickly evaluate a large number of plans in a comprehensive manner. The efficiency - in time and costs - as well as the possibility of reproduction of the analyses are an important asset of the DSS approach, especially when a large number of alternatives have to be evaluated according to a clearly defined methodology.

After computation of the 1D- and 2D results, these can be analysed with the information system. Results of the mathematical models can be displayed in graphs and maps. After aggregation of the results they can also be displayed in the table of effects.

The Expert system can be used in the analyses to compare the results of different cases which each other. The newly computed case can therefore be compared with some standard situations, making it easier to evaluate the effects of the measures taken.

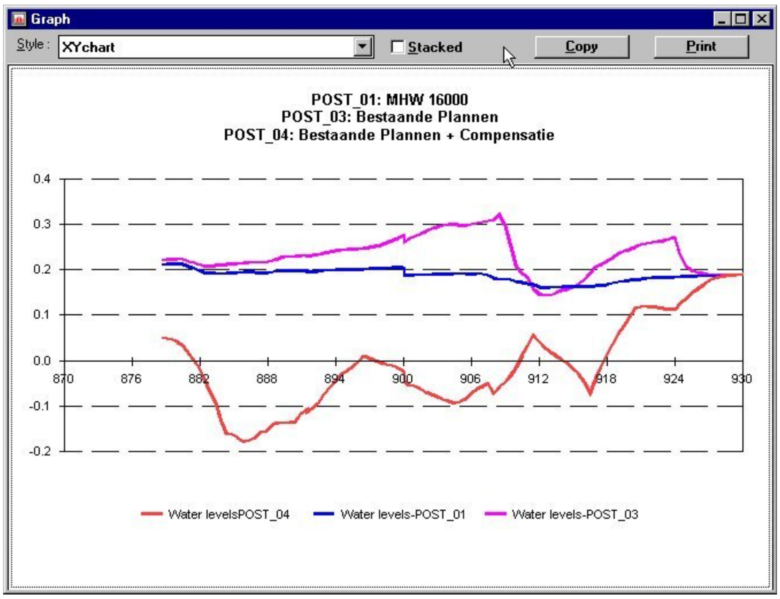


Figure 17: Graphical presentation of results

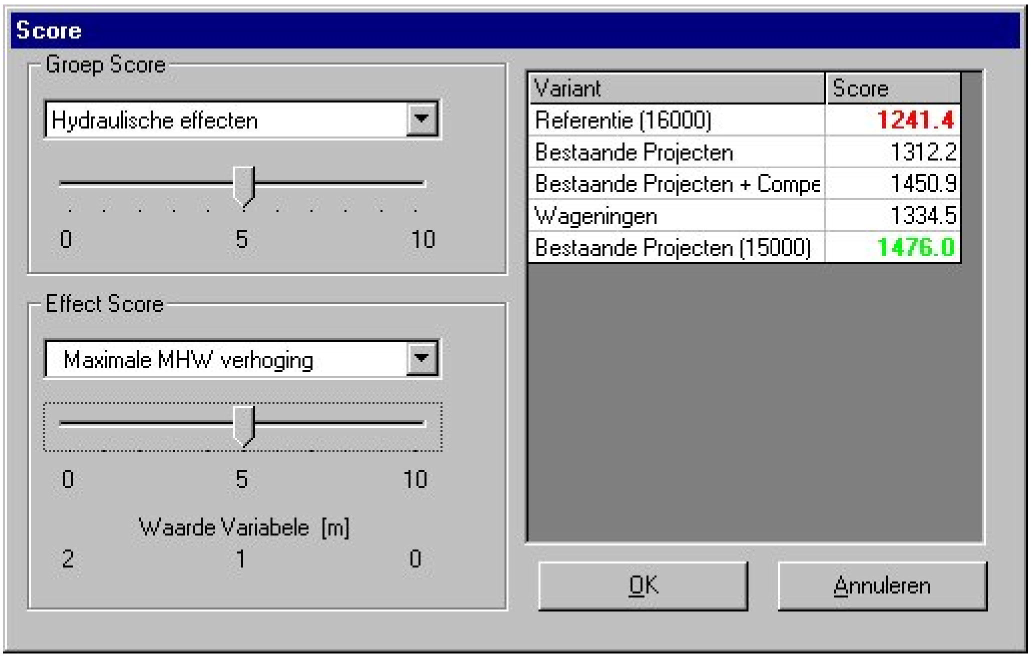


Figure 18: Allocation of weights to scores

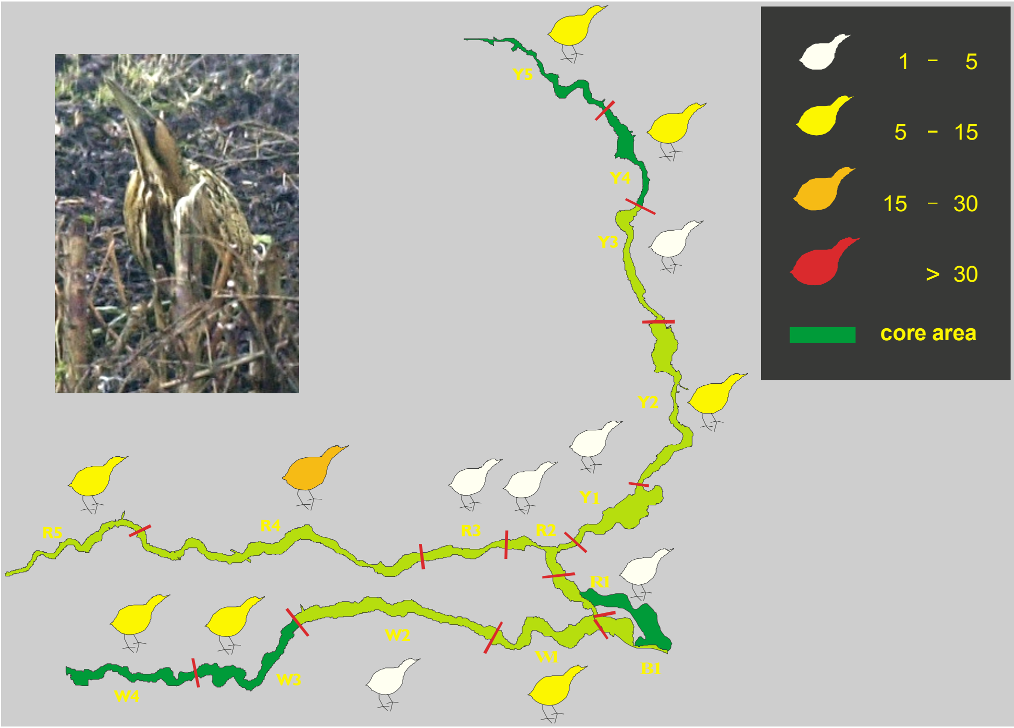


Figure 19: Habitat suitability per section for bittern (potential number of breeding pairs), a bird of reeds and marshes (in final stage of succession).

4.3 Case: Detention ponds

Detention ponds are polders and other areas that can be flooded in a controlled way at certain water levels in the river. In this way they provide a storage opportunity for the peak of the flood.

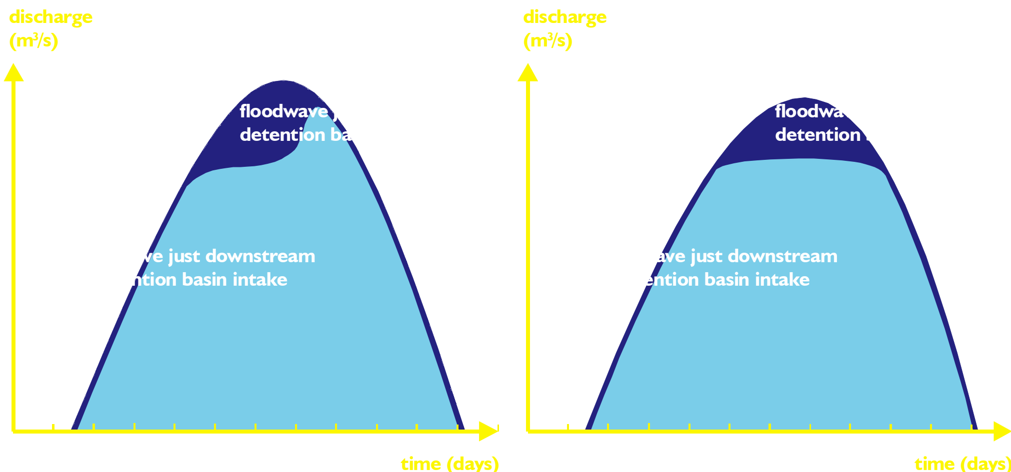


Figure 20: Effects of different activation levels of detention ponds on flood levels in the river.

Preliminary versions of the DSS have been used to analyse the effects of different types of river measures and landscape planning projects along the river Rhine branches in The Netherlands, while the DSS-LR has also been applied to study the effects of detention ponds in Germany on the German-Dutch Lower Rhine area.

The DSS was used to determine the effect of a total of 10 interventions (projects) of which four were dike-displacement measures, five within-dike detention measures and one a winterbed detention area. Within the DSS each intervention was laid out as a separate project. Using the 10 projects a total of 13[1] cases was determined and selected for 1D dynamic calculations. One case for each separate project, one case for the combined detention projects, one case for the combined dike-displacement projects and one case for all projects combined. The discharges and water levels with the interventions were compared with the reference case (no interventions) on the locations along the river.

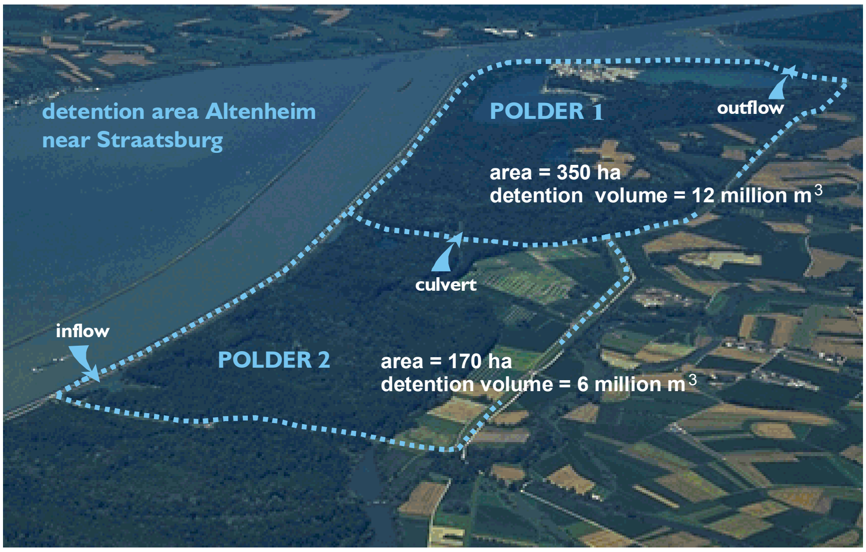


Figure 21: Plans for the Altenheim detention ponds

5 Conclusions and Recommendations

This project can actually be divided into two parts: the development of the DSS itself, and the application of it on a case study dealing with retention in Northrhine Westphalia. Conclusions and recommendations can be drawn for both parts, where the conclusions and recommendations for the case study obviously have a more technical nature.

5.1 Conclusions

A total of four dike displacement measures (floodplain widening), five detention measures inside the dike-protected area and one detention measure in the floodplain were investigated using the DSS. The following conclusions are based on a scenario that uses an up-scaled version of the 1988 flood (a multi-peaked event) at Andernacht and dynamic calculations. Reported reductions in water level are those seen at Lobith (km 858) unless stated otherwise.

- Of all detention measures the one at Bylerward showed the largest maximum reduction in water level (5.6 cm) although the reduction at the highest point of the flood peak was much less at 3 mm. The measure at Köln-Langel (the most upstream measure) showed the smallest reduction: a maximum of 8 mm and a reduction during the highest point of the flood peak of less than 1 mm. Combining all detention measures in one DSS calculation gives a maximum reduction of 9.4 cm while the sum of all separate cases gives 13.9 cm. This is caused by the fact that the maximum reduction of the cases is obtained at a different time for each case.

[1] *Ate present (24-10-01) the mea-1 case cannot be run as the needed measure is not working yet.*

- The reduction at the exact time of the highest point of the flood peak is largest for the Bylerward measure; a 3mm reduction. The combined effect of all detention measures causes a reduction at the highest point of the flood peak of 9 mm, the same amount as the sum of all separate measures.
- At Grieterbush a detention measure within the floodplain was used. It caused a 2 mm increase in water level during the peak and a maximum reduction of 1.6 cm at a time before the first peak.
- In general the maximum reduction obtained with the floodplain widening measures is seen at the highest point of the peak making them very effective at local and upstream water level reductions. The obtained reductions at the peak of the flood range from 6 cm (Itter Himmelgeist) to 28 cm (Monheim). The measures have little to no effect downstream.

Regarding the development of DSS-LR, the conclusions can be divided into technical ones (on the development and on the use of the DSS) and ones related to the societal environment. We start however with a general conclusion:

- Development of a DSS in the same project where sub-projects depend on the use of that same DSS (i.e. the project IRMA-SPONGE as a whole) is impractical.

The following addition conclusions on the DSS can be drawn:

- The intended Rapid Application Development that on which the DSS-LR was based, has not functioned well enough. Although in introductory workshops detailed information from the end-users was collected and also implemented, it turns out that for a proper RAD approach there has to be more frequent feedback with the end users. Only in that way, the developers can adjust the software accordingly. On the other hand it is noticed that the implementation of the wishes of the end-users in the final version of the DSS is both recognised and (hence) appreciated.
- The Technical Design was deliberately not elaborated in too much detail, to be able to react on recent developments. Looking back, the benefits of this flexibility do not weigh up to the discussions that had to be held over the exact functionality and implementation. The Technical Design has to be defined in a strict way, leaving as little room for discussion as possible.
- The development time stretches out over several years. During those years, versions of software change, and even versions of operations systems change. The organisations for which the DSS was developed didn't always follow these updates which hinders the progress considerably.

With regard to the use of the DSS, the following conclusions can be drawn:

- DSS-LR is a tool that may be very helpful in landscape planning and river restoration. It is, however, not the ultimate solution but will often be used in combination with common sense and, depending on the project, with other software tools.
- In the Netherlands, landscape planning and river restoration is usually planned in three phases: exploration (on the scale of river stretches), design (on the scale of individual floodplains) and actual implementation. Due to the structure of the DSS (1 dimensional models versus 2 dimensional models) and the exchange between the approaches DSS-LR is especially useful for the first two phases.
- Due to the generic character of DSS LR, it is easy to adapt the system for several lowland rivers, provided that the data that is needed for the various modules is available. Collection of the necessary (international) data however, is something which is often underestimated due to varying formats and a different management of the data in various countries.

With respect the societal (and political) points of view, the following conclusions can be drawn:

- In developing software to accomplish a Decision Support System, the changing view of policy makers towards solutions to handle possible flooding problems and the corresponding attitude of the public work, brings along that a DSS can never be up-to-date. Solutions that once were rejected as unfeasible may get a different status only a few years later.
  Furthermore, a long development period has also the risk that the functionality of the DSS is overtaken by recent decisions made by policy-makers. As an example, the cost-module may be mentioned. In the first interviews it was denoted that a cost module may come in handy to get a first insight in the costs of individual measures, projects and cases. In a later stage, this idea was already extended in the sense that also insight in the uncertainty of those estimates would be convenient. Hence, a Monte-Carlo analysis was wanted. In the recent project 'Integral Exploration of the river Meuse', it is even the wish to perform a multi-criteria analysis.
- It is almost impossible to develop a DSS that satisfies the requirements of policy-making and of policy preparation at the same time. The latter use requires technical knowledge and to a lesser extend an extensive user-interface, and the former requires the opposite. The DSS-LR is not intended to be used by policy-makers, but in policy preparation.

5.2 Recommendations

Also the recommendations can be divided into two parts. One for the development of the DSS itself and one for the case study. We start with the latter:

- A barrier with adjustable height for retention areas is useful to reduce water levels in case of discharges with multiple peaks. Fixed barriers might result in retention basins that are already (partly) filled when a second peak passes by, and hence have only a limited effect. A more efficient use of the retention basins results in lower water levels downstream.

On the development of the DSS, the following recommendations can be made:

- A DSS should be developed in components where each part comes along with a detailed functional and technical description. This makes it possible to adapt to the rapidly changing environment, both of technical and societal nature.
- Communication between the developers of the various components of the DSS should be smoothened by using the same terms for the same items. This is also vital for the actual use of the DSS in projects.
- The data generated by the DSS is often not accessible for the general audience. Additional tools which contain parts of the data (results of calculations, maps, meta-information) of the DSS (a sort of rapid accessible toolbox) turns out to be very helpful to get quick impressions of certain combinations of measures.