MIPWA: A Methodology for Interactive Planning for Water Management

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Keywords: *Decision support, model-construction process, groundwater, participation, model interface, multi-actor process*

EXTENDED ABSTRACT

The interests of the various parties involved in water management often conflict. The project 'Development of a Methodology for Interactive Planning for Water Management' (MIPWA) is intended to resolve these conflicts. For the first time in the Netherlands, 17 water management parties (provinces, water companies, waterboards and some municipalities) have joined forces to develop a large-scale high-resolution decision-making tool for groundwater-related issues. It consists of (1) a groundwater model encompassing the entire north of the Netherlands at a resolution of 25 x 25 m^2; (2) an impulse-response database containing effects of interventions and scenarios that can be collected and explored by decision makers around the conference table; and (3) a via internet accessible user-interface making it possible for water managers to access model data in an easy way.

The basis of the decision-making tool is a numerical groundwater model. This model describes the groundwater system over an area of more than 24.000 km^2 at a resolution of 25 x 25 m^2. To our knowledge, it is rather unique that such a large groundwater model has been developed at such a high resolution. The reason for developing this large model was the strong need for consensus on model results and the wish to use the model on both regional and local scale. Many technical innovations were needed to build the model, including parallel computing, data compression and issues related to communication.

One of the main applications of the groundwater model is to calculate effects of interventions on groundwater dynamics. These calculations form the main input in the decision-making process where effects of many alternative interventions and scenarios need to be analysed and weighed. For this purpose, an impulse-response database have been developed. The basic idea of such a database is that effects of numerous pre-defined interventions are calculated a-priori and stored in a database. During the decision-making process these results can be accessed instantaneously, making it possible to scan many alternative interventions and scenarios quickly and in an easy way.

During the model-construction process, each conceptual choice was made by the whole group of stake-holders themselves, based upon options provided by model experts. This procedure required easy and direct communication between stake-holders and model experts. Therefore a via internet accessible interface was introduced allowing users to access the model results on-line. In addition, workshops were held frequently to verify intermediate model results. This approach has resulted in a consensus on model results, it has strengthened the cooperation between the participating organisations enormously, and it created a level playing field for environmental planning processes.

1. INTRODUCTION

1.1. Background

Currently the Dutch water policy sector is in change: traditional techniques for water management – stemming and containing floods by levees and dams – are no longer viable because of their extensive negative societal impacts. The acknowledgement that 'controlling' water as the key principle for 'keeping our feet dry', is no longer feasible. This has lead to a new policy framework. This framework advocates to accommodate flooding and to provide water systems with more space. As a consequence innovative policies are needed to accommodate these new perspectives on water management. The required innovations must result in new solutions to make the water system robust for its new and still developing requirements.

In 2003 the National Governance Agreement Water was signed by the water management parties in the Netherlands. It was agreed that one of the policies to reach a better balance between water management and spatial development, was to implement a so-called 'desired surface and groundwater regime'. This regime helps to identify the appropriate combinations of groundwater levels and spatial functions such as agriculture, housing, nature, and recreation. It also helps to decide on feasible policy measures to influence surface and ground water levels in the desired direction.

To determine the regime for each water management area a new and detailed groundwater model was needed. A model that would help water management authorities – mainly provinces and water boards – to evaluate (or pre-test) the impact of future groundwater measures, before being implemented. But also a model that is widely accepted among water management authorities. Obviously, during the past years numerous models have been built by various parties for several purposes. This inevitably resulted in conflicts on different model results and, as a result, in different conflicting decisions on water-management related issues. From this point of view, one model acknowledged by all participants was highly desirable.

For this reason, in 2005 the 'Development of a Methodology for Interactive Planning for WAter management' (MIPWA) project has been started. In this project seventeen water management organisations in the north of the Netherlands (four provinces, three drinking water companies, six waterboards and three municipalities) developed – under leadership of TNO and together with research institute Alterra and two consultancy agencies – a high-resolution regional decision-making tool for groundwater management. In addition to technical goals such as the detailed scale (25 x 25 m^2) and an interactive graphical modelling environment, the project aimed at full support of the instrument not only by hydrologists but also by decision makers. This last goal changed the typical technical focus of model projects and required influx from social science to keep the group of stakeholders together in moving towards a technically high-standard, consensus groundwater model.

1.2. Description of Project Area

The MIPWA project area is shown in Figure 1. It is a varied agricultural and natural area with little urban development. Almost half of the area is near sea level and a spread of small channels controlled by weirs and pumps dominates the water system here. The other half of the area has a more natural sloping drainage system. Total groundwater withdrawal for drinking water and industrial needs is 380 million m^3 per year.

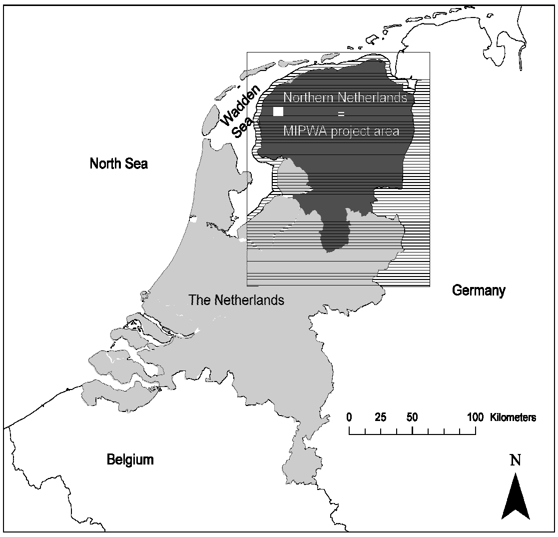

Figure 1. MIPWA project area (dark grey) and total model area (shaded)

1.3. Water Management Issues

The main challenges for water managers in the project area are planning issues, the increasing need for domestic water, and the expected climate induced increase in floods and droughts. Both Dutch and European legislation such as Water management 21st century (anticipating on floods and droughts), and the European Water Framework Directive, regulate these challenges.

In the Netherlands, responsibilities for water management are divided over several governmental institutions each having their own responsibilities. In addition, other stake-holders such as drinking water supply companies, industry, agriculture, and individual households play important roles. Over the last decade participation of these stake-holders in decision-making processes has increased. In this arena communicational means are just as important as technical means.

2. MODEL-CONSTRUCTION PROCESS

2.1. Technical Overview

The geographic setting and the water management challenges require a detailed groundwater model on a regional scale that can be used for various groundwater issues. The primary focus in the MIPWA model is on spatial planning and water management, with possibilities for future extensions to other management issues.

The MIPWA model covers the area of interest plus a buffer area to decrease the impact of the model boundaries (145 km East-West and 167 km North-South). It is a MODFLOW (McDonald and Harbaugh, 1988) model with 25 m grid cells. In total the model has ca. 238.000.000 active model grid cells (Fig. 1) over 7 quasi-3D model layers. The model time step is 1 day and it has been run for a period of 13 years (1989-2001).

With its focus on planning, shallow groundwater processes were given high priority (Fig. 2). The unsaturated zone was modelled using the newly developed coupled MODFLOW–SIMGRO code (Veldhuizen et al., 2006).

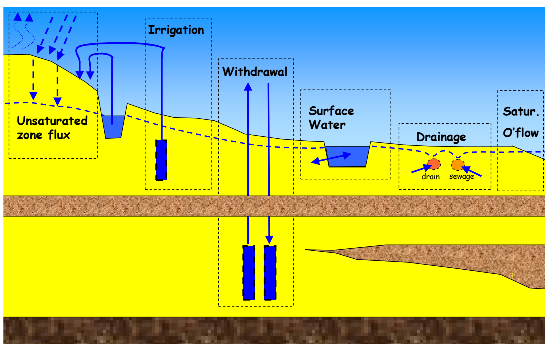

Figure 2. Processes described by the MODFLOW-SIMGRO model

The high level of detail is reflected in Figure 3 showing the large number of surface water bodies that were modelled, ranging from the smallest ditches to the largest lakes, and Figure 4 showing the mean highest groundwater level for a small part of the model area.

Transmissivities and vertical conductances were calibrated in a stationary mode using the Representer method (Valstar et al., 2004). For this purpose 8171 measurement locations were used. River conductances, phreatic storage coefficients, capillary rise and storage in the root zone were calibrated on time series of groundwater fluctuations in a transient mode using parallel PEST.

Figure 3. Representation of individual surface water bodies in the model. Scale ranges from light grey to black, from small ditch to river.

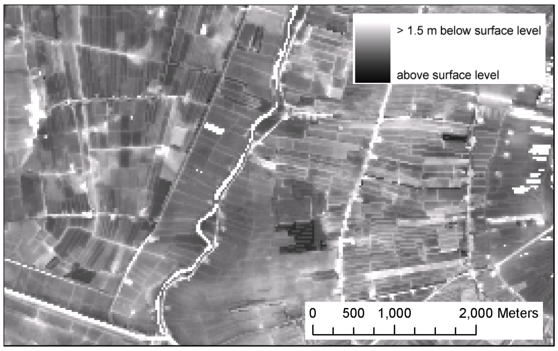

Figure 4. MIPWA model result: mean highest groundwater level.

2.2. Participatory Process

The construction of the groundwater model was a participatory modelling process in which scientists, engineers and policy professionals from seventeen water management organisations worked together and 'fuse' their knowledge into a model that is scientifically viable and has practical meaning for policy making. In this fusion process between actors, learning was the key driver: scientists, engineers and policy professionals learned to discover the possibilities of the intended model while constructing it. In addition they together identified the 'blank spots' in the knowledge available to fully live up to the expectations they and their constituents had before starting the modelling process. And although the construction of the groundwater model was largely supported by knowledge and insights from natural science, the participatory process towards a policy instrument was essential for a successful embedding of the instrument in policy making.

During the model construction process participation was realised by developing an interactive modelling interface iMOD (Vermeulen et al., 2006). During model construction intermediate model input and results were stored on a computer server. All participants were able to log on to the server and access the data with iMOD. Moreover, they were encouraged to leave their comments on digital notes. This form of communication opened the way to interactive model construction and greatly helped to improve the model. During the project more than 100 notes were sent to the modellers. The majority of the comments were on the improvement of local scale issues, such as fluxes (seepage, infiltration and drainage fluxes), surface water levels, and depths of drainage systems. In this way experience and knowledge of local hydrological systems were brought into the model.

In addition to an interactive model-construction process, 20 workshops were organised. During these workshops the seventeen organisations jointly decided on model conceptualisation and parameterisation on the basis of model calculations and advises of the scientists and engineers. Each step in the model-construction process was made by the whole group. This approach have proven to be the basis of the current consensus: the model is not a black box anymore built by scientists and engineers, but in fact a model built by the organisations themselves.

Figure 5. Deciding on model concepts and parameters during a workshop.

2.3. Policy Support: the Impulse-Response Database

Once the groundwater model has been built and calibrated, model results have to be made accessible in an easy way, so that it can support decision making in spatial planning processes. For this purpose the concept of the impulse-response (IR) database has been developed.

The basic idea of an IR database is that effects of a number of pre-defined interventions are calculated a-priori for each model cell. The calculated effects are stored in a database. Calculation of effects is done in the following way. If, for instance, an intervention is to raise the surface water stage with 20 cm, then for each model cell containing surface water, the stage is raised with 20 cm sequentially.

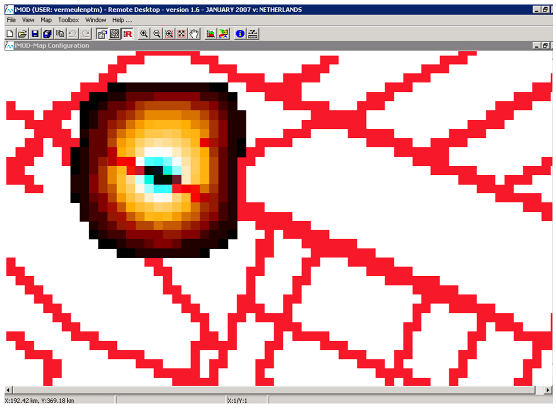

Figure 6. Effect of raising surface water stage in one model cell as stored in the IR database.

Hence a small submodel is constructed around the specific model cell. The reference groundwater level is calculated. Sequentially, the stage is raised with 20 cm and the groundwater level is calculated again. The difference between these two model results is the effect we are looking for and is stored in the database (see Figure 6). We then proceed to the next cell and do the calculations again.

Following this procedure the IR database was filled with effects of cell-scale interventions. When consulting the database for effects of interventions on a multi-cell scale (e.g. multiple parcels) effects are simply superimposed. This implies that non-linearity is being ignored. The IR database therefore only gives a rough estimate of the total effect and is only valid for selected interventions. Nevertheless, it is perfectly suited for quick-scan purposes, analysing effects of many alternative interventions and scenarios quickly and in an easy way.

3. DATA MANAGEMENT AND MAINTENANCE

Now the groundwater model and impulse-response database have been delivered, the process needs to be continued. The delivered model is referred to as model version 1.0. This means that the parties involved in this project intent to continue with the development and improvement of the model.

When using and applying the model, errors in input data and conceptual shortcomings will come forward. Therefore we are now working on a system for managing and maintaining the model data. This system will handle additional model data and model improvements. The model will be updated on a regular basis to a new version. In this way the model will continually improve and will remain up-to-date. Moreover, we will need to take the challenge to keep the consensus we worked so hard for during the last two years.

4. CONCLUSIONS

In this MIPWA project seventeen water management organisations in the north of the Netherlands developed together with research institutes and consultancy agencies, a high-resolution regional decision-making tool for groundwater management. One of the main objectives was that the model would be fully acknowledge by all parties. A lot of effort was therefore put in consensus on model concepts and results. Participation of all parties during the process of model construction was crucial to embed the model in the policy and decision-making process.

In addition to the participatory process, tools were developed to bridge the gap between numerical modelling and decision making. The interactive modelling interface iMOD appeared to be an easy accessible tool. Using iMOD model data and results can be consulted with only a few mouse-clicks. The impulse-response database – also accessible via iMOD – is often used to do a quick-scan on different scenarios. It works very easy and provides quick insight into effects of interventions.

Management and maintenance of the model data is now the challenge to be taken. We need to keep consensus on the model by improving the model together with all parties involved.

5. ACKNOWLEDGMENTS

The authors would like to thank to all parties involved in the MIPWA projects. Especially, we want to acknowledge research institute Alterra and consultancy agencies Royal Haskoning and Tauw for their valuable contribution to this project.

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