SUMMARY

High resolution monitoring as the basis for integral groundwater (quality) management within municipal areas

Motivation

In order to investigate the applicability of High Resolution Monitoring (HRM) for soil related questions within municipal and provincial authorities the project 'High resolution monitoring as the basis for integral groundwater (quality) management within municipal areas' was carried out. This project obtained a subsidy from the Centre for Soil Quality Management and Knowledge Transfer.

The pilot project Waterstad 2000 in Delft is being carried out since February 2000. This is a demonstration project in which a HRM network has been installed. In conventional monitoring networks measurements are taken every 2 weeks by hand. HRM stands for carrying out measurements in a measurement network with a high spatial density and a high measurement frequency (for example every hour). In addition, in the near future it will become possible to read the instruments remotely with the use of radio transmitters and receivers. The goal of this telemetry system is to collect data in a central database that can be accessed by the data owners (for example on the internet).

Within the town of Delft a HRM network has been developed that spans a large part of the water cycle. It concerns groundwater and surface water levels, sewage overflow and precipitation that are registered with high frequency. Currently the network consists of at least 200 measurement points (both groundwater and surface water). We have focussed on the 146 groundwater and precipitation measurement points. The groundwater monitoring points are fitted with so-called divers which register groundwater height. Within the framework of this project we installed a locally more dense network around a former soil cleanup site. The divers we used at this location were able to monitor groundwater height, temperature and soil water conductivity.

Goals of the project

The demonstration project Waterstad 2000 is primarily focussed on demonstrating the hardware within the monitoring network. Questions concerning the use of the network and the resulting data for the muncipality or the province are not addressed. Within this project we focussed on the requirements municipal and provincial authorities have for groundwater (quality) management. The aim is:

- to identify possible questions that municipal and provincial personnel have that could be answered with the data coming from a HRM network;
- to identify critical factors that have to be accounted for before one decides to lay out a HRM network;
- to provide recommendations concerning the design, lay out, maintenance of the HRM network and especially recommendations concerning the interpretation of the data coming from the HRM network.

We have not tried to be complete and very thorough. The aim of the project was to do a reconnaissance of the possibilities of a HRM network. We expect to provide an overview of possibilities which can serve as a handle to potential end users of a HRM network (in our case the municipal and provincial authorities) in order to make a decision if they want to investigate the possibilities a HRM network could provide for their own situation.

Results

The main characteristic of the HRM network (in the technical execution as implemented within Delft) is the large flexibility. The measurement frequency can be set by the user, the spatial distribution is very flexible because each instrument is fitted with it's own power source and data logger and has a potential to be fitted with it's own radio transmitter/receiver. Based on this, HRM has the potential to be an ideal tool for an integral approach to water (quality) management within municipal areas.

The application of HRM can become very complex because it can be applied to a wide range of different fields. In order to make a decision about the possible employment of a HRM network, end users should have an insight in the most important processes that play a role in the choice. These processes are discussed in the chronological sequence that could occur in the daily practice.

Why should we want to measure?

The most important reason to start measuring is the need for (more) data. This need often arises from being confronted with (new) problems that require a solution. A large number of problem fields can be identified (see table I). Taking the expected developments in the field of spatial development and the importance water will play in this field in to account, the development of underground building and the recent developments concerning soil management we expect that the need for (detailed) information will increase enormously.

A number of problem fields have been addressed in more detail within this project and we expect that it is easy to approach other problems in a similar way.

Table I. Conclusions *HRM* per problem field.

problem field	specific (example)	parameter	measurement frequency	density network	necessity telemetry
water inconvenience (precipitation)*	basement	gwl	hour	quarter	yes
	crawl space	gwl	day	quarter	yes
evaporation risk*	crawl space/basement	gwl	hour	street	yes
spreading*	groundwater pollution	gwl; EC	month	street	no
degradation*	natural	EC; T	month	street	no
	stimulated	EC; T	hour	street	yes
setting (large scale extraction)		gwl	month	quarter	no
water shortage		gwl	week	town	no
energy storage		T	month	quarter	no
leaking sewers		gwl; (diver in sewer: T, EC)	week	street	no
salting up	by extraction	EC	week	quarter	no
	by drainage	EC	month	town	no
forcing up of constructions		gwl	hour	quarter	yes

gwl groundwater level
EC electrical conductivity (groundwater)
T temperature
* addressed in more detail within this project

How necessary is it to apply telemetry?

- High resolution and telemetry are useful in general for those applications in table I that have a number of yellow boxes. These applications require a locally dense network combined with a short measurement interval and a short response time. The application of telemetry allows for a fast intervention.

- Applications with a number of green boxes can be included in a HRM network. The costs of a HRM network can be earned back by using the measurements for as many applications as possible. Using the network for a number of applications has the additional benefit that the network becomes uniform and that is suitable as a tool for integral water management in a certain region.
- Resolution in time is no longer a limiting factor with the currently available technology. The spatial resolution will be the cost determining factor in most cases.
- We will be confronted with a combination of automated and manual (laboratory) measurements for a long time. Automated measurements will more often than now be used to fill in trends.
- A high resolution system can be used to monitor bottlenecks and sudden changes in the water regime in a certain area. The high resolution in time allows for detecting short period fluctuations, including possible causes. The high resolution in space generates insight in the distribution of the problems within the control area.
- Telemetry is only necessary in those problem fields that require a direct (within a number of hours) insight in the situation. In the other cases, the application of telemetry will depend on the costs.

What are the costs of HRM?
- We have compared the costs of three scenarios: (1) 'traditional' manual measurements, (2) divers with manual read out and (3) divers with telemetry. The costs that are identical for all three scenarios have not been taken in to account. These costs concern, amongst others, the installation and maintenance of the monitoring wells.
- The costs depend on the measurement frequency and the number of times one wants to access the measurements in the measurement instruments.
- The costs are primarily determined by the man hours and for the divers with telemetry by the costs for the hardware and the subscription. Because it was not clear within the demonstration project what these costs are going to be we used three variants.
- Comparing the results from the different scenarios showed that within the HRM network in Delft application of a diver is already cost effective at four measurements per year when it is compared to manual measurements and one interpretation moment per year. At measurement frequencies of 12 to 24 times a year diver measurements combined with telemetry prove to be more cost effective than divers without telemetry. The turning point depends on the costs for the subscription to the telemetry service.

What additional issues are important for the implementation of a HRM system?
- The goals for the HRM network should be clear at the start. A goal should at least give insight in what questions are to be answered with the data and what needs should be fulfilled.
- The HRM system can be implemented in a efficient and effective manner if the implementation is preceded by a characterization period. In the characterization period it is necessary to carry out intensive measurements without the direct need for telemetry.
- Using the insights obtained from the characterization period it is possible to determine the optimal monitoring density and measurement frequency using statistical techniques. Hardware that becomes obsolete after optimization can be used in other locations. A continuously improving insight in the groundwater system of the measurement region is obtained by storing all time series in a single database.

How are the measured time series translated in to insights?
- The data obtained with a HRM system have to be processed before they can be interpreted. The processing concerns the translation from the measured quantity to meaningful values, correcting for errors in the measurements and the subsequent translation in to a presentation format that fits the goal of the HRM network.

- The first steps in the data processing are straight forward and as a result are easy to catch in a protocol and perhaps even in an automated system. The results of this project could serve as a first step.
- The final step, the translation to meaningful results in the framework of the goals of the HRM system is highly dependent on the end user. People interested in the substance of the matter (hydrologists, soil scientists etc.) are primarily interested in the raw data, the presentation of the data in time series charts and spreadsheets combined with summaries of the data together with the statistical properties. People who are responsible for management or policy require presentations that show the relevant issues at a glance. Especially the use of maps is a good tool for this type of presentation. In this project we have worked out a number of maps as an example. More extreme insights can be obtained by combining different maps within a GIS environment.

Recommendations

Interpretation of the results from the Delft HRM network has given us a large number of insights. We have translated a number of these in to recommendations:

- We recommend to consider using automated measurements for every question requiring data on groundwater levels. In first instance the data should be collected with a relatively high temporal resolution (in the order of hours). Our experience is that with these data the insight in the behaviour of the groundwater system increased immediately.
- The purchase of a system with the size of the HRM network in Delft is costly. By co-operation as a municipality with other parties interested in integral water data such as provinces, water board districts etc., costs can be shared. In this respect it is also important that a HRM network will never be installed for only one purpose such as soil or groundwater management. In addition to quantity related questions one should realise that a need from integral management will have to exist combining issues from groundwater, surface water, sewage and soil management.
- A HRM system will generate a huge amount of data. An operational application of a HRM system will only be successful if the data processing and interpretation is largely automated. For a consistent data management it is essential to register all activities carried out in the field.
- In the case of the HRM network in Delft we recommend to leave the divers in place for at least one year in order to get an idea in the seasonal fluctuations. After one year it is possible to optimize the HRM network, however it is important to define some goals first. A future development that could benefit from the HRM network is for example the future underground rail road through Delft.