XXXVIII
IAH Congress

Groundwater Quality Sustainability
Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University
of Silesia
Press 2010

abstract id: **134**

topic: **1**
Groundwater quality sustainability

1.6
Groundwater monitoring

title: **Groundwater level monitoring: the ideal network versus reality**

author(s): **Phil Stewart**
Environment Agency, United Kingdom,
Phil.Stewart@environment-agency.gov.uk

Richard Boak
Schlumberger Water Services, Netherlands, rboak@slb.com

Dave Johnson
Environment Agency, United Kingdom,
David.Johnson@environment-agency.gov.uk

keywords: groundwater, monitoring, water levels, network, conceptual modelling

INTRODUCTION

The Environment Agency is the environmental regulator for England and Wales, with a duty to manage water resources to ensure that sufficient water is available to meet the needs of people and the environment. To fulfill this duty, the Environment Agency monitors the environment by collecting and analysing a wide variety of data, and by regulating the use of water through a system of abstraction licences. At the heart of the Environment Agency's monitoring programme is a national network of over 6,000 boreholes (see Fig. 1) from which data on groundwater levels are collected regularly. This network has grown up over time, responding to changes in the roles and functions of the Environment Agency and its predecessors, which are in turn responding to changes in legislation and other business drivers. This paper describes a fundamental review of the national groundwater level monitoring network for England and Wales, which is approaching its conclusion.

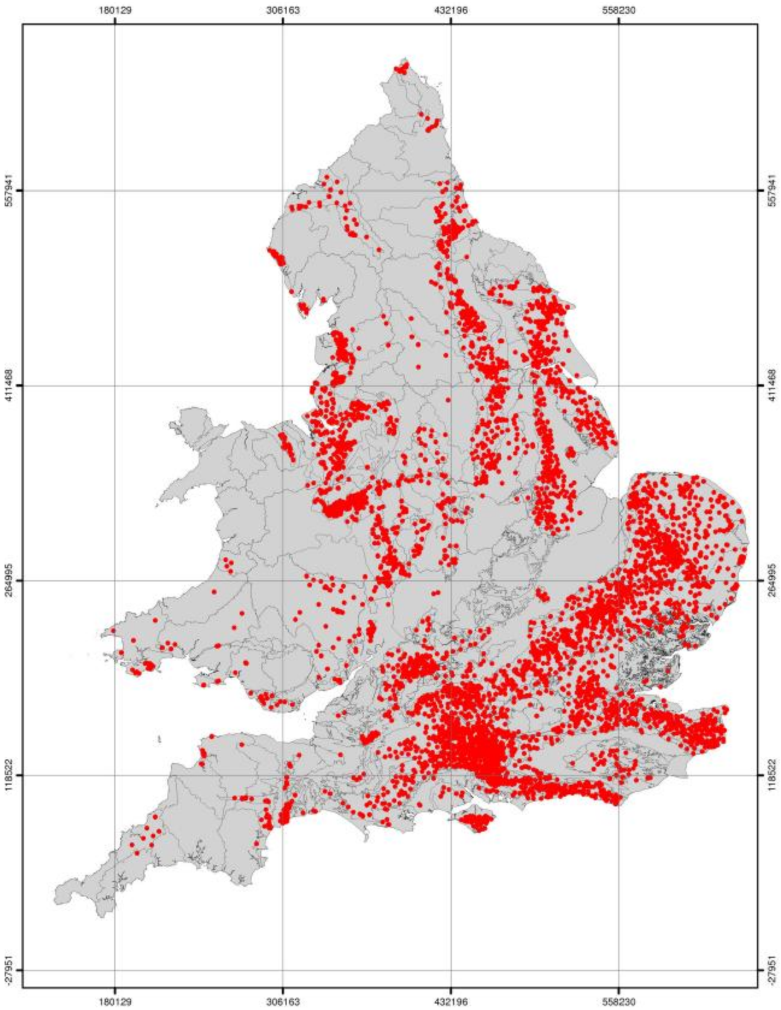

Figure 1. Locations of groundwater level monitoring sites in England and Wales.

KEY OBJECTIVES FOR A NATIONAL MONITORING NETWORK

It is essential that the Environment Agency monitor groundwater levels, and that this should be done in an efficient and coordinated manner. The key objectives for the national groundwater level monitoring network are to:

- Contribute to the fulfilment of the Environment Agency's principal roles as environmental regulator and monitor of the state of the environment.
- Comply with its duties under UK and international (mainly European) legislation.
- Comply with its non-statutory commitments and environmental initiatives.
- Evaluate, protect and manage groundwater resources quantitatively and qualitatively.
- Provide groundwater level data across England and Wales on a consistent basis.
- Define the behaviour of and identify trends in all aquifers (with early warning of low water levels, groundwater flooding and minewater rebound; identification of over-abstraction and impacts of climate change).
- Identify links between groundwater, surface water and ecosystems, and thus feed into other monitoring programmes (groundwater quality, river flows, wetland status, etc).

WHAT DO GROUNDWATER LEVELS REALLY TELL US?

The European Water Framework Directive (2000/60/EC) is one of the key legislative drivers for the collection of groundwater level data. The wording of the Directive suggests that groundwater level is the main parameter to be used when assessing the quantitative status of groundwater bodies. However, we need to understand what groundwater levels are really telling us. When interpreting groundwater levels, we need to be aware of the following:

- *Head not flow:* groundwater levels measured in monitoring boreholes indicate the hydraulic head, or potential, at that point. Groundwater flows cannot be measured directly in situ, and have to be inferred from hydraulic gradients and aquifer properties. The same observed groundwater levels could mean very different things (see Fig. 2).

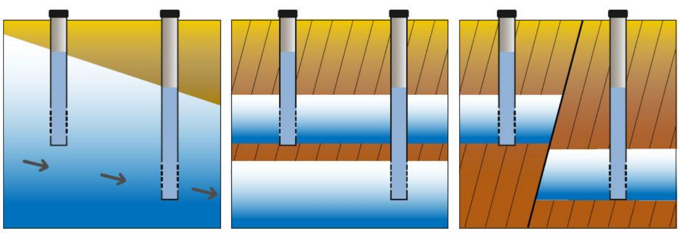

Figure 2. Different interpretations of the same groundwater levels.

- *Beware of open holes:* in a layered aquifer system, the groundwater level measured in a monitoring borehole that is open to several aquifer layers is ambiguous, because it provides no information about the actual head in any one layer or the vertical hydraulic gradients between the layers.
- *Changing levels:* a groundwater body is part of a dynamic system that is responding to changing inputs to and outputs from the system, often with a time lag between change and

response. Falling groundwater levels do not necessarily indicate over-abstraction, because there might be natural multi-year cycles.

- *Pegged levels:* groundwater levels in a monitoring borehole may be pegged or anchored, if, for example, the borehole is next to a major surface water body or aquifer discharge area. This could give a false impression of the 'health' of the aquifer.
- *Karst:* in aquifers such as karstic limestone where the majority of flow takes place in discrete fractures, fissures and conduits, it is most unlikely that the groundwater level measured in a monitoring borehole will yield useful information about the aquifer as a whole, even if it intersects a flow conduit. Spring discharges provide a much better indicator in these circumstances. This also applies to some low-permeability aquifers.
- *Saline intrusion:* long-term saline intrusion can occur even without an alteration in flow direction in a coastal aquifer, because of the density differences between saline and fresh water. Using groundwater levels alone to infer flow directions will not lead to a full understanding of how the aquifer system is behaving.

It is therefore essential that we interpret groundwater level data in the light of a good conceptual model of how the groundwater system operates, including the influence of vertical hydraulic gradients. It is also essential that we interpret groundwater level data alongside other data, such as spring flows, river stages, wetland water levels and water quality data.

CRITERIA FOR AN 'IDEAL' MONITORING NETWORK

The existing groundwater level monitoring network in England and Wales is not yet ideal. There are still gaps in the network, duplication of monitoring points, and incomplete information about the key characteristics of some monitoring points. The questions are: What would the ideal groundwater level monitoring network look like? How do we adapt or refine the existing network so that it is closer to the ideal? In answering these questions, we need to be realistic about the resources available for monitoring, the uses to which the data will be put, and the benefits to be gained from an efficient network. In other words, the network needs to be cost-effective, risk-based and targeted at the areas of concern, while at the same time avoiding bias in network coverage, which could give a false impression of the state of the environment. The criteria for an 'ideal' national network can be described as follows:

- The national groundwater level network must be 'fit for purpose' and able to answer policy and operational questions relating to the national groundwater resource.
- The questions are defined by the business drivers, which will change, so there must be a mechanism for the network to adapt, in response to the changing drivers.
- All data should be collected for a well-defined reason, and if the reason is no longer valid at a certain monitoring point, then data collection at that point should stop.
- All data collected should be quality controlled, with a feedback loop for dealing with quality issues, quickly, so that only high-quality data are archived, and we can have confidence in our historical datasets.
- The data should be stored in easily-accessible national databases, which can be linked to other types of data (such as groundwater quality and aquifer characterisation data), to build up a complete picture of the groundwater system.

- We should use the data that we are collecting and understand what the data mean. We should be able to add value to the raw data by processing and analysis.
- We need to identify and maintain monitoring points and datasets for long-term purposes such as detecting the impacts on groundwater of climate change.

DESIGN OF AN EFFICIENT MONITORING NETWORK

If we define what the most efficient groundwater level monitoring network would look like, we can compare that to the existing network, and refine the existing network by filling in gaps and removing duplication. Network design can be considered in terms of three aspects:

1) Distribution of groundwater level monitoring points: In an efficient network, groundwater level data should be available at enough points in the aquifer system to enable us to understand the key hydrogeological processes that govern the way the system works and the way in which it responds to pressures and management interventions. It is helpful to use the 'recharge-pathway-discharge' concept (analogous to the 'source-pathway-receptor' concept from the field of groundwater protection). The aim is to have groundwater level monitoring points in the following places:

- Where the recharge gets into the system. This is likely to involve fairly shallow boreholes that monitor the water table and its response to recharge events.
- Where groundwater leaves the system, either as natural discharge to rivers, wetlands, the sea or other aquifers, or in the form of abstractions.
- In sufficient places to define the 'structure' of the hydrogeological pathway between the recharge area and the discharge areas or points. This is where information on vertical hydraulic gradients is most likely to be useful.
- Where there is a legal requirement to monitor groundwater levels, for compliance with licence conditions, for example.
- In one or more places that are unaffected by abstraction and other anthropogenic influences. Interpreting 'pure' signals from such sites is much easier than having to naturalise hydrographs. This is important for drivers such as climate change.

There is an understandable tendency to concentrate monitoring points in areas that are under pressure, which, for example, are 'At Risk' of not meeting Water Framework Directive objectives. More monitoring is certainly needed in those areas, but at the same time we must avoid introducing bias into the network when reporting on the overall state of the environment. Otherwise, undue weight will be given to the 'problem' areas.

2) Frequency of groundwater level monitoring: In an efficient network, groundwater level data should be collected at each of the monitoring points at a frequency that enables us to understand the key processes that govern the way the system works and the way in which it responds to pressures and management interventions. The required frequency may be different at each monitoring point, and they should be assessed individually. This is because different types of aquifer behave in different ways, with the storage coefficient being the key hydraulic property that influences an aquifer's response to transient events, such as recharge or abstraction (although transmissivity also plays a part).

3) Quality of groundwater level monitoring data: When considering the overall quality of groundwater level data, four aspects need to be taken into account:

- *Measurement accuracy:* If a water level is obtained by manual dipping, the reading is normally quoted to the nearest 0.5 cm. The typical accuracy of water level readings from pressure transducers is 0.05% of the full range of the instrument. This level of accuracy is perfectly adequate for most hydrogeological purposes.
- *Data acquisition:* Correct procedures should be established and followed for measuring groundwater levels, setting up dataloggers, recording manual data and retrieving data from dataloggers. Common sources of error include using different local datums.
- *Quality control before archiving:* It is important to quality control data before archiving, to correct issues such as data outliers and unexplained steps or gaps in the time series.
- *Cleaning up historical data:* Many hydrogeological studies depend on the retrieval of historical data from archives, but if those data have never been checked and cleaned up, then their value is greatly diminished. Significant effort may be required to clean up historical groundwater level data, but this is an investment for future studies.

REFINING THE EXISTING NETWORK

The Environment Agency is refining the existing groundwater level monitoring network by implementing a process that consists of the following elements:

a) National business rules: These are being developed and applied nationally, and cover the aspects of spatial design (distribution of monitoring points), frequency of monitoring, and quality control of monitoring data, as just described. In addition, national business rules are being developed on network governance, covering the following:

- *Responsibility:* The national groundwater level monitoring network should have one central owner with nominated regional owners, so that responsibilities for and custodianship of the data are clear.
- *Training:* Hydrometric staff and any other monitoring staff who dip boreholes will be trained in all the correct procedures, so that they reach the required level of capability, and so that procedures are applied consistently. Internal users of groundwater level data will also be trained in the added value that can be gained from the data.

b) Network reviews: These will be undertaken at two levels, strategic and annual:

- *Strategic network reviews:* will be undertaken on a 6-year cycle, to ensure that the network delivers high-quality groundwater level data for use by internal and external customers. The strategic review checks whether there have been any changes in our conceptual understanding of any part of the groundwater system that would necessitate changes in the monitoring network; whether any new business drivers have appeared (new legislation, for example) that require new monitoring boreholes; and whether any monitoring boreholes are now redundant.
- *Annual network reviews:* will be undertaken to ensure that data quality is consistently high; that basic information about individual monitoring points is up to date; that protocols on frequency of data collection are being applied consistently across all regions; and that the

data being collected are fit for purpose (including consideration of the frequency of monitoring in relation to aquifer behaviour).

c) Regional implementation plans: These are perhaps the most important part of the process because it is at regional level that most of the hard work of implementing the findings of the reviews takes place (the Environment Agency divides England and Wales into eight regions). The structure of a regional implementation plan can best be described in the form of a Table 1.

Table 1. Structure of regional implementation plan.

	Component	Comments
1	Conceptual modelling	Develop a conceptual model for each groundwater body, using the best available information.
2	Spatial design	Design the optimal distribution of monitoring points, taking into account the identification of which specific national and local business drivers are relevant to the region.
3	Monitoring frequency	Decide the optimal monitoring frequency at each site.
4	Quality control	Implement the correct quality control procedures, including correcting quality issues in archived data.
5	Network comparison	Compare the existing network to the most efficient network, to identify gaps in the network or superfluous monitoring points.
6	Regional strategy	Prepare a regional groundwater level monitoring strategy, describing the results of Components 1 to 5 (which together constitute a strategic review at regional level).
7	Action plan	Prepare a detailed plan, directly linked to the regional strategy, of how to adapt or refine the existing regional network. This will include information to support the annual regional capital expenditure bids.
8	Annual review	Undertake annual network reviews, as described above, and take action as necessary.
9	Repeat strategic review	Repeat the strategic network review on a 6-year cycle. Note that this includes updating the conceptual models of the groundwater bodies, in the light of new information obtained during the review cycle.

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0