

At a time of increasing demands on water resources, we need to manage our aquifers sustainably. **Jon Ford, Simon Price, Andrew Newell** and **Peter Hopson** explain how new technologies are helping to keep taps running.

# Understanding aquifers in 3D

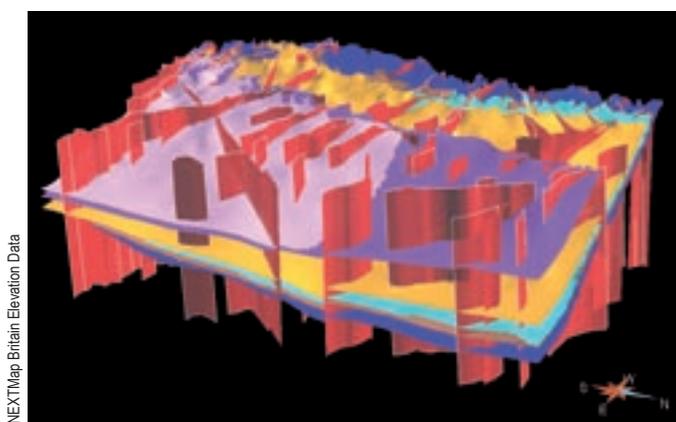
Groundwater is the source of drinking water for millions of people in the UK and is important in sustaining water levels in many rivers and wetland habitats. An understanding of the stratigraphy and geological structure of an aquifer in three dimensions is fundamental to understanding the distribution and behaviour of groundwater contained within the pores and fractures of the rock. Advances in computer-aided visualisation are now being applied to geoscientific problems making it possible to unite varied information from outcrop, boreholes, mine plans, and seismic sections to build 3D models of the UK's aquifers.

The Chalk is the most important aquifer in the UK, primarily due to its very widespread outcrop in south-east England where there is a high population density, low rainfall, and little potential to build large surface reservoirs. Superficially, the Chalk may appear as a relatively homogeneous block of soft white carbonate and flint.

However, in detail there is considerable variation. The clay content and amount of cementation can both vary, and laterally continuous marl beds and hardgrounds may be encountered. This lithological variation can have an important influence on groundwater flow. The differences in the physical properties shown by different strata

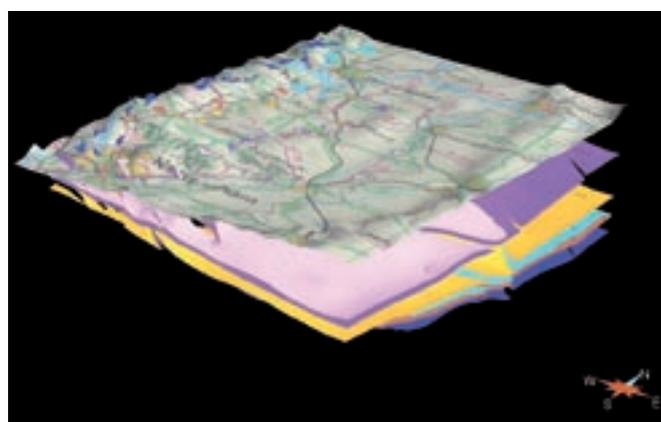
within the Chalk have only been appreciated relatively recently. The BGS now subdivides and maps the Chalk of southern England into nine divisions in place of the former threefold division of 'Lower', 'Middle', and 'Upper'. The ongoing programme of remapping the Chalk of southern England is driving much of the effort into building new subsurface 3D models of the Chalk.

While the old threefold subdivision of the Chalk often masked the presence of folds and faults, the new high-resolution mapping is revealing much about the previously unknown structure. Using sophisticated computer software, often employed by the oil industry, this new



NEXTMap Britain Elevation Data

*Bedrock geology model, including the Sherwood Sandstone aquifers. The model highlights faults which split the geology beneath the East Midlands and Yorkshire into a series of compartments and determine the way in which groundwater can be used.*

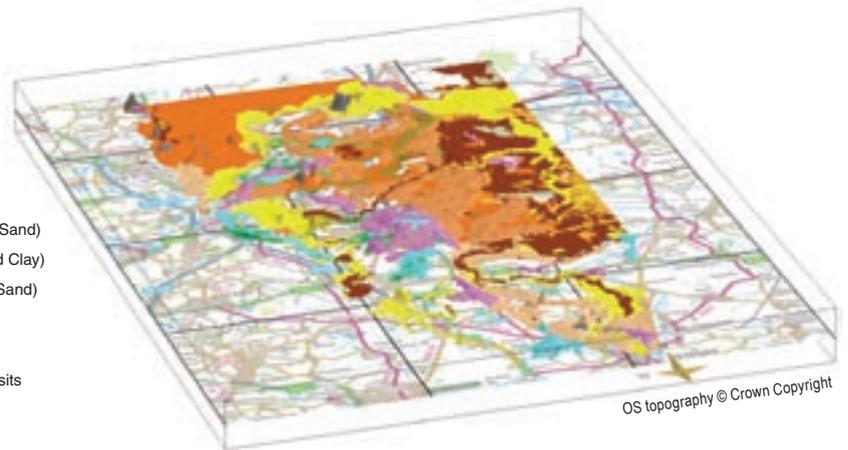


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*Detailed view of the bedrock 3D model showing the bedrock horizon, including the Sherwood Sandstone aquifer, concealed beneath the Nottinghamshire region.*

*Geological model showing the relationships and geometry of the main superficial units above the Sherwood Sandstone aquifer; this is used to create hydrogeological domains in order to understand how water reaches the underlying aquifer.*

- Made Ground
- Warp
- Peat
- Alluvium
- Blown Sand
- River Terrace Deposits
- Head
- Glaciolacustrine Deposits (Upper Sand)
- Glaciolacustrine Deposits (Silt and Clay)
- Glaciolacustrine Deposits (Basal Sand)
- Glaciofluvial Deposits
- Older River Gravel
- Pre-Ipswichian Glaciofluvial Deposits
- Till
- Channel Deposits



mapping can be combined with digital terrain models, borehole information, and seismic sections. Combining information in this way allows us to appreciate, in full, the three-dimensional geological structure and stratigraphy of the onshore Chalk of southern Britain. Much of this work is commissioned by the Environment Agency which is now routinely building 3D geology into mathematical models of groundwater flow in the chalklands of southern England. The models can be used for many purposes such as predicting the possible adverse effects of groundwater extraction on environmentally sensitive chalk streams.

The Sherwood Sandstone Group of Yorkshire and the East Midlands is the second most important aquifer in the UK. It provides a source of groundwater for industry, agriculture, and the home, especially in northern and central England. Increasing demands on this natural resource, and corresponding legal processes including the EU Water Framework Directive require that the Environment Agency, the authority responsible for licensing the way in which the aquifer is used, enhance their understanding of the region's water by producing a groundwater model.

The BGS has recently contributed to the Environment Agency's groundwater model by providing a 3D geological model of the aquifer and overlying superficial deposits, highlighting the structure of the Sherwood Sandstone Group and its relationship to other geological units. This geological model

provides a framework into which specific information on the distribution of water can be integrated to provide a decision-making tool for groundwater management in Yorkshire and Nottinghamshire.

The geological model produced by the BGS covers an area extending from Nottingham to Doncaster, covering some 4000 square kilometres. By combining information from geological maps, existing boreholes, seismic data and regional geological expertise, the geological model provides information on the main rock units down to a depth of over 1000 metres.

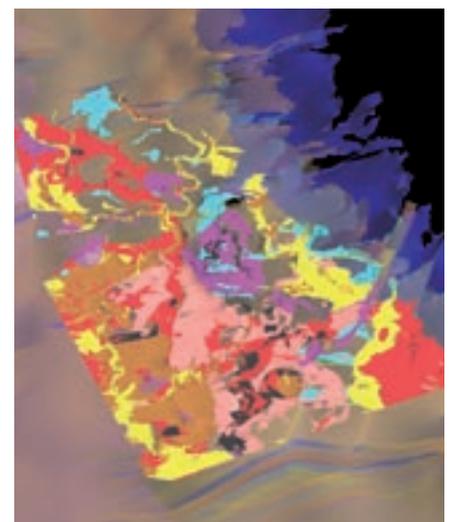
In addition to showing the position and thickness of the Sherwood Sandstone Group, the geological model includes geological faults. These structures contribute significantly to the way in which the aquifer works. Some faults form barriers to the movement of groundwater by offsetting the water-bearing sandstone against impermeable mudstone. Other faults act as underground channels, bringing water from limestones and other geological units below the sandstone into the aquifer. Understanding these geological structures is essential in the Environment Agency's decision-making process.

Computer modelling has for the first time allowed us to construct a detailed 3D model of the superficial geological deposits. This model has shown how deposits associated with the last ice age can affect the way in which water falling as rain and flowing in rivers can interact with the aquifer.

A geological framework for this aspect of the aquifer system can show how some areas provide a potential pathway for surface water to recharge the aquifer. It also highlights those areas that are most at risk to potential pollution of this key natural resource. By understanding these processes the Environment Agency is able to plan and implement sustainable groundwater management strategies.

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*Superficial geological model shown above the Sherwood Sandstone aquifer bedrock model. The superficial deposits are shown in brighter colours. Integration of the two 3D models is important for the effective management of groundwater resources. Viewed from the north-east.*