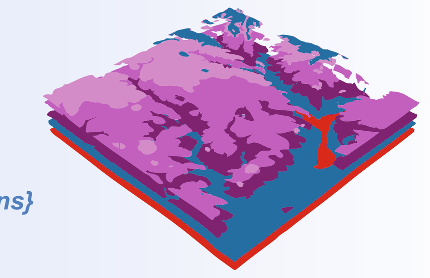
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

GSI3D Research Consortium
{Geological surveying and investigation in three dimensions}



3D Geological Mapping - Uncovering the subsurface to increase environmental understanding

Holger Kessler, Rachel Dearden, Steve Mathers and Denis Peach, British Geological Survey, United Kingdom

BGS 3D geological modelling philosophy

DRAW Geological models are created through the delineation of geological cross sections, maps and other geological objects.

INTERPRET The methodology reflects the 200 year old tradition of geologists drawing cross sections by interpreting borehole data, images, mine plans, maps and a terrain model. Data is never perfect, so where the geologist deems it to be inaccurate, it can be ignored.

CONTEXT The objects drawn by the geologist resemble real geological features and so their context can be understood by future geologists who may revise the model.

WHOLE Geological units are expressed as volumes, not by surfaces, and so the completed model represents a complete stratigraphy, rather than a series of layers that may not exist in a natural sequence.

PREDICT Where little hard data exist, the geologist populates the model using their experience of geological processes and landscape evolution gained from years of field experience.

MAP The geological map is a crucial part of the model and is used to define the spatial extents of the geological units, both at surface and subcrop.

TODAY'S GEOLOGY Once the model cross sections and geological extents are complete, the model is 'calculated', binding the nodes of each geological unit together to create the geological volumes, which ultimately become the geological model.

DYNAMIC The calculated 3D model is a representation of the geology at one moment. When new data becomes available, the geological map and the sections can be edited and the model can be recalculated.

INTUITIVE This methodology is GSI3D. It is built by geologists, for geologists, not for IT specialists. It's a methodology that manifests itself in a piece of software; it's transparent like any other piece of science. There are no black boxes and interoperability is its core requirement.

JOIN US GSI3D is distributed by the BGS through the GSI3D research consortium, the members of which help to direct its future development

Kessler, H., Mathers, S.J. and Sobisch, H.-G., 2009. The capture and dissemination of integrated 3D geospatial knowledge at the British Geological Survey using GSI3D software and methodology. Computers and Geosciences, 35, 1311-1321

3d geological modelling

Geological models provide geologists with a mechanism to express their geological knowledge and concepts in an explicit form. The construction of accurate and defensible 3D geological models requires therefore, not only high quality data such as geological maps and borehole records, but also an understanding of geological processes and features. This is a necessity, particularly in complex geological environments, where the data available is unlikely to be sufficient to describe geological structures alone. Figure 1 shows such an example, where discontinuous lense of clays, silts, sands and peats have been delineated by a geologist using the best available data and conceptualisation of geological processes.

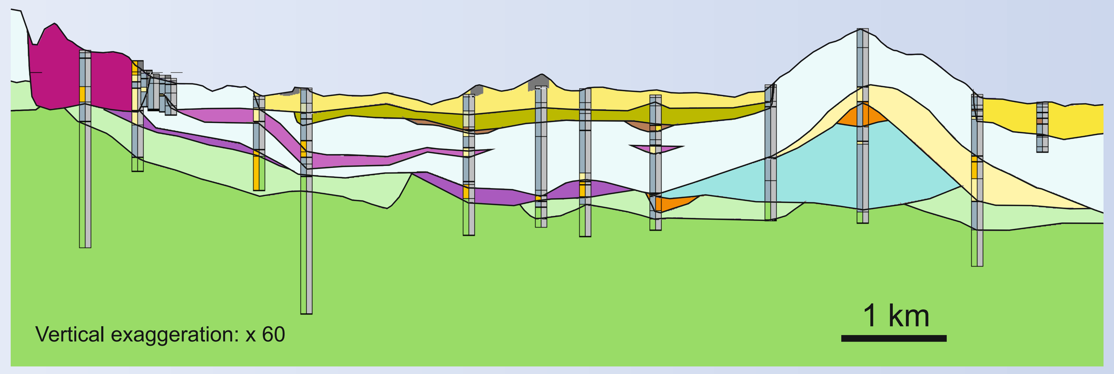
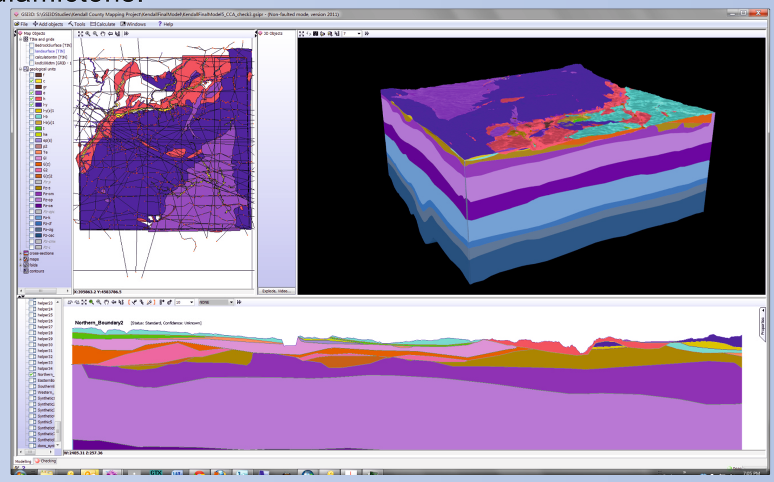


Figure 1. Cross section from a geological model of Holderness, East Yorkshire, showing linework associated with complex Quaternary deposits over Chalk

A 3D geological model of Kendall County, Illinois is being created in response to rapid suburbanisation. The succession of glacial deposits (~100 m) and Paleozoic rocks are being modelled over an 800 km^2 area to better understand the distribution and character of the aquifers and confining units. The model has enabled the Survey to understand the interconnections between the glaciofluvial and glaciolacustrine sediments. It has highlighted that shallow groundwater recharge occurs mostly through postglacial river channels, being limited elsewhere by the widespread occurrence of fine-grained diamictons.



The model identified significant volumes of sand below the diamictons and throughout the glacial sequence. These sediments are likely to cause significant leakage to the underlying bedrock aquifers, but due to the low porosity, the potential for groundwater abstraction is low.

Figure 2. 3D geological model of Kendall County, Illinois, shown within the GSI3D software interface.

Don Keefer
Illinois State Geological Survey, USA

A 1.5 x 7 km 3D geological model comprising a sequence of 55-100 m of Quaternary sediments, was constructed to show the groundwater potential and vulnerability within the Kuusistonloukko region. The geological model was used to help inform engineers within the water supply company, and exports from the model were used to populate a groundwater flow model.

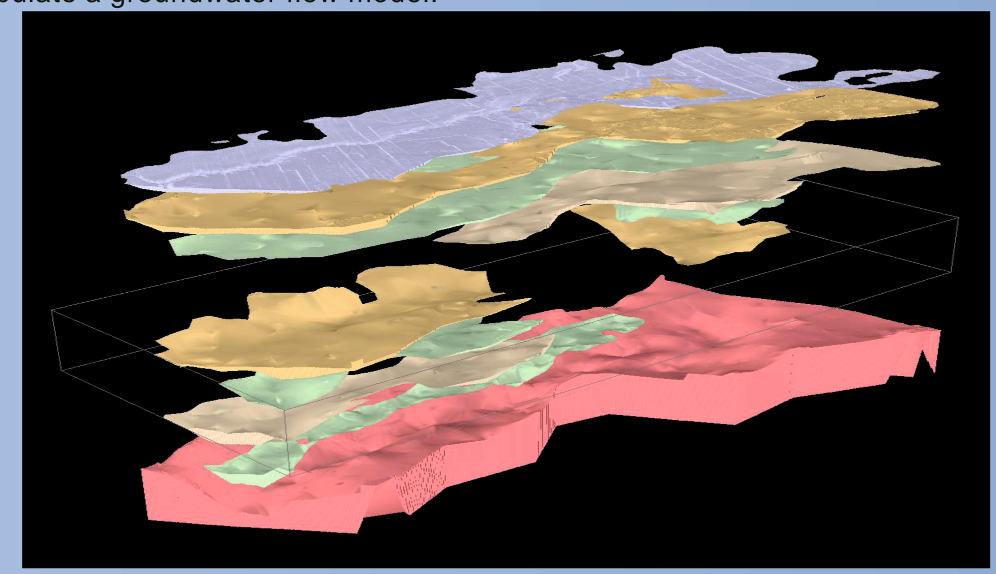


Figure 3. 3D geology of the Kuusistonloukko area, showing basal till units (yellow and brown), interbedded with sands (green) and overlain by a fine silt (purple) that protects the main source of groundwater within the undermost sands.

Niko Putkinen
Geological Survey of Finland

Parameterisation of 3D geometries

Parameterisation of 3D models via bulk attribution (Figure 4) or via population with measured or predicted quantitative parameters enables the characterisation of geological properties. Such parameterised models are essential for decision makers and environmental scientists who may use them to develop conceptual models and even incorporate them into numerical process models.

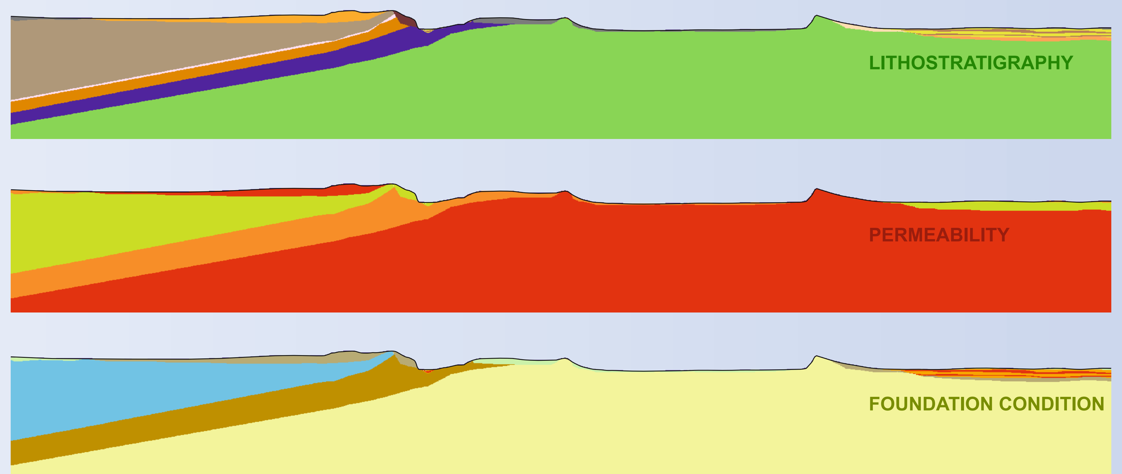


Figure 4. Cross sections from a bulk parameterised geological model of Thurrock, London, UK, showing lithostratigraphy, permeability and foundation condition.

Construction of a 3D geological and anthropogenic model of Bryggen, Norway, provided a framework to help assess the preservation potential of buried archaeology and heritage (Figure 5). The geological model and other spatial and process models, contributed to the development of a decision support system for sustainable urban development and regeneration that aimed to safeguard the subsurface cultural heritage.

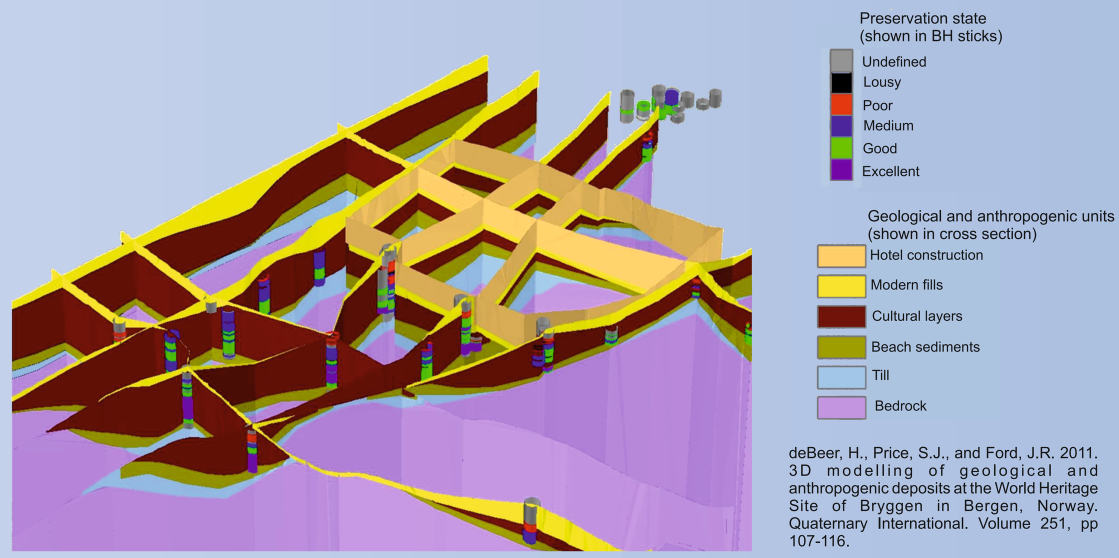


Figure 5. Cross section diagram from the Bryggen 3D geological model with borehole sticks documenting state of preservation

Hans deBeer
Geological Survey of Norway

A 3D geological model of the Thames Basin, UK (Figure 6a) was used to conceptualise the hydrogeology and design a groundwater flow model. The geological model was attributed to illustrate the connectivity between the principal (blue) and secondary (yellow) aquifers (Figure 6b). The model highlighted that these aquifers were hydraulically separated by clay-rich units and therefore required separate groundwater flow models that were linked via the river network.

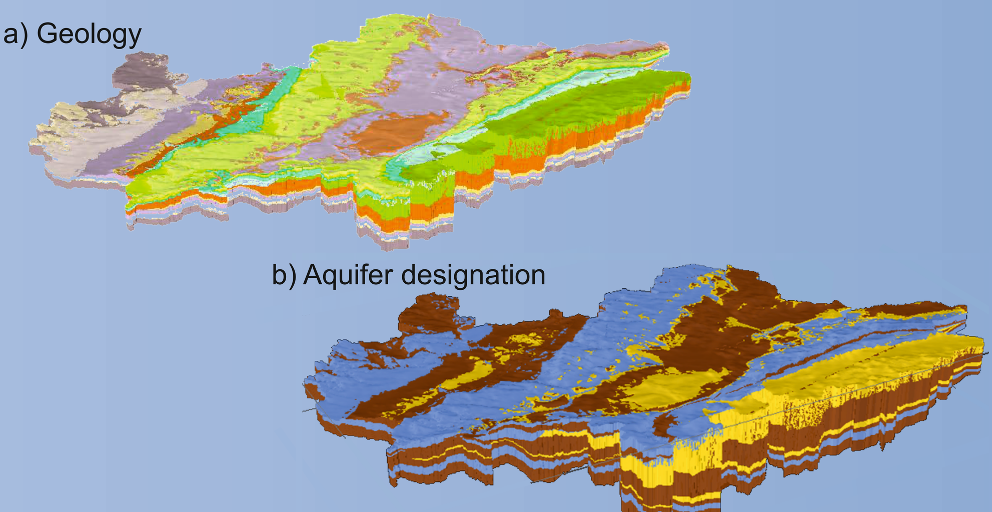


Figure 6. Geological model of the Thames Basin attributed with a) geology and b) aquifer designation classifications

Steph Bricker
British Geological Survey

Models for planning and prediction

The principal aim of developing geological models is to improve our ability to predict future scenarios and mitigate their impacts. It is therefore essential that 3D geometries, and in some cases, parameters, can be incorporated into numerical process models, and that the results of these process models can be viewed in relation to the 3D geology. This not only allows improved representation of the geology within the process model, but it also facilitates validation of the simulation results, and provides an opportunity to compare results of multiple scenarios and outputs. Furthermore, the 3D model provides a platform within which to disseminate outcomes to stakeholders.

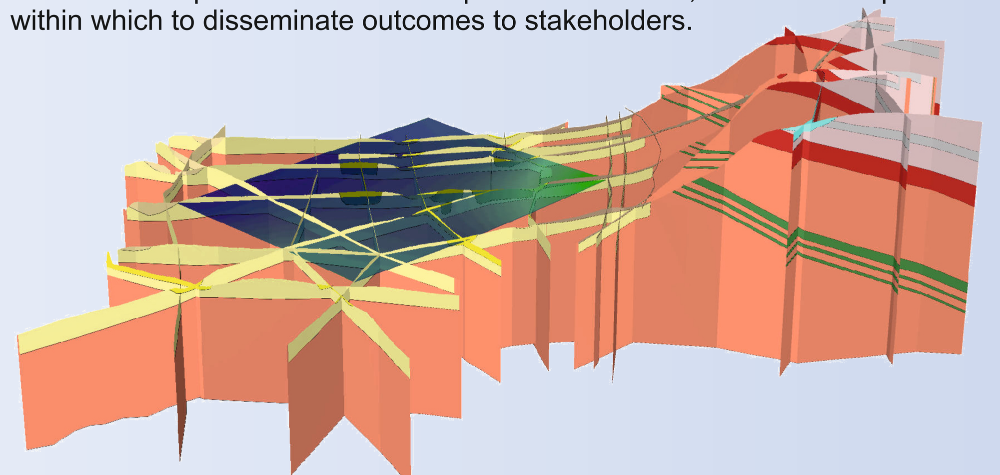


Figure 7. Cross sections from a 3D geological model of Shelford near Nottingham, intersecting a water table exported from a numerical groundwater flow model that was simulated using the geometries from the 3D geological model.

The Water Board of Oldenburg and East Frisia, OOWV, supply drinking water from unconsolidated Quaternary and Tertiary aquifers to over 350,000 households. The groundwater resource in these shallow aquifers needs to be managed to ensure sustainable abstraction and to protect groundwater quality. The land-use in this area is predominantly arable and hence the aquifers are particularly vulnerable to contamination from fertilisers and pesticides, where they are not protected by clay units near the surface.

A 3D geological model (Figure 8) of the region was constructed to show the spatial distribution of shallow clays over the permeable aquifers. This allowed an assessment of aquifer vulnerability and resulted in the development of a groundwater vulnerability map (Figure 9).

To enable OOWV to manage the water resources sustainably, a groundwater flow model was constructed using the geometries from the geological model (Figure 10a). This model is used regularly to determine the likely groundwater drawdown associated with groundwater abstraction scenarios (Figure 10b). It is used for assessing Water Rights, planning new drilling locations and for optimising groundwater observation networks.

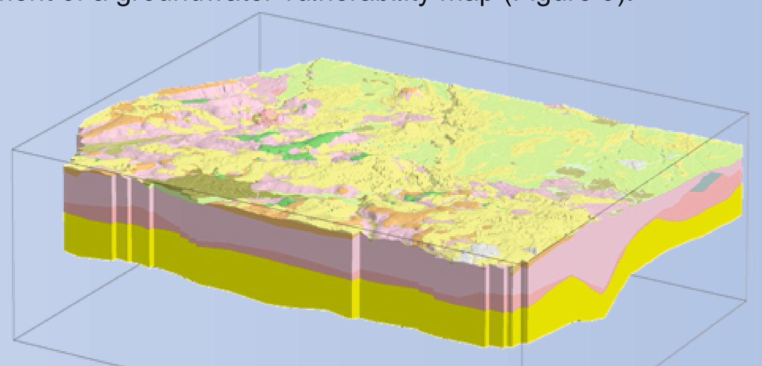


Figure 8. A section of the geological model from the area around Thülsfelde

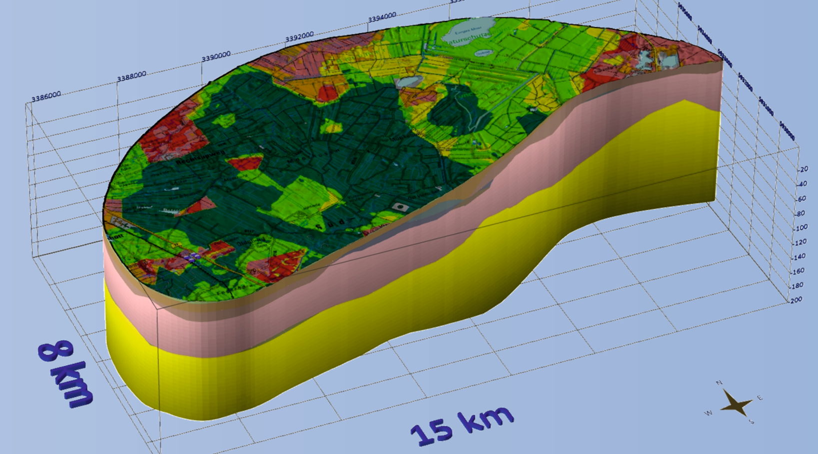


Figure 9. Groundwater vulnerability map

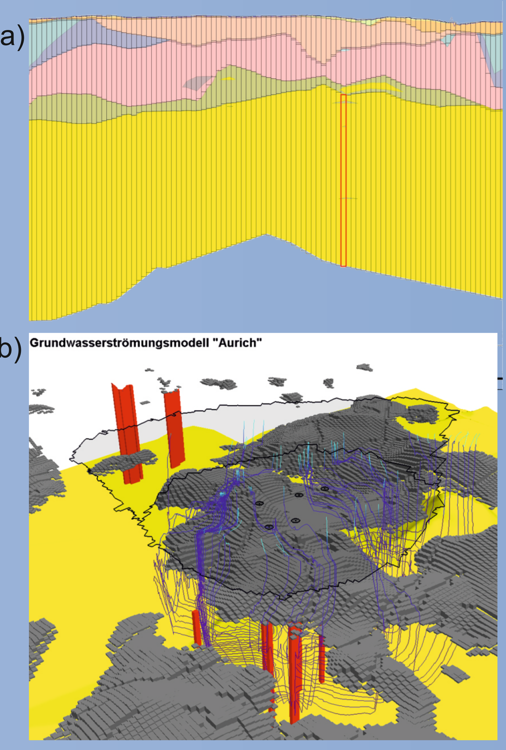


Figure 10. a) Groundwater flow model incorporating 3D model geometries and b) groundwater flow model results

Michael Howahr
OOWV

GSI3D LinkedIn Group
GSI3D Research Consortium