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

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

Geological models provide geologists with a mechanism to express their geological knowledge and concepts in an explicit form. The construction of accurate and delineable 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 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.

A 3D geological model of Kendall County, Illinois is being created in response to rapid suburbanisation. The succession of glacial sands (> 100 m) and Pleistocene sands are being modelled over an 800 km² area to better understand the distribution and character of the aquifers and confining units. The model has enabled the user to understand the cross sections of the geological unit and the geographical extent of the aquifers (Figure 9). It has highlighted that shallow groundwater recharge occurs mostly through postglacial river channels, being limited elsewhere by the widespread occurrence of fine-grained sediments.

The geological model is used regularly to determine the likely groundwater drawdown associated with groundwater abstraction scenarios (Figure 9). A 3D geological model of the Thames Basin, UK (Figure 10a) was used to conceptualise the hydrostratigraphy and develop a groundwater flow model. The geological model was distributed to illustrate the connectivity between the principal (blue) and secondary (yellow) aquifers (Figure 9b). 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 centralised model. These models were used to evaluate potential abstraction scenarios.

The Water Board of Östergötland and East Fries, OWGW, supply drinking water from unconfined Quaternary and Tertiary aquifers to over 500,000 households. The groundwater reservoir in these shallow aquifers needs to be managed to ensure sustainable abstraction and to protect groundwater quality. The test use in this area is predominantly irrigated 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 clay units that separate the permeable aquifers. This allowed an assessment of aquifer vulnerability and resulted in the development of a groundwater vulnerability map (Figure 9).

To enable OWGW to manage the water resources sustainably, a groundwater flow model was constructed using the GSI3D software interface. This model is used regularly to determine the likely groundwater drawdown associated with groundwater abstraction scenarios (Figure 10a). It is used for assessing Water Rights, planning new drilling locations and for optimising groundwater observation networks.

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.

Geological and anthropogenic units are depicted using 3D model geometries and surfaces. Incorporating 3D spatial data and process models with the geological model allowed an assessment of aquifer vulnerability and resulted in the development of a groundwater vulnerability map (Figure 9).

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

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

Figure 3. 3D geological model of the Kuusistonloukko area, showing bed 8 units (yellow and brown), interbedded with sands (green) and overlain by a fine silt (purple) that protects the main source of groundwater within the underlying sands.

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

Figure 5. Cross section diagram from the Bryggen 3D geological model with borehole sticks documenting state of preservation (Figure 5a) and aquifer designation classifications (Figure 5b).

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

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

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

Figure 9. Groundwater vulnerability map.