



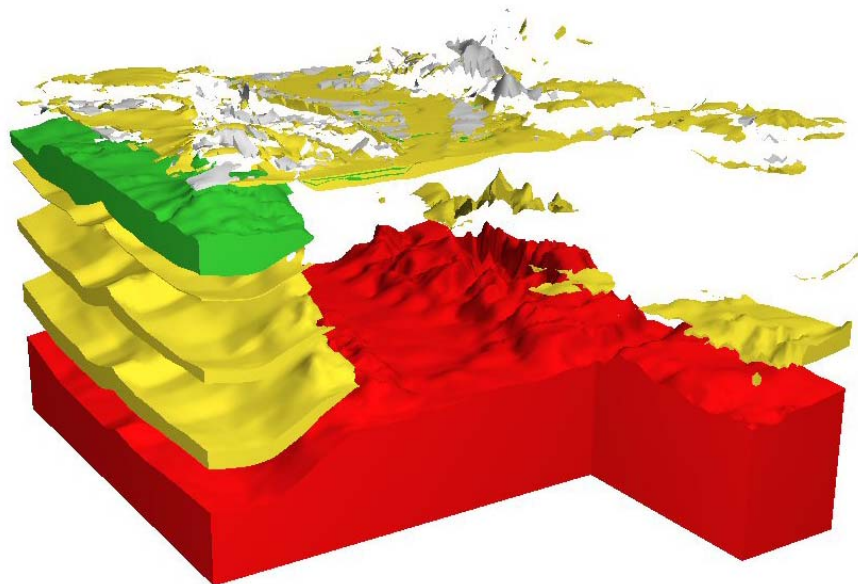
**British
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

Hydrogeological parameterisation of the Thames Gateway GSI3D model

Physical Hazards Programme

Internal Report IR/06/042



BRITISH GEOLOGICAL SURVEY

PHYSICAL HAZARDS PROGRAMME

INTERNAL REPORT IR/06/042

Hydrogeological parameterisation of the Thames Gateway GSI3D model

H.K. Rutter, J. Cunningham, C.R. Jackson, M. Lewis

The National Grid and other Ordnance Survey data are used with the permission of the Controller of Her Majesty's Stationery Office. Ordnance Survey licence number Licence No:100017897/2005.

Keywords

Thames Gateway; GSI3D;
Hydrogeological model.

Front cover

Cover picture details, delete if no cover picture.

Bibliographical reference

RUTTER, H.K., CUNNINGHAM, J., JACKSON, C.R., LEWIS, M. 2005. Hydrogeological parameterisation of the Thames Gateway GSI3D model. *British Geological Survey Internal Report*, IR/06/042. 44pp.

Copyright in materials derived from the British Geological Survey's work is owned by the Natural Environment Research Council (NERC) and/or the authority that commissioned the work. You may not copy or adapt this publication without first obtaining permission. Contact the BGS Intellectual Property Rights Section, British Geological Survey, Keyworth, e-mail ipr@bgs.ac.uk You may quote extracts of a reasonable length without prior permission, provided a full acknowledgement is given of the source of the extract.

© NERC 2005. All rights reserved

Keyworth, Nottingham British Geological Survey 2006

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham, Edinburgh and London; see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.geologyshop.com

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgs london@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

☎ 028-9038 8462 Fax 028-9066 2835
e-mail: gsmi@detini.gov.uk

Maclea Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345
e-mail: hydro@bgs.ac.uk

Sophia House, 28 Cathedral Road, Cardiff, CF11 9LJ

☎ 029-2066 0147 Fax 029-2066 0159

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Contents

| | |
|---|-----------|
| Contents | i |
| Summary | iv |
| 1 Background and scope of study | 6 |
| 2 Parameterisation of GSI3D model with hydrogeological information | 8 |
| 2.1 Data sets | 8 |
| 2.2 Methodology | 10 |
| 2.3 Resulting model | 11 |
| 3 Incorporation of groundwater level surfaces | 15 |
| 3.1 Data sets | 15 |
| 3.2 Methodology | 16 |
| 3.3 Resulting model | 16 |
| 4 Incorporation of hydrogeologically related borehole data | 20 |
| 4.1 Aquifer properties data | 20 |
| 4.2 Water level data | 20 |
| 4.3 Borehole geophysical data | 24 |
| 5 Incorporation of groundwater flow model output | 27 |
| 5.1 Data sets and methodology | 27 |
| 6 Concluding remarks | 35 |
| References | 36 |
| Appendix 1 Metadata catalogue | 37 |

FIGURES

| | | |
|-----------|--|----|
| Figure 1 | The Thames Gateway pilot study area | 6 |
| Figure 2 | The Thames Gateway pilot study's 3D lithological model covering an area from Creekmouth in the west to Tilbury in the east | 7 |
| Figure 3 | Cross-section NS7 coloured according to permeability type | 11 |
| Figure 4 | Cross-section NS7 coloured according to maximum permeability | 11 |
| Figure 5 | Cross-section NS7 coloured according to the EA's WFD aquifer classification | 11 |
| Figure 6 | Volume model coloured to show maximum permeability | 12 |
| Figure 7 | Exploded volume model coloured according to the EA's WFD aquifer classification | 12 |
| Figure 8 | Distribution of recorded karstic features and dissolution hazard | 14 |
| Figure 9 | Section WE11 through quarries | 17 |
| Figure 10 | Section NS15 | 17 |
| Figure 11 | Intersection of the water table with geology | 18 |
| Figure 12 | Construction of the geology at the potentiometric surface map using GSI3D and ArcMap | 19 |
| Figure 13 | Spatial coverage of water data used | 21 |
| Figure 14 | Rest water level borehole logs | 22 |
| Figure 15 | Resulting 3D model of the rest water level data combined with modelled geology | 23 |
| Figure 16 | Temperature and conductivity log for TQ57SW29 | 26 |
| Figure 17 | Boundary of the Swanscombe groundwater model and the Thames Gateway pilot study area. Simulated groundwater level contours are shown in red for February 1995 | 29 |
| Figure 18 | Simulated and observed groundwater levels for an observation borehole close to the southern boundary of the pilot study area. Groundwater level conditions for February 1995 (wet) and October 1997 (dry), which were chosen for inclusion in GSI3D, are highlighted | 30 |
| Figure 19 | Intersection of simulated groundwater table for February 1995 (blue) with DTM within Thames Gateway pilot study area | 31 |
| Figure 20 | Intersection of simulated groundwater table (green) for October 1997 with DTM within Thames Gateway pilot study area | 32 |
| Figure 21 | 3D GSI3D image showing position of simulated water table for February 1995 in relation to geological sections (fence diagram) | 33 |
| Figure 22 | 3D GSI3D image showing position of simulated water table for October 1997 in relation to geological sections (fence diagram) | 34 |

TABLES

| | | |
|---------|---|----|
| Table 1 | Hydrogeological attributes applied to GSI3D model | 8 |
| Table 2 | Columns of the GVS showing aquifer and permeability classification | 9 |
| Table 3 | Key to dissolution codes used in risk map | 13 |
| Table 4 | Water levels bid file (Wls.bid) | 21 |
| Table 5 | Water levels blg file (Wls.blg) | 22 |
| Table 6 | Water levels ThamesG_v5_0.gleg file | 22 |
| Table 7 | Summary of temperature and conductivity logs available for the Project area | 24 |
| Table 8 | Conductivity ($\mu\text{S cm}^{-1}$) classification for display in GSI3D | 25 |
| Table 9 | Temperature ($^{\circ}\text{C}$) classification for display in GSI3D | 25 |

Summary

In 2005 the British Geological Survey undertook a pilot study to examine whether there was a requirement for, and interest in, geoscience data by stakeholders in the Thames Gateway region (Royse et al., 2005). The project found that there was a genuine demand for geoscience information and that BGS's data needed to be able to address the specific problems that clients are faced with in the region. It was considered that there was a requirement to develop 3D geological models that could be used to integrate this information and provide it to potential users in a clear and easily accessible form. Consequently, a GSI3D model was developed of a pilot area within the Thames Gateway region and attributed with information of use to stakeholders.

The aim of this project has been to build on the GSI3D model developed by Royse et al. (2005) by incorporating hydrogeological information into it. The project has been split into a number of tasks through the completion of which a suite of different types of hydrogeological data have been collated, processed and incorporated into the GSI3D model. The results of each of these tasks are summarised below.

Task 1: Identify, build metadata catalogue, and quality assure all available hydrogeological data sets.

- All collated data have been quality assured and a metadata catalogue has been developed (Appendix 1).
- All the data used in the project have been added to BGS corporate databases, where required.

Task 2: Methods to parameterise lithostratigraphy within GSI3D models using existing hydrogeological lexicons.

- The GSI3D model of the Thames Gateway pilot study area has been attributed with the following information:
 - Aquifer type according to Environment Agency classification for the Water Framework Directive.
 - Permeability type: fractured, mixed or intergranular
 - Maximum permeability: very high, high, moderate, low, very low.
- Karstic features contained in three separate BGS databases have been collated and plotted using a GIS but not incorporated into GSI3D.

Task 3: Methodologies to incorporate and represent groundwater level surfaces into GSI3D models.

- Published groundwater contours have been digitised and incorporated into GSI3D as DEMs for January 2004, January 1990, 1965 and "pre-development".
- Insufficient groundwater level data exists to develop more detailed contours from borehole records.
- Contours could only be produced for Chalk groundwater levels because of insufficient data for other aquifers.

Task 4: Methodologies to incorporate hydrogeologically-related borehole data into GSI3D models.

- Only one cored borehole aquifer properties data record exists in the BGS Aquifer Properties database within the pilot study area. Consequently, down-hole variations in permeability and porosity could not be visualised using GSI3D.
- Post-1980 minimum and maximum borehole groundwater levels have been incorporated in the GSI3D model and can be visualised as borehole logs in conjunction with geological cross-sections and fence diagrams.
- Down-hole geophysical logs (temperature and conductivity) have been extracted from the UK Wellog database, and displayed within GSI3D as numerical data.

Task 5: Methodologies to incorporate output from groundwater flow models into GSI3D models.

- Simulated groundwater level surfaces produced by the BGS's "Swanscombe groundwater model" have been incorporated into GSI3D. Chalk groundwater level surfaces for February 1995 and October 1997, representing "average" high and low levels, have been processed.

1 Background and scope of study

The Thames Gateway pilot study area as defined by Royse et al. (2005) is shown in Figure 1. The region covers a 250 km² area of the Thames Gateway from Bexley in the west to Tilbury in the east. The initial project focusing on the Thames Gateway, undertaken by Royse et al. (2005), constructed a geological model of the pilot area using GSI3D (Figure 2). This GSI3D model forms the basis of this project, the aim of which has been to collate and process hydrogeological information for incorporation into GSI3D. Once this has been performed the GSI3D model becomes a valuable tool for the storage, presentation and interrogation of these various types of information.



Figure 1 The Thames Gateway pilot study area

The project is split into five components, or tasks, each of which is defined below. The first of these relates to the quality assurance of the data and the construction of a metadata catalogue to describe the collated data. The final four tasks relate to the processing and incorporation of the different data sets into the GSI3D model. Information on aquifer properties, observed and modelled groundwater levels and geophysics, both across the pilot area and at individual boreholes, is processed and presented within GSI3D. The following bullet points summarise the individual components of the project.

- Task 1: Identify and build a metadata catalogue, and quality assure all available hydrogeological data sets.
- Task 2: Parameterise lithostratigraphy within the Thames Gateway GSI3D model using existing hydrogeological lexicons according to:
 - Aquifer type (aquifer, non-aquifer).
 - Permeability type (fractured, mixed or intergranular flow).
 - Permeability classification (very high, high, moderate, low or very low permeability).

- Karstic potential.
- Task 3: Incorporate and represent groundwater level surfaces into the Thames Gateway GSI3D model using:
 - Existing digital surfaces.
 - New groundwater level surfaces generated using borehole data (e.g. from BGS's WellMaster database).
- Task 4: Incorporate hydrogeologically-related borehole data into the Thames Gateway GSI3D model including:
 - Aquifer properties data from borehole core.
 - Geophysical and aquifer properties data.
- Task 5: Incorporate output from a groundwater flow models into the Thames Gateway GSI3D model using data from BGS's Swanscombe groundwater modelling project.

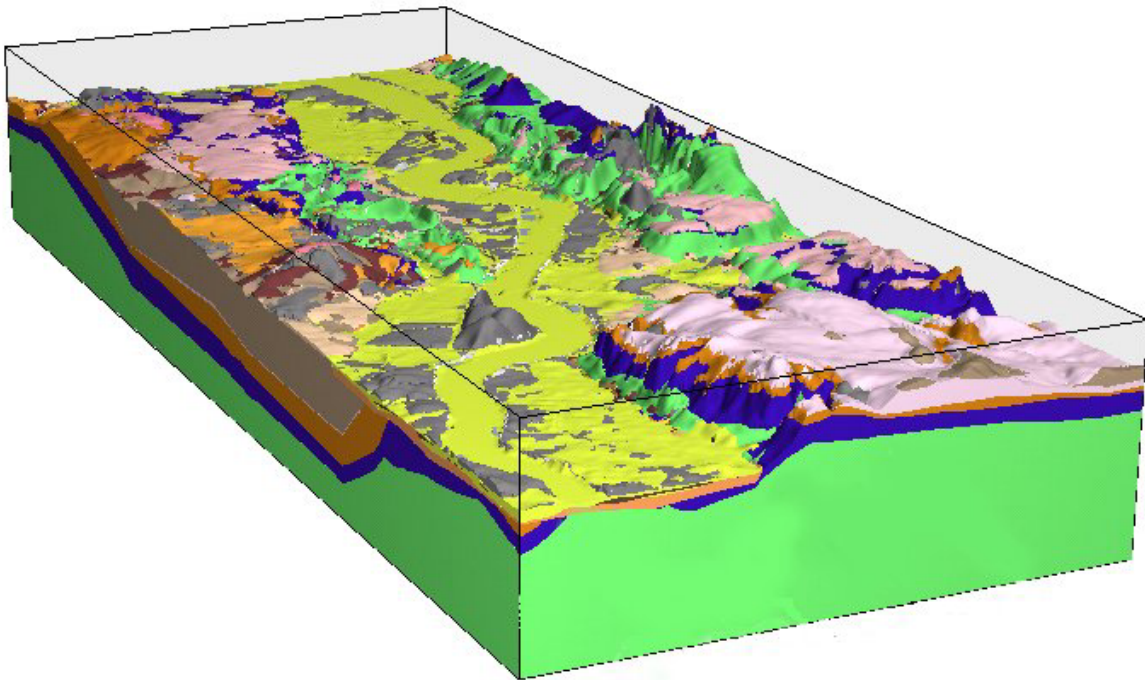


Figure 2 The Thames Gateway pilot study's 3D lithological model covering an area from Creekmouth in the west to Tilbury in the east

2 Parameterisation of GSI3D model with hydrogeological information

This task involved the attribution of the Thames Gateway GSI3D model with hydrogeological information relating to the properties of the aquifer material. The attribution with aquifer properties is a simple one, and enables the visualisation of the way in which these properties vary in 3D.

Karstic potential was also considered, as this attribute would provide additional value to the model. Karstic potential depends ultimately on the rock type. In this area the Chalk is the only formation at risk. However, it also depends on other factors, in particular the proximity of Palaeogene deposits, where acidic runoff may enhance dissolution processes in the Chalk. The depth to which karst has developed is also important: in general it is of interest in the shallow subsurface where there is the potential for subsidence. Deep karst is known at Swanscombe, where it appears to have developed beneath thick Palaeogene cover where previously higher water levels intercepted the base of Palaeogene: however, this does not pose a threat to property at the surface as there is little risk of subsidence. A karst hazard map was developed under the GeoSure project (see Section 2.1). Using this, the Chalk could be subdivided into areas at risk or not at risk, and subdivided within GSI3D. This would not give any detail in 3D, but it should highlight the areas that are at high risk from shallow karst.

2.1 DATA SETS

Permeability indices and permeability types were taken from the attributed DiGMap 1:50K table (Lewis et al., In press). Aquifer type was also added to the GVS based on the Environment Agency's classification scheme for the Water Framework Directive (WFD). The classifications are summarised in Table 1 and Table 2 shows the relevant columns of the GVS. It had been hoped that it would be possible to display the variation of permeability or porosity data with depth for individual boreholes across the area, and assess the correspondence of these with the permeability indices. However, a search of the database identified four boreholes that had permeability values that varied with depth, with only lithostratigraphic information for one of these. There were no porosity data.

Table 1 Hydrogeological attributes applied to GSI3D model

| |
|---|
| Aquifer type: unproductive, secondary, principal (according to EA classification for the Water Framework Directive) |
| Permeability type: fractured (F), mixed (M) or intergranular (I) flow. |
| Maximum permeability: very high, high, moderate, low, very low. |

Table 2 Columns of the GVS showing aquifer and permeability classification

| Name | ID | Stratigraphy | Lithology | Permeability type | Permeability (max) | EA aquifer classification (WFD) |
|-------------|-----|--------------|-----------|-------------------|--------------------|---------------------------------|
| ThamesG_DTM | 0 | DTM | | | | |
| Bathy | 1 | BATHY | | | | |
| 1930_dtm | 2 | DTM | | | | |
| Water | 3 | WAT | water | | | |
| MBRO | 4 | MBRO | undif | I | VHIGH | |
| MBFL | 5 | MBFL | undif | I | VHIGH | |
| MBRA | 6 | MBRA | undif | I | VHIGH | |
| wgr | 7 | WGR | void | | | |
| mgr | 8 | MGR | undif | I | VHIGH | |
| wmgr | 9 | WMGR | undif | I | VHIGH | |
| soil | 10 | SOIL | undif | I | | |
| btfu | 11 | BTFU | CZSV | I | HIGH | Secondary |
| tfd | 12 | TFD | CZPV | I | HIGH | Unproductive |
| trd | 13 | TRD | CZVSP | I | HIGH | Unproductive |
| alv_t | 14 | ALV | CZSV | I | HIGH | Secondary |
| peat | 15 | PEAT | P | M | LOW | Unproductive |
| alv | 18 | ALV | CZSV | I | HIGH | Secondary |
| peat1 | 20 | PEAT | P | M | LOW | Unproductive |
| alv1 | 25 | ALV | CZSV | I | HIGH | Secondary |
| peat2 | 30 | PEAT | P | M | LOW | Unproductive |
| alv2 | 35 | ALV | CZSV | I | HIGH | Secondary |
| peat3 | 40 | PEAT | P | M | LOW | Unproductive |
| alv3 | 45 | ALV | CZSV | I | HIGH | Secondary |
| peat4 | 50 | PEAT | P | M | LOW | Unproductive |
| alv4 | 55 | ALV | CZSV | I | HIGH | Secondary |
| peat5 | 58 | PEAT | P | M | LOW | Unproductive |
| alv5 | 60 | ALV | CZSV | I | HIGH | Secondary |
| rtdu | 65 | RTDU | VS | I | VHIGH | Secondary |
| head | 70 | HEAD | CZSV | M | HIGH | Secondary |
| igd | 75 | IGD | CZSPV | M | HIGH | Secondary |
| kpgr | 78 | KPGR | VS | I | VHIGH | Secondary |
| tpgr | 80 | TPGR | VS | I | VHIGH | Secondary |
| hagr | 90 | HAGR | VS | I | VHIGH | Secondary |
| lhgr | 100 | LHGR | VS | I | VHIGH | Secondary |
| ilsi | 102 | ILSI | ZC | I | MODERATE | Unproductive |
| cfsi | 104 | CFSI | ZC | I | MODERATE | Unproductive |
| dasi | 110 | DASI | ZC | I | MODERATE | Unproductive |
| bht | 115 | BHT | VS | I | VHIGH | Secondary |
| bpgr | 120 | BPGR | VS | I | VHIGH | Secondary |
| supd | 125 | SUPD | CZSVP | M | HIGH | Secondary |
| clgb | 130 | CLGB | SZC | I | HIGH | Secondary |
| lc | 132 | LC | CZS | M | MODERATE | Unproductive |
| hwh | 134 | HWH | SV | I | VHIGH | Secondary |
| tham | 270 | THAM | CZSV | M | HIGH | Secondary |

Table 2. continued

| | | | | | | |
|-------------------|-----|------|------|---|-------|-----------|
| lmbe | 280 | LMBE | CZSV | M | HIGH | Secondary |
| tab | 290 | TAB | S | I | VHIGH | Secondary |
| a_bPalaeogene | 295 | TAB | | | | Secondary |
| ck | 300 | CK | CHLK | F | VHIGH | Principal |
| topCK_LOCUS | 305 | CK | CHLK | F | VHIGH | Principal |
| b_base_Cretaceous | 310 | CK | | | | Principal |

Karstic data was more difficult to obtain and use. There are three main datasets accessible within BGS:

- Natural cavities database (constructed for the then Department of Environment and held by Brett Associates). This includes point data with locations of natural karstic features such as sink holes, dolines, etc. Data are also collected by the Chelsea Speleological Society, but in this area, the data are almost all man made features
- Karst Geohazard database. This includes any recorded karstic features recorded by BGS.
- Karst hazard map, produced for GeoSure (under S:\GeoSure\Shapefiles\Dissolution\dissolution_V2). The dissolution assessment is based on domains that encompass a particular association of causal factors rather than the addition of causal factors attributed to lithostratigraphic polygons. The assessments incorporate a significant element of expert judgement and local knowledge by Andy Farrant. The dissolution hazard assessment already incorporates a large element of local knowledge and expert judgement but there will always be scope for additional local knowledge especially where small dissolution features are present that could not be captured by a national scale model.

As detailed above, the natural cavities database data and the hazard map can be displayed in 2D within the GIS, and the data also overlaid on the model within GSI3D. However, there are no three dimensional data, and thus there are limitations in the way it can be incorporated within the 3D model.

2.2 METHODOLOGY

To incorporate the aquifer properties information into GSI3D, new LEG_ID columns were added to the generalised vertical section file (GVS) for

- Aquifer classification, according to the Water Framework Directive requirements (WFD classification) e.g. unproductive / secondary / principal (column 10).
- Maximum permeability (Column 4).
- Permeability type (Column 3).

The fields were also then added to the legend file (GLEG) such that the model could be coloured up appropriately.

The method for displaying the attributed model is as follows. In the section window, select Properties, then Borehole log display settings. Select the appropriate GVS column number for the colour of the correlated section. The sections can be displayed in the 3D window with the same symbology as in the section window, by right clicking on cross-sections in the Section

window, and linking to the 3D window. (Note: any changes to the section properties after linking to the 3D window will not be propagated through to the 3D window). It is also possible to display the volumes in the 3D window, coloured by their attributes. The volumes are calculated from the TINs (Analysis: Create Full Objects) and their properties can be set by right-clicking on the volumes in the table of contents. Set the GVS column to be the appropriate attribute column, and link the objects to the 3D window. It should be noted that the volumes cannot be saved within GSI3D (Version 1.5). When the project is closed, they are lost.

2.3 RESULTING MODEL

Examples of the resulting model are shown below. Cross section NS7 is used to illustrate the variation in permeability type, maximum permeability, and aquifer classification in Figure 3, Figure 4 and Figure 5, respectively.

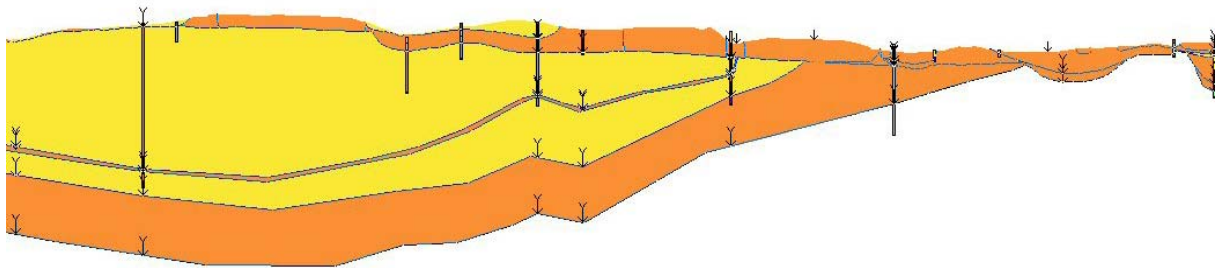


Figure 3 Cross-section NS7 coloured according to permeability type

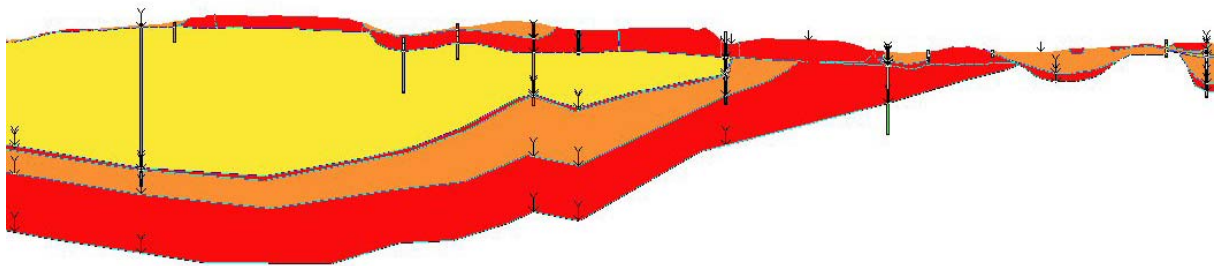


Figure 4 Cross-section NS7 coloured according to maximum permeability

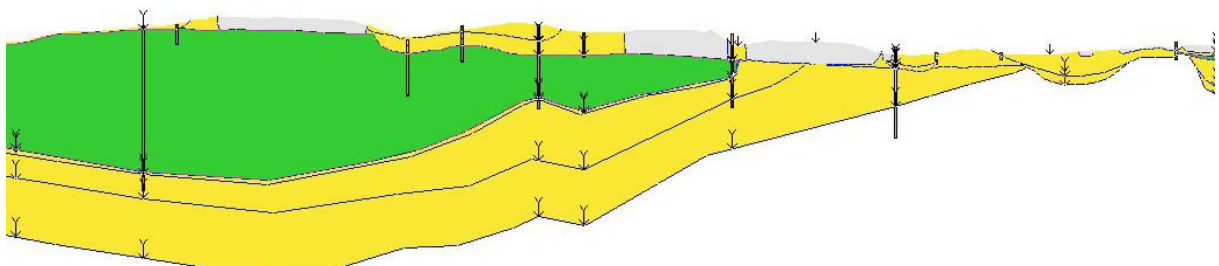


Figure 5 Cross-section NS7 coloured according to the EA's WFD aquifer classification

The volume model coloured to show maximum permeability is illustrated in Figure 6.

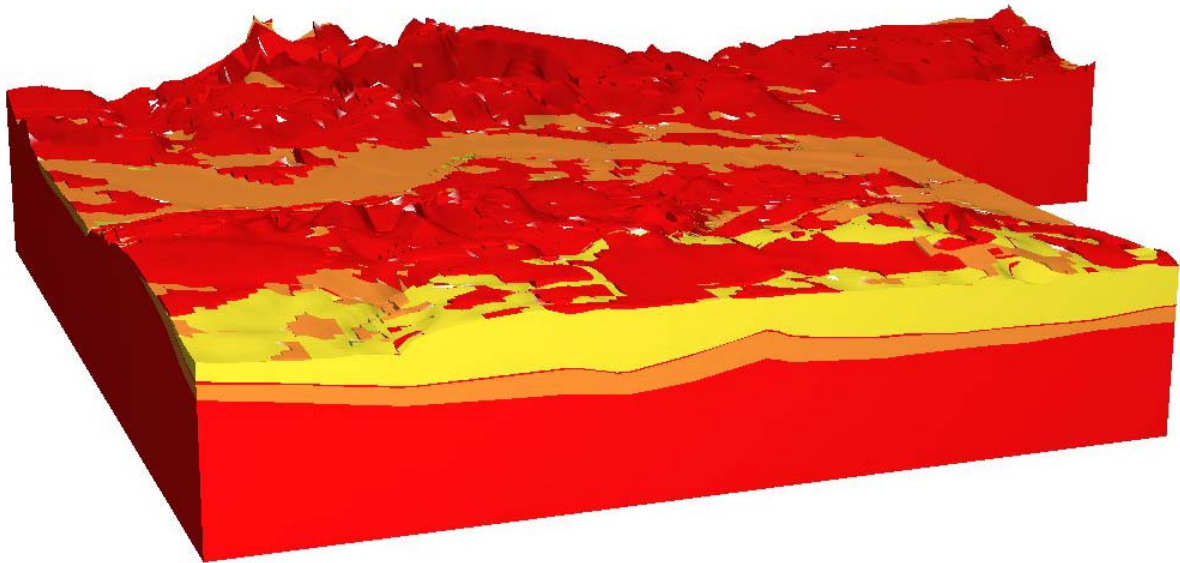


Figure 6 Volume model coloured to show maximum permeability

The volume model can be “exploded” to enable improved understanding of the geometry of the individual horizons: this is illustrated in Figure 7 showing the WFD aquifer classification, with the Chalk coloured as Principal aquifer in red, the Upper Cretaceous formations shown as Secondary aquifers in yellow, and the London Clay Formation as unproductive in green.

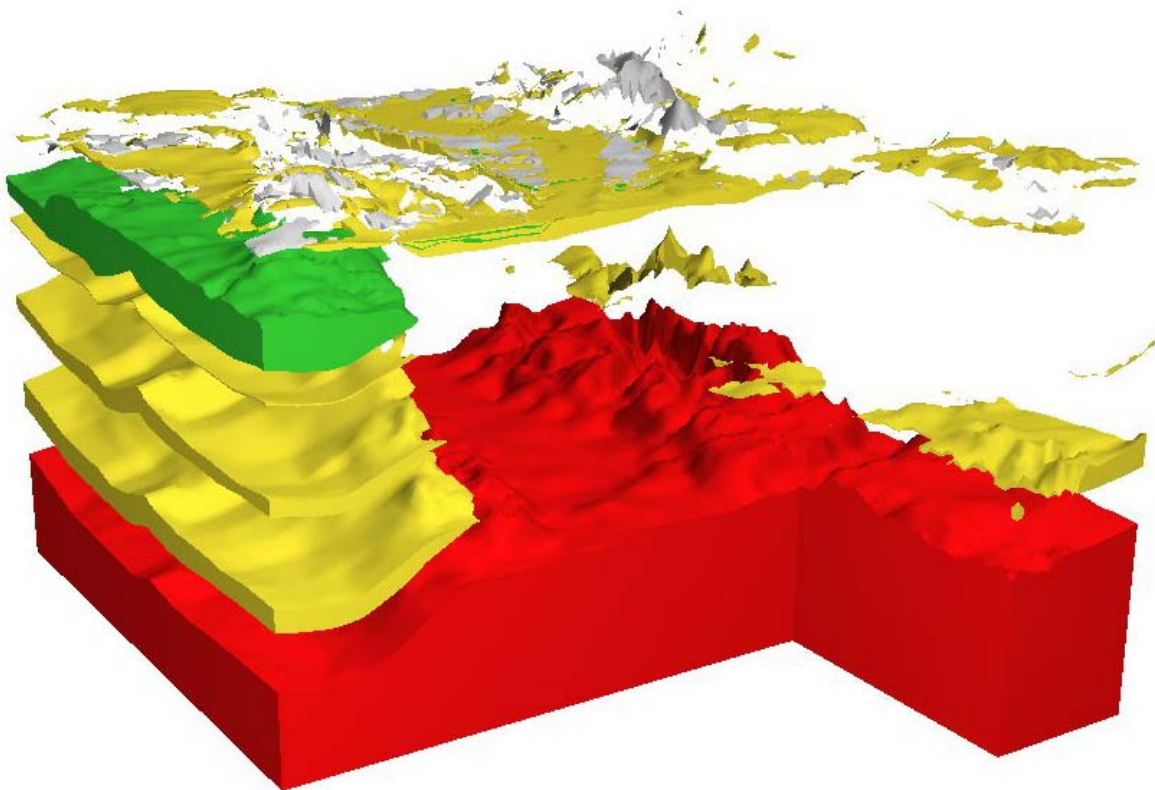


Figure 7 Exploded volume model coloured according to the EA’s WFD aquifer classification

As described previously, it is difficult to use the karst data within a three-dimensional model in a useful way. The two-dimensional hazard map showing potential for karst development, together with observed karst features from the Natural Cavities Database, is shown in Figure 8.

Table 3 Key to dissolution codes used in risk map

| | |
|---|--|
| A | Soluble rocks are present, but unlikely to cause problems except under exceptional conditions. |
| B | Significant soluble rocks, but few dissolution features and no subsidence; unlikely to cause problems except with considerable surface or subsurface water flow. |
| C | Significant soluble rocks, where there are dissolution features, and no or very little recorded subsidence, but a low possibility of it occurring naturally or in adverse conditions such as high surface or subsurface water flow. |
| D | Very significant soluble rocks, where there are numerous dissolution features and/or some recorded subsidence with a moderate possibility of localised subsidence occurring naturally or in adverse conditions such as high surface or subsurface water flow. |
| E | Very significant soluble rocks, where there are numerous dissolution features and/or considerable recorded subsidence with high possibility of localised subsidence occurring naturally or in adverse conditions such as high surface or subsurface water flow |

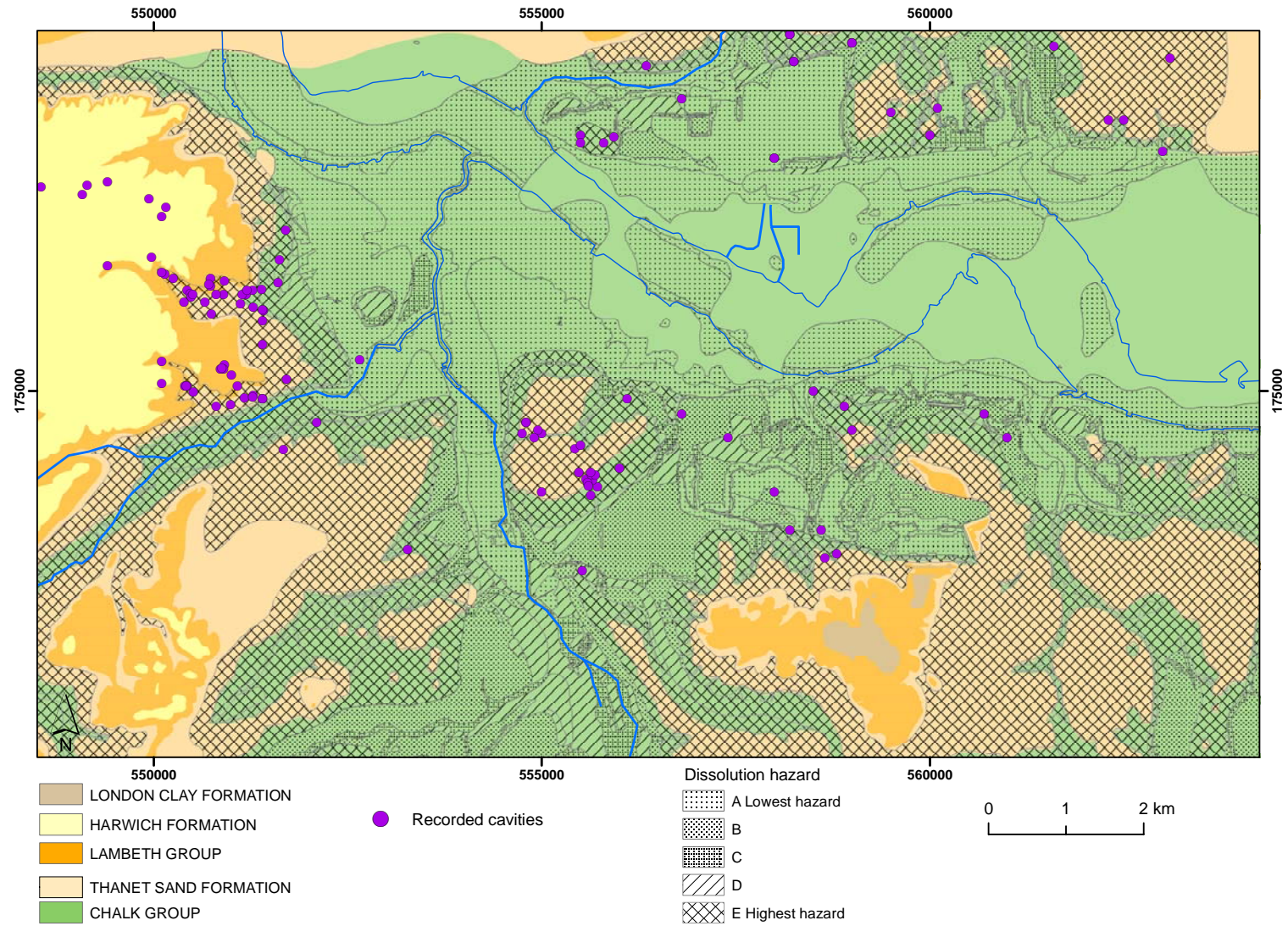


Figure 8 Distribution of recorded karstic features and dissolution hazard

3 Incorporation of groundwater level surfaces

By incorporating groundwater surfaces within GSI3D, it is possible to enhance understanding of the relationship between the potentiometric surface (here meaning the pressure surface which includes the water table for unconfined aquifers or the piezometric surface for confined aquifers) and the geology. By viewing the relationship between geology and the water surface in section and in 3D, it is possible to assess where groundwater is in relation to the ground surface. This may be relevant in terms of future land development, and in terms of abstracting groundwater. For example, it is possible to view where the potentiometric surface may be close to the surface, and, perhaps, pose a risk in terms of groundwater flooding. If the potentiometric surface is displayed together with the DTM, it is also easy to delineate areas of flooding or wetlands (for example see Figure 19). This can also serve as a check on the potentiometric surface, identifying areas where the contour data or interpolation was incorrect.

It is also possible to intersect the potentiometric surface with the geological model, to create a map of the geology at the potentiometric surface.

3.1 DATA SETS

The objective of this task was to incorporate groundwater level surfaces from both published contours and from new surfaces generated using borehole records. To this end four sets of published groundwater contours have been digitised and incorporated into GSI3D. These are all based on Chalk groundwater levels. These are for the following dates:

- January 2004 from Environment Agency (2004): Rising groundwater levels in the Chalk-basal sands aquifer of the Central London basin – May 2004.
- January 1990 from Environment Agency (1990): Rising groundwater levels in the Chalk-basal sands aquifer of the Central London basin – 1990.
- 1965 from Ellison (2004): Geology of London - special memoir for 1:50,000 geological sheets 256 North London), 257 (Romford), 270 South London) and 271 (Dartford) (England and Wales)
- “Pre-development” from Water Resources Board (1972). The hydrogeology of the London Basin.

The “pre-development” contours contained in the report of the Water Resources Board (1972) are likely to represent a date towards the start of the nineteenth century. In addition to these contours sets two modelled surfaces are also available for February 1995 and October 1997, however, these are discussed in detail in Section 5.

An attempt was made to develop additional contours from borehole water level records using data from BGS WellMaster database, from data collected during the Swanscombe groundwater modelling project (Jackson et al., 2003) and from new data requested from the Environment Agency. However, groundwater level data proved to be limited within the area of interest and only 58 post-1980 groundwater levels could be identified in, or near to, the pilot study area. This proved to be insufficient to develop other groundwater level surfaces.

3.2 METHODOLOGY

The contours were digitised and surfaces interpolated within the Surfer software package. These surfaces were then exported from Surfer and converted into ArcGIS grid export (ascii) files. After setting up the GSI3D model, these were then added by adding the grids but not defining them as DTMs. The water level surfaces were then displayed in the Section or 3D views. To display the surface in Section view, the “line” option is selected under “Set colour of synthetic section”.

The surface can be linked to the 3D view by right clicking on the grid in the table of contents and sending it to the 3D view.

The surface can also be used to intersect with the 3 dimensional geology, and produce a geology map at the potentiometric surface/water table. The approach is simple: the potentiometric surface is defined as the DTM, and volumes calculated from the TINs. In this way, the potentiometric surface is the upper bounding surface, rather than the land surface. After the volumes have been created, the result can be exported as a shapefile.

3.3 RESULTING MODEL

The potentiometric surface can be viewed in different ways, as has been described. These are illustrated below.

Figure 9 shows a west-east section (WE_11), including the quarries at Swanscombe. The proximity of the potentiometric surface to the base of the western quarry is clear, as is the fact that groundwater outcrops in the base of the eastern quarry.

Figure 10 shows the modelled potentiometric surfaces for February 1995 and October 1997, and illustrates the minimal variation between the two surfaces.

Figure 11 illustrates the potentiometric surface displayed in the 3D view together with the cross-sections. The relationships between the ground surface, potentiometric surface, and the geological formations can be examined in this way.

Figure 12 shows the geology map at the potentiometric surface for Area 1. This shows how the surface is within the Chalk in the south of the area, but moves into younger formations to the north, as the geological structure dips to the north, bringing the younger formations closer to the surface, and confining the Chalk at depth.

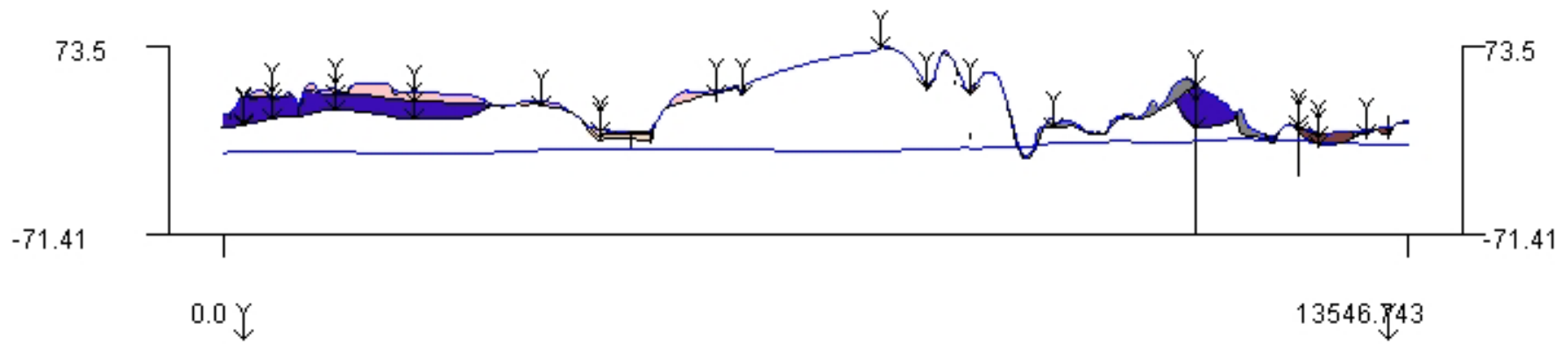


Figure 9 Section WE11 through quarries

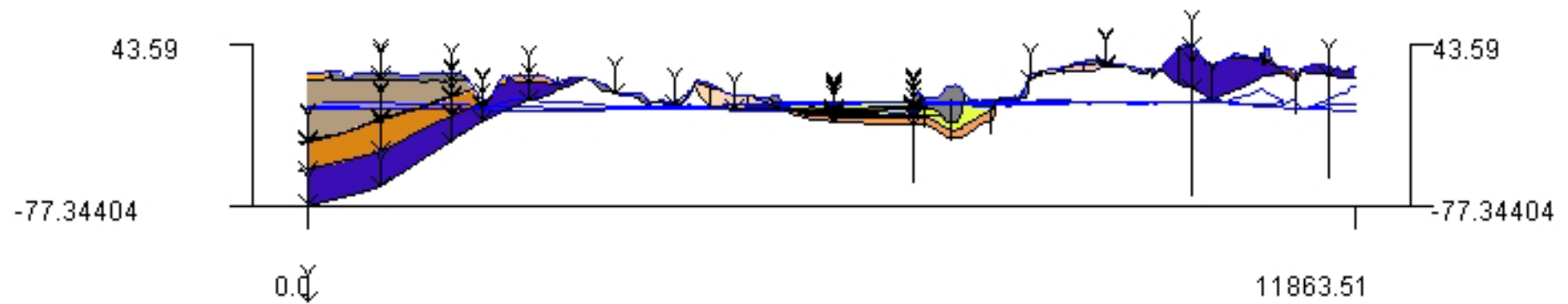


Figure 10 Section NS15

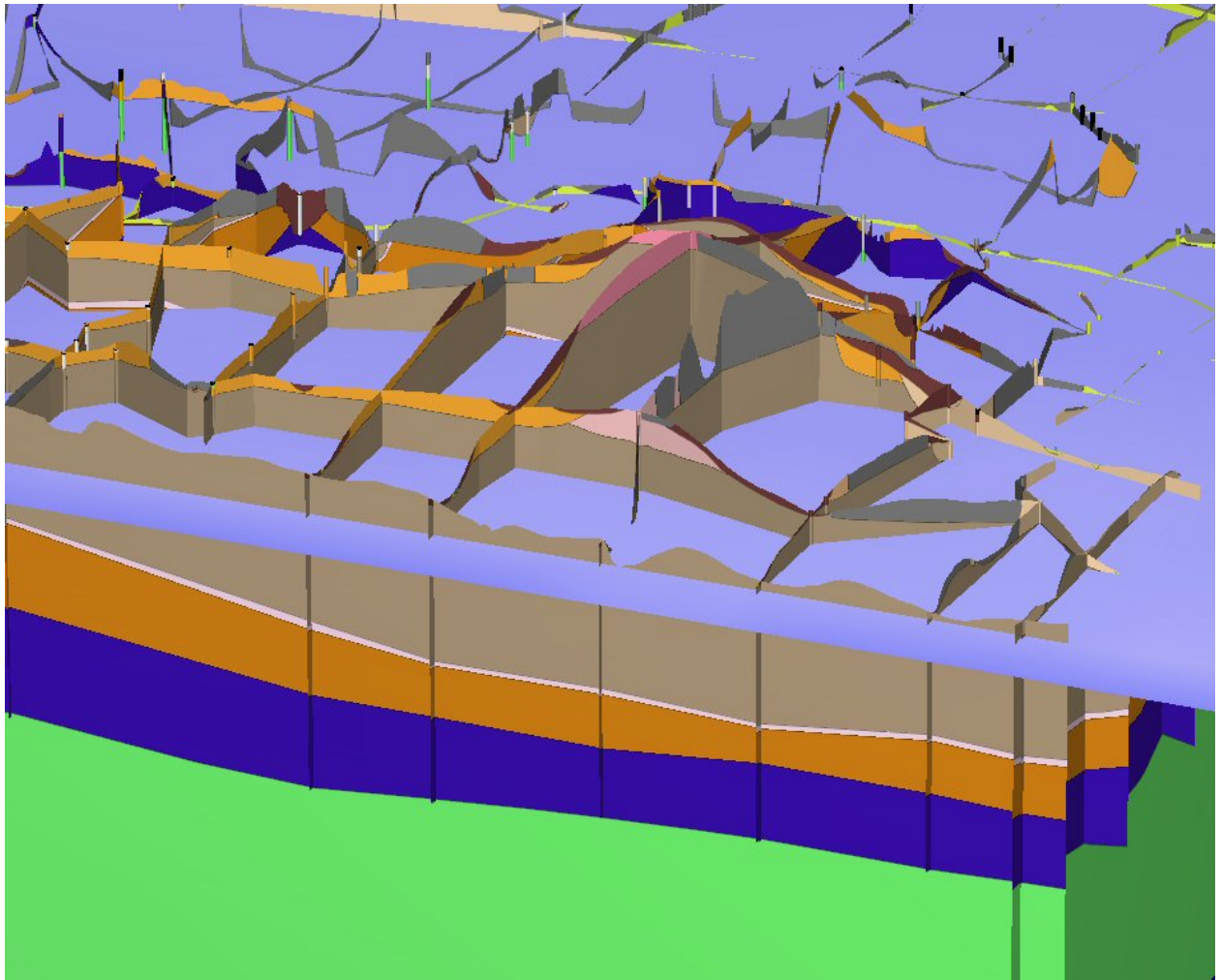


Figure 11 Intersection of the water table with geology

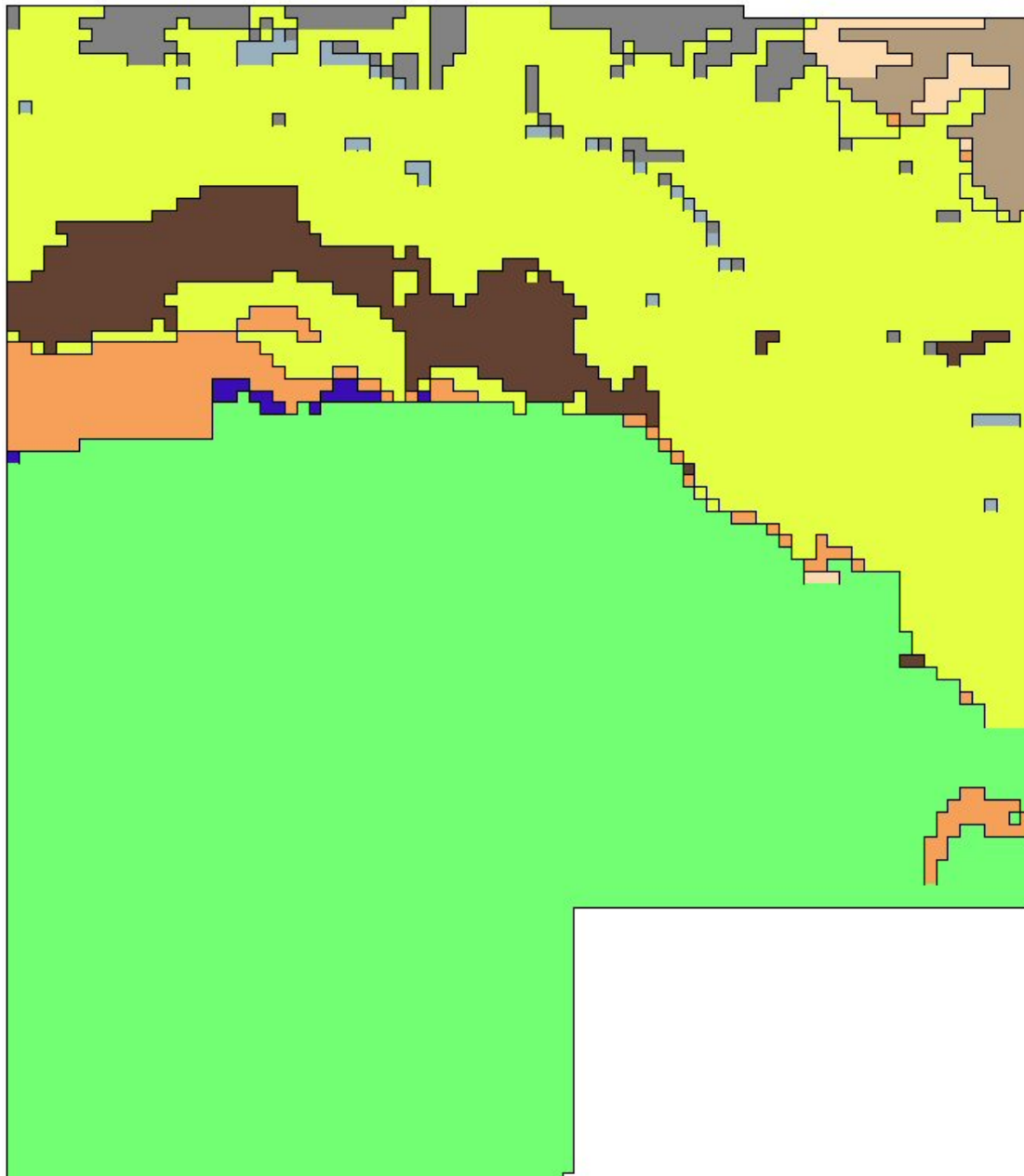


Figure 12 Construction of the geology at the potentiometric surface map using GSI3D and ArcMap

4 Incorporation of hydrogeologically related borehole data

4.1 AQUIFER PROPERTIES DATA

It was envisaged that it would be possible to visualise down-hole variations in hydraulic properties using GSI3D, however, as described in Section 2.1, there were very few permeability data points, and no porosity data, in the Aquifer Properties database within the pilot study area. Consequently, this task could not be carried out. Transmissivity and storage coefficients were available for some boreholes in the area, and can be displayed in 2D in a GIS. However, similarly to the karst data, these data cannot be meaningfully represented in 3D.

4.2 WATER LEVEL DATA

In addition to incorporating groundwater level surfaces into the model, GSI3D has been used to store and visualise point groundwater level data at boreholes.

4.2.1 Datasets

Figure 13 shows the boreholes for which groundwater levels have recorded. Whilst there appears to be a relatively large number of boreholes, at many of them only a few water levels have been recorded. If only post-1980 groundwater levels are considered, the number of boreholes with water level records reduces to 58: 10 from the BGS WellMaster database, 47 from the BGS Swanscombe project (Jackson et al., 2003) and one newly obtained record from the Environment Agency (Bush Farm Pit borehole) (see Figure 13). Groundwater levels in the London Basin have been rising since the 1960s because of reduced groundwater abstraction and this complicates the interpretation of the water level data. For this reason only water levels recorded after 1980 have been incorporated into the model. The groundwater level data after this time has been processed to extract the minimum and maximum levels. It is these that are added to the model for visualisation.

4.2.2 Methodology

For most of the 58 boreholes a minimum and maximum water level could be obtained. The levels were converted to metres below ground level from m AOD, using the project DTM, derived from NextMap. Further data manipulation was required to change the data into a format that could be loaded into GSI3D. New BID and BLG files were created to display the water level data; in addition the GLEG file was edited to include groundwater attributes. Extracts from these files are shown in Tables 4 to 6. To load the water borehole data into GSI3D alongside the geology data the Wls.bid and Wls.blg files were loaded together with the DEM. Examples of the presentation of the groundwater level data as “borehole sticks” are shown in Figure 14. This method of visualisation provides a clear indication of the position of the water table when plotted in conjunction with geology cross-sections or fence diagrams.

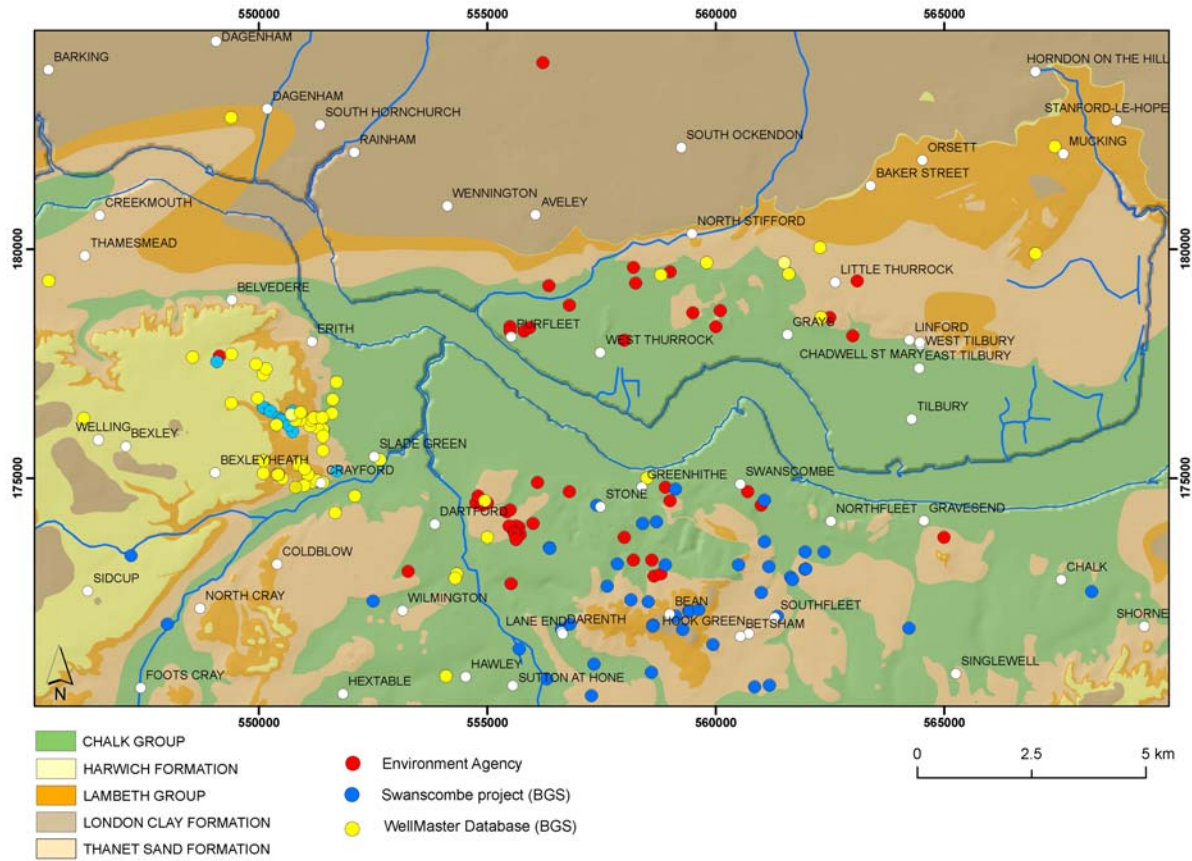


Figure 13 Spatial coverage of water data used

Table 4 Water levels bid file (Wls.bid)

| | | | |
|----------|--------|--------|-------|
| TQ47/102 | 545400 | 179300 | 2.11 |
| TQ48/63B | 549390 | 182880 | 1.23 |
| TQ57/10 | 556360 | 173470 | 47.98 |
| TQ57/118 | 558800 | 179430 | 21.5 |
| TQ57/12B | 554100 | 170660 | 24.92 |
| TQ57/61E | 554330 | 172900 | 8.1 |

Table 5 Water levels blg file (Wls.blg)

| | | | |
|----------|--------|--|------------------------------|
| TQ47/102 | 0.35 | MaxRWL | (18 Oct 1995) |
| TQ47/102 | 2.109 | MinRWL | |
| TQ47/102 | 30 | Saturated (Base of BH) | |
| TQ48/63B | 2.721 | MaxRWL | (13 Mar 1980) |
| TQ48/63B | 2.991 | MinRWL | (15 Aug 1980) |
| TQ48/63B | 143.6 | Saturated (Base of BH) | |
| TQ57/10 | 43.11 | MaxRWL | (24 Jan 1980 & 19 Feb 1980)r |
| TQ57/10 | 43.54 | MinRWL | (26 Sep 1980)r |
| TQ57/10 | 155.5 | Saturated (Base of BH) | |
| TQ57/118 | 22.24 | MaxRWL | (31 May 1981)r |
| TQ57/118 | 24.09 | MinRWL | (10 May 1980)r |
| TQ57/118 | 60 | Saturated (Base of BH) | |
| TQ57/12B | 10.125 | MaxRWL | (26 Sep 1980 & 24/01/1980) |
| TQ57/12B | 10.995 | MinRWL | (26 Sep 1980)r |
| TQ57/12B | 13.1 | Saturated (Base of BH) | |
| TQ57/61E | 3.1 | MaxRWL | (17 Dec 1990)r |
| TQ57/61E | 60 | MinRWL | |
| TQ57/61E | 60 | Saturated (Base of BH, unknown MinRWL) | |

Table 6 Water levels ThamesG_v5_0.gleg file

| | | | | | | |
|-------------------------------|-------------------------------|------------|------------|------------|------------|---------------------------|
| ALV | DESCRIPTION | 229 | 255 | 67 | 255 | TEXTURES/cz.jpg |
| BHT | DESCRIPTION | 254 | 200 | 200 | 255 | TEXTURES/vs.jpg |
| BPGR | DESCRIPTION | 254 | 146 | 174 | 255 | TEXTURES/vs.jpg |
| Saturated (Base of BH) | Saturated (Base of BH) | 1 | 139 | 255 | 255 | textures/black.jpg |
| MaxRWL | MaxRWL | 255 | 255 | 255 | 255 | textures/black.jpg |
| MinRWL | MinRWL | 1 | 216 | 255 | 255 | textures/black.jpg |

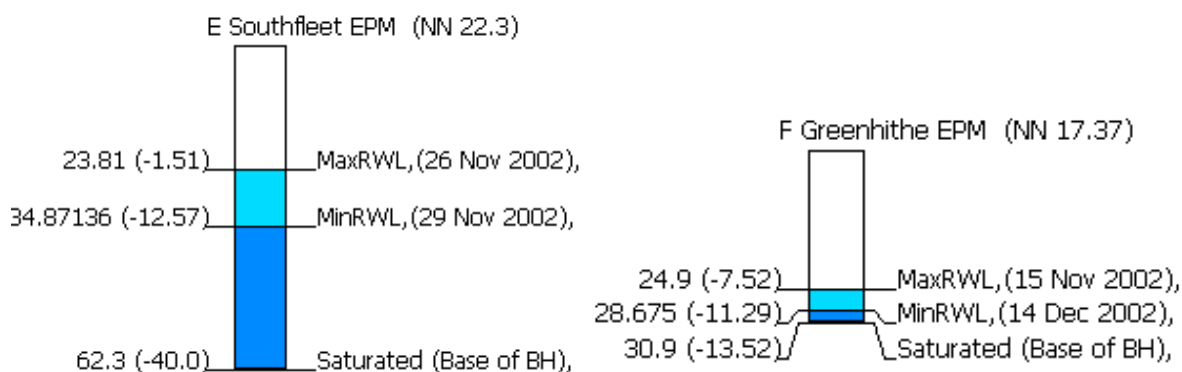


Figure 14 Rest water level borehole logs

4.2.3 Resulting model

To examine the hydrogeology in the area the water level data were viewed within the geological model. The data were loaded as a single section (through the Add Object menu: Load single section) along with the project cross sections for Area 1. Once in the cross section window all these layers were linked to the 3D window and viewed as in Figure 15.

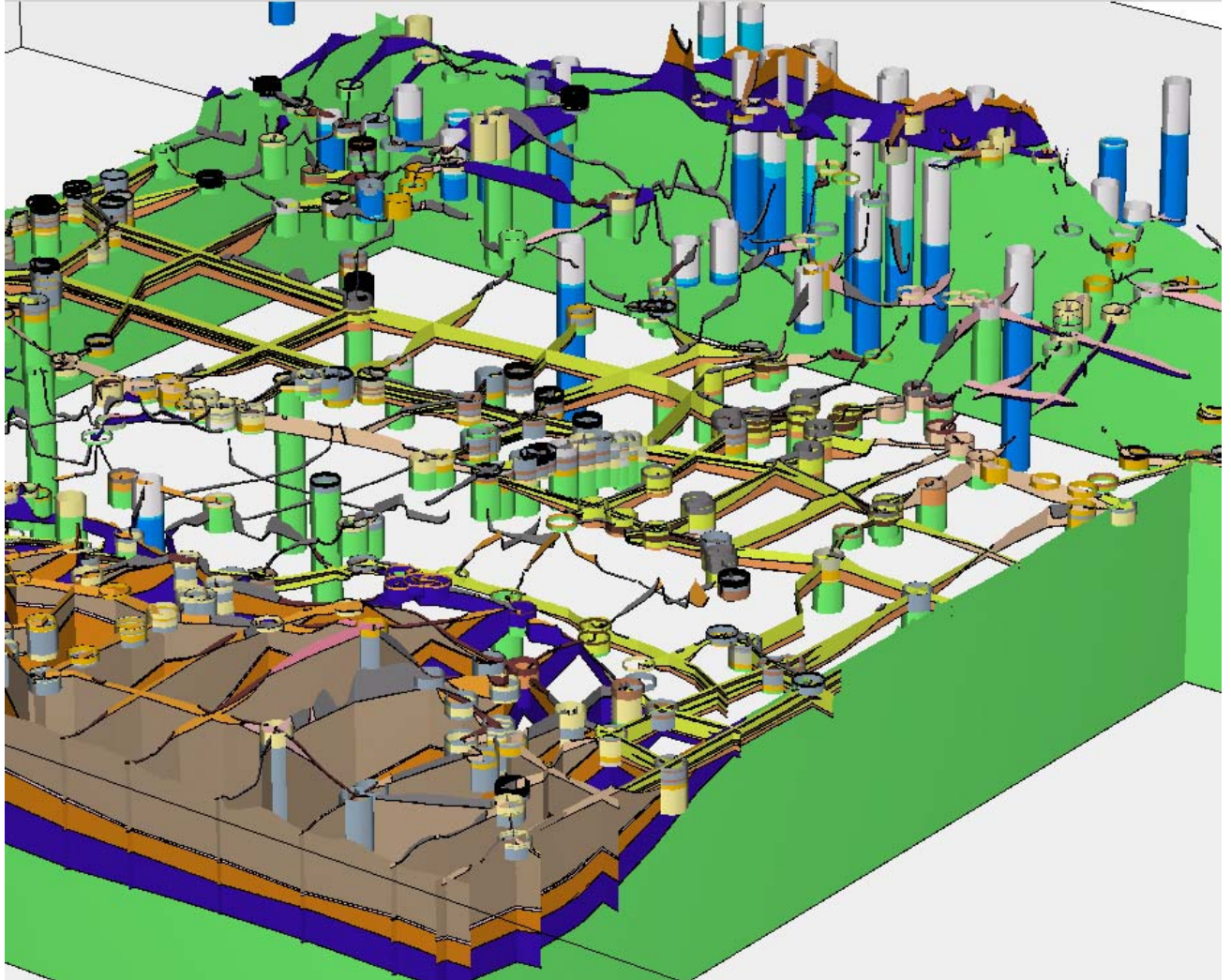


Figure 15 Resulting 3D model of the rest water level data combined with modelled geology

4.3 BOREHOLE GEOPHYSICAL DATA

The only way that down-hole information can be displayed within GSI3D is as numerical down-hole information. This means that rather than displaying a wireline down-hole log, the data must be classified into pre-determined classes, and displayed as colour-coded intervals. After extensive discussion it was decided that many geophysical logs would lose too much detail in this classification process to retain any meaningful information. As a result, only temperature and conductivity logs were extracted from Recall for use in the model.

If there are lithological and geophysical data for the same borehole, these can be displayed alongside each other (this was not the case for the data collated for this project). In addition, if the boreholes with geophysical data were used in the construction of the sections, then the geophysical data could be displayed as logs in the sections. Obviously, the ability to display the lithological and stratigraphic data alongside the geophysical logs would enhance the understanding of the logs: for example, temperature increases may be observed as water inflows along lithological boundaries. A temperature change in the log could also identify an inflow horizon not associated with lithological changes, for example along a fractured horizon in the Chalk. Thus, although the general approach is detailed here, as there were no boreholes with both lithostratigraphic and geophysical logs, the geophysical data in this area do not aid in our understanding of the geology.

4.3.1 Datasets

Data were available from various BGS sources, originally held within the UK Wellog database. These data have recently been migrated to Recall, and can now be interrogated and downloaded on-line. Data were extracted for the grid squares as shown in Table 7.

Table 7 Summary of temperature and conductivity logs available for the Project area

| Grid square | No. temperature logs | No. conductivity logs |
|-------------|----------------------|-----------------------|
| TQ47 | 4 | 3 |
| TQ48 | 1 | No logs |
| TQ57 | 11* | No logs |
| TQ58 | No logs | No logs |
| TQ67 | No logs | No logs |
| TQ68 | No logs | No logs |

N.B. Many logs were available for one site (TQ57SW83 – TQ57SW90: Wilmington). Only data for the deeper logs were extracted.

4.3.2 Methodology

As previously described, geophysical log data were collected and collated within the UK Wellog database, and were accessed through Recall, and extracted into *.las files. This gives the logs as values every 10cm. In order to display the data in GSI3D, it was desirable to pre-process the data into classes. (If this pre-processing is not carried out, the 10cm intervals are each separated by a black line, and no data can be observed except when zoomed in to a high degree). In order to classify the data, an executable file was developed that took the *.las files,

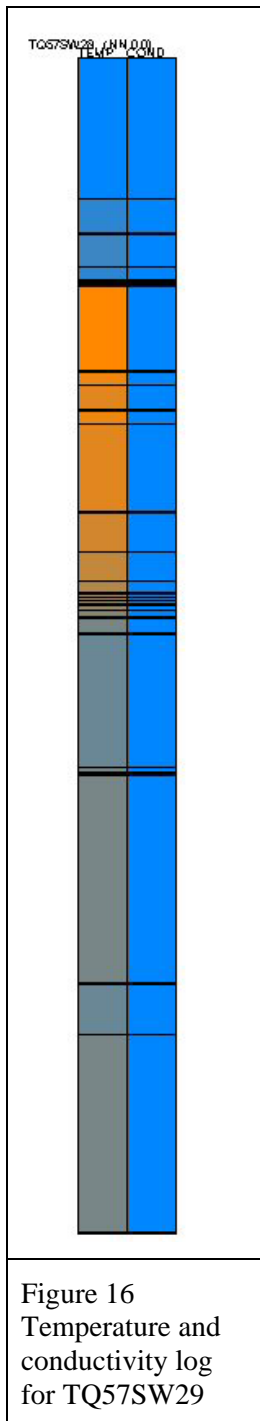
removed the header information, and reclassified the data according to the classes shown in Table 8 and Table 9.

Table 8 Conductivity ($\mu\text{S cm}^{-1}$) classification for display in GSI3D

| Class | Conductivity from | Conductivity to |
|-------|-------------------|-----------------|
| 0 | -999 | -999 |
| 1 | 300.0 | 400.0 |
| 2 | 400.0 | 500.0 |
| 3 | 500.0 | 600.0 |
| 4 | 600.0 | 700.0 |
| 5 | 700.0 | 800.0 |
| 6 | 800.0 | 900.0 |
| 7 | 900.0 | 1000.0 |
| 8 | 1000.0 | 1100.0 |
| 9 | 1100.0 | 1200.0 |
| 10 | 1200.0 | 1300.0 |
| 11 | 1300.0 | 1400.0 |
| 12 | 1400.0 | 1500.0 |
| 13 | 1500.0 | 1600.0 |
| 14 | 1600.0 | 30000 |

Table 9 Temperature ($^{\circ}\text{C}$) classification for display in GSI3D

| Class | Temperature from | Temperature to |
|-------|------------------|----------------|
| 0 | -999 | -999 |
| 1 | 10.7 | 10.8 |
| 2 | 10.8 | 10.9 |
| 3 | 10.9 | 11.0 |
| 4 | 11.0 | 11.1 |
| 5 | 11.1 | 11.2 |
| 6 | 11.2 | 11.3 |
| 7 | 11.3 | 11.4 |
| 8 | 11.4 | 11.5 |
| 9 | 11.5 | 11.6 |
| 10 | 11.6 | 11.7 |
| 11 | 11.7 | 11.8 |
| 12 | 11.8 | 11.9 |
| 13 | 11.9 | 12.0 |
| 14 | 12.0 | 12.1 |
| 15 | 12.1 | 12.2 |
| 16 | 12.2 | 12.3 |
| 17 | 12.3 | 30 |



The output from the executable then becomes the parameter log (*.plg) file. The other file that is required is the numerical value legend file (*.nvleg) giving the parameters for the upper and lower threshold values, and the respective colour coding. In this case, the parameters had already been set through the executable file, and these classes were then entered in the *.nvleg together with the colour coding.

It was found to be useful to also create a *.bid file with only the geophysical boreholes in it. This enables the user to see the spatial extent of the geophysical data, and to select the appropriate boreholes to display in the borehole viewer.

Once the nvleg and plg files are set up, the point data can be added through the Add Objects menu: Load point data (*.xml). After adding the point data, the *.nvleg also needs to be added through the Add Objects menu. To make the points visible on the map, under the same Menu, select "Show geochemical sample map". Once the boreholes are visible in the 2D view, they can be displayed in the Borehole Viewer, by using the Identify tool and clicking on a borehole. The loaded numerical down-hole parameters can then be displayed together with lithological and stratigraphical logs. To display the data, right click within the window to open up the Properties dialogue. The parameter name given in the *.plg (for the downhole data), or the column number of the field required in the *.blg (for lithostratigraphic data) should be entered in the appropriate field in the *Drill-log layout setting box* of the borehole viewer. Up to four parameters can be viewed alongside each other. The numerical data appear according to the *.nvleg colour scheme and in the intervals defined in the *.plg file.

4.3.3 Resulting model

As there were no boreholes with both geophysical and lithostratigraphic data, it not possible to demonstrate the full potential of this approach. A log showing temperature and conductivity variation with depth for borehole TQ57SW29 is shown in Figure 16.

5 Incorporation of groundwater flow model output

The construction of a “good” groundwater model depends on the development of a sound *conceptual model* of the hydrogeology system under consideration. A *conceptual flow model* incorporates a description of the inputs to, flow processes within, and outputs from, an aquifer, both in qualitative and quantitative terms. The starting point for any hydrogeological conceptual model, however, is a description of the geology. In general a better description of the geology will lead to a better hydrogeological conceptual model.

Historically groundwater modellers have either not had access to geological modelling packages, or been unable to use them routinely because of constraints on time. Consequently, many groundwater models have been developed and their output interpreted using limited geological information. The use of GSI3D enables this situation to be improved. In this section the use of GSI3D for the visualisation and interpretation of the results of a groundwater flow model is presented. This is based on the existing “Swanscombe groundwater model” developed by BGS (Jackson et al., 2003) for Thames Water Utilities Ltd (TWUL). The use of GSI3D during the development of a numerical groundwater model, will produce tangible benefits, however, these are not discussed further here.

The Swanscombe regional groundwater flow model was developed by BGS for TWUL between 2001 and 2004. This model was developed to investigate groundwater flow processes in the Chalk aquifer predominantly but also represents areas of thicker Palaeogene cover to the west of the River Cray. The area of the groundwater flow model, which encloses the Thames Gateway pilot study area, is shown in Figure 17.

The model simulates groundwater flow in the Chalk and Palaeogene for the period from January 1970 to December 2003 and can produce groundwater head data in x, y, z format for user-specified dates. To demonstrate the incorporation of simulated groundwater levels into GSI3D, two sets of data were transferred from the numerical flow model to the geological model of the Thames Gateway pilot study area. The following subsections describe this process.

5.1 DATA SETS AND METHODOLOGY

The Swanscombe groundwater flow model was developed using BGS’s numerical code ZOOMQ3D (Jackson & Spink, 2004). Similarly to other groundwater flow modelling packages (e.g. MODFLOW), this code produces groundwater level data in a number of formats during a simulation. In ZOOMQ3D one of these is an ASCII tab-delimited x, y, z format and the user can specify the time for which groundwater level data is written to a set of files named “contour_dd-mm-yyyy.txt”, where dd, mm and yyyy represent the day, month and year during the flow simulation. Multiple files can be produced containing groundwater head data for different times dates.

In this exercise the Swanscombe model was re-run and two dates selected for which groundwater head data was output. These dates are the end of October 1997 and the end of February 1995, and represent low and high groundwater level conditions, respectively (see Figure 18). Consequently, the ZOOMQ3D model simulation generated the two tab-delimited text files “contour_28-02-1995.txt” and “contour_31-10-1997.txt” containing groundwater head data (m aOD) in x, y, z format. These files were then converted to gridded data sets in ArcGIS ASCII grid format. This was done programmatically (e.g. by using VBA within Excel) but could be achieved using a number of different methods. The resulting files, “Feb95.asc” and “Oct97.asc” were then imported into GSI3D.

In Figure 19 and Figure 20 the simulated groundwater level surfaces for February 1995 and October 1997 are visualised in conjunction with the DTM. These plots indicate clearly the relationship of the groundwater surface with the water table, for example, corresponding to the various marshes along the banks of the River Thames. The intersection of the water table with Eastern Quarry, a large chalk quarry to the south of the Thames is also clearly visible.

In Figure 21 and Figure 22 the two simulated groundwater level surfaces are visualised in conjunction with the fence diagram. Such plots help to understand the relationship between the water-table and the base of the Palaeogene, which is often of interest as there may be enhanced dissolution of the Chalk near this contact.

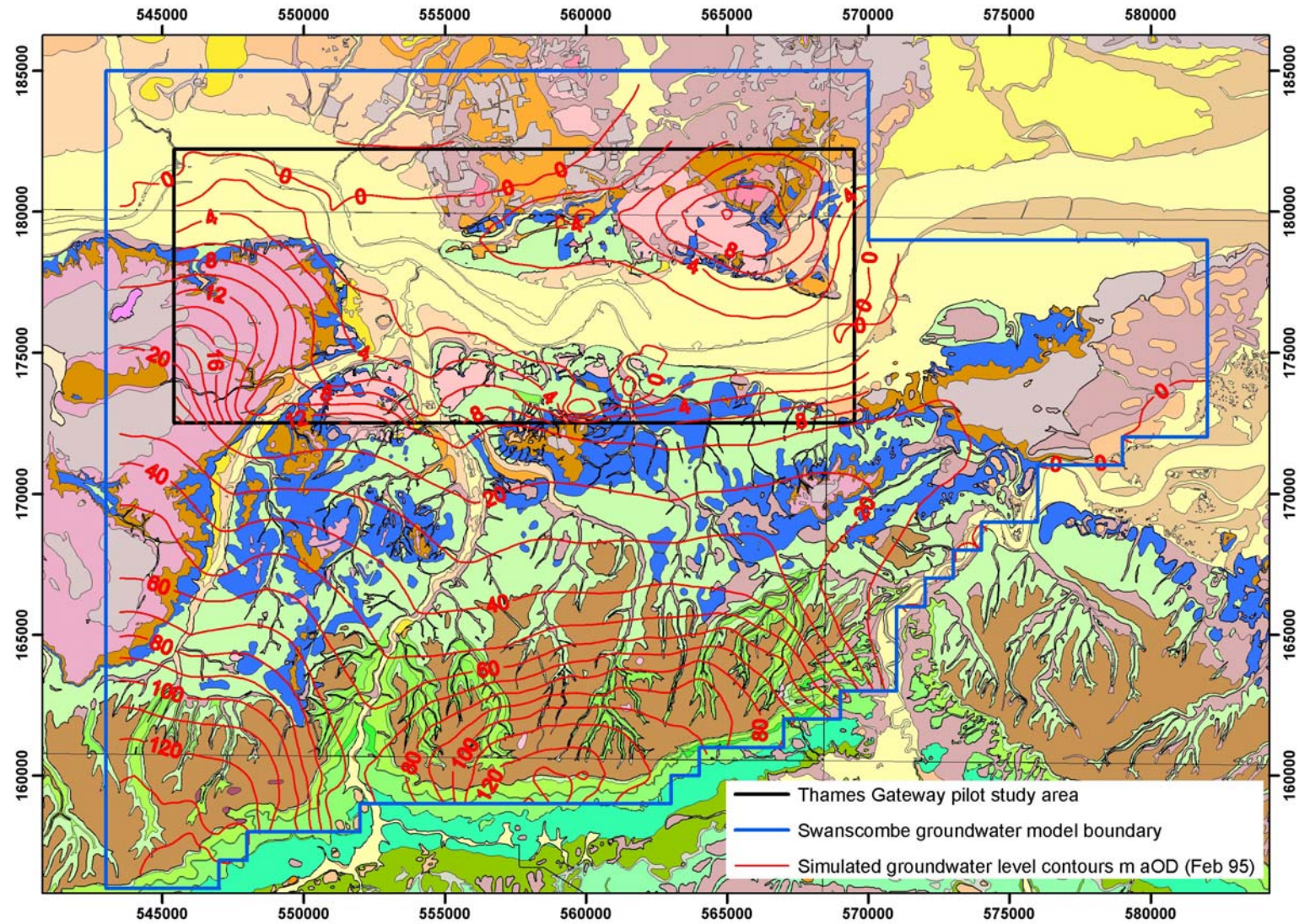


Figure 17 Boundary of the Swanscombe groundwater model and the Thames Gateway pilot study area. Simulated groundwater level contours are shown in red for February 1995

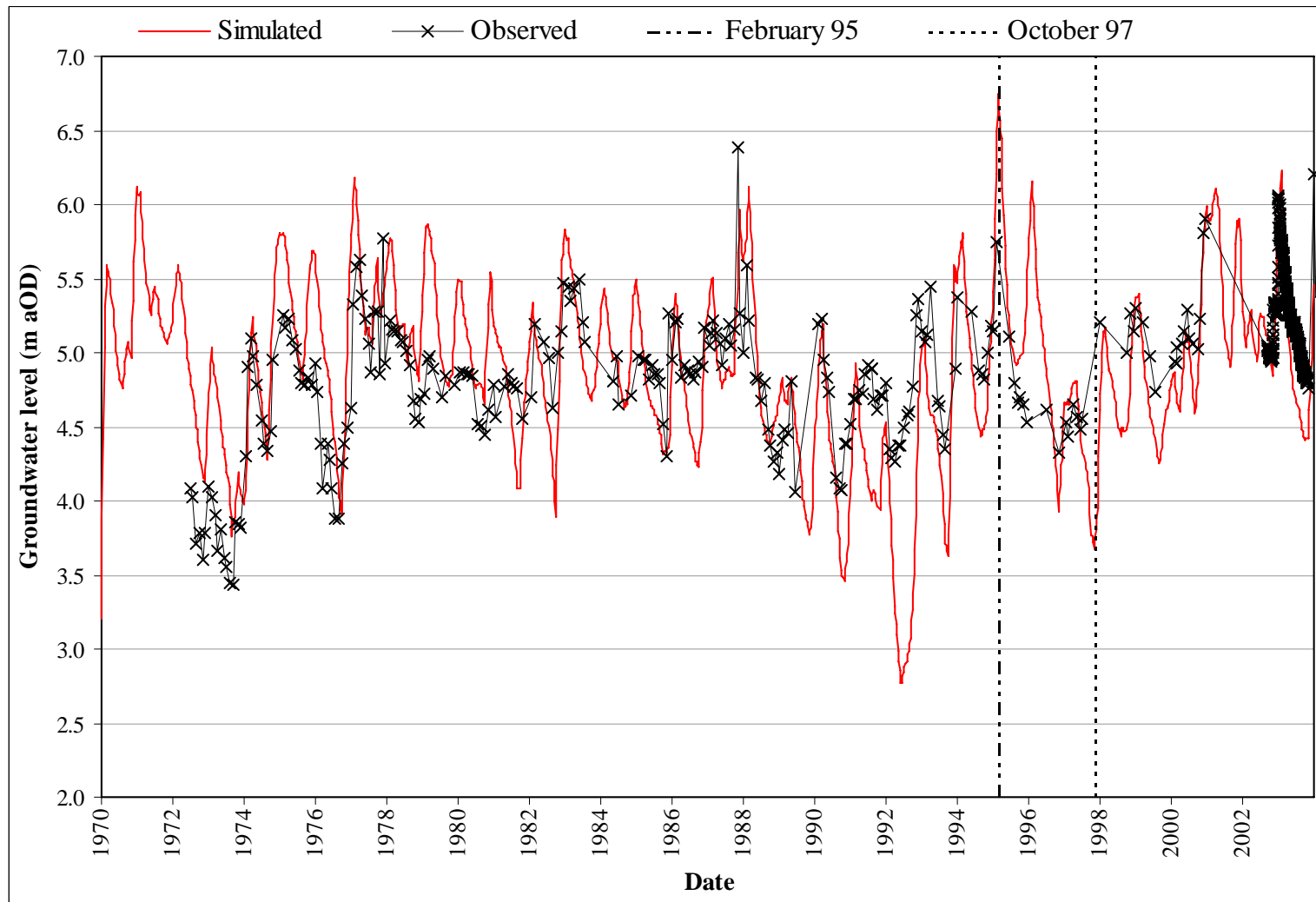


Figure 18 Simulated and observed groundwater levels for an observation borehole close to the southern boundary of the pilot study area. Groundwater level conditions for February 1995 (wet) and October 1997 (dry), which were chosen for inclusion in GSI3D, are highlighted

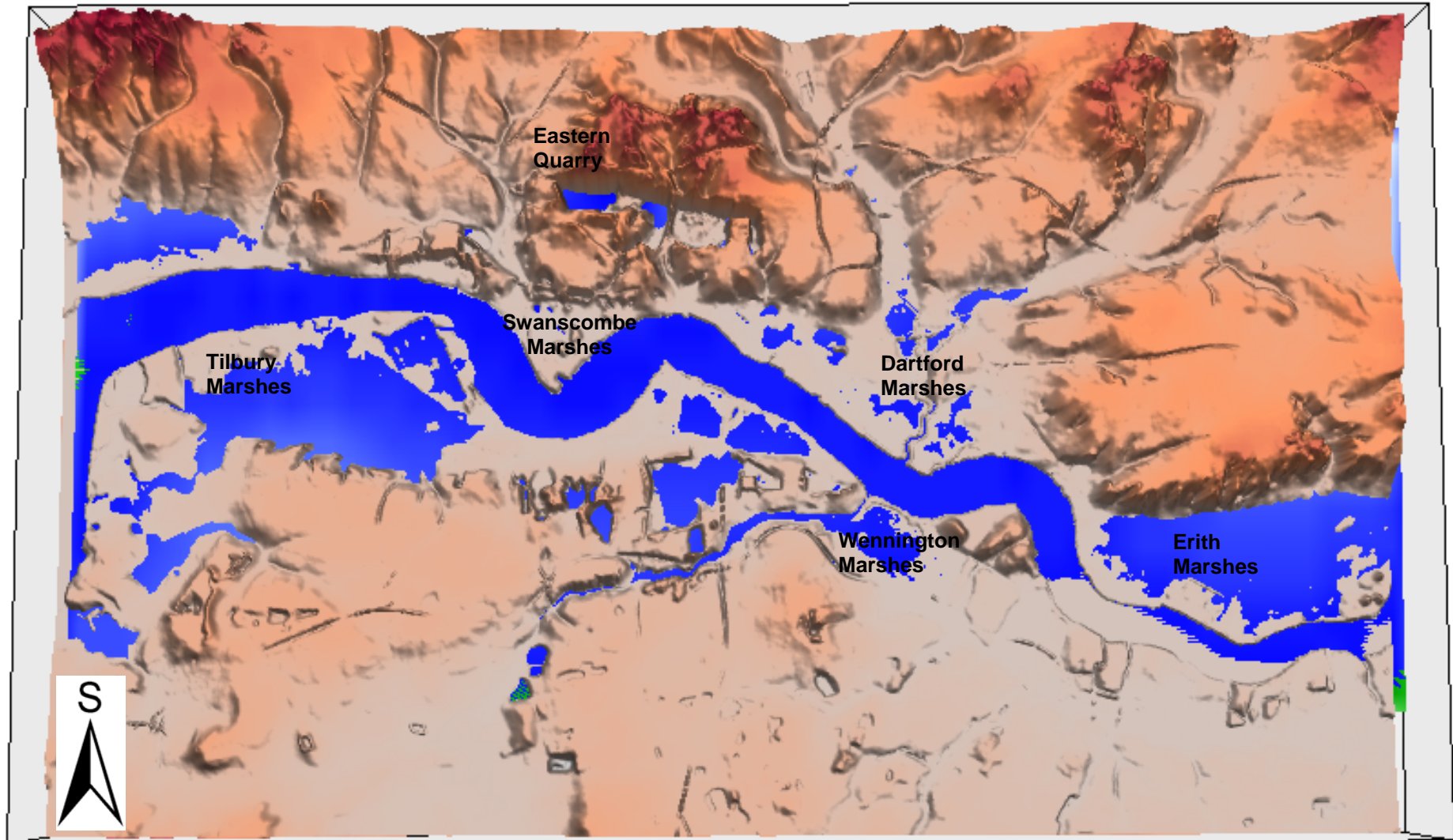


Figure 19 Intersection of simulated groundwater table for February 1995 (blue) with DTM within Thames Gateway pilot study area

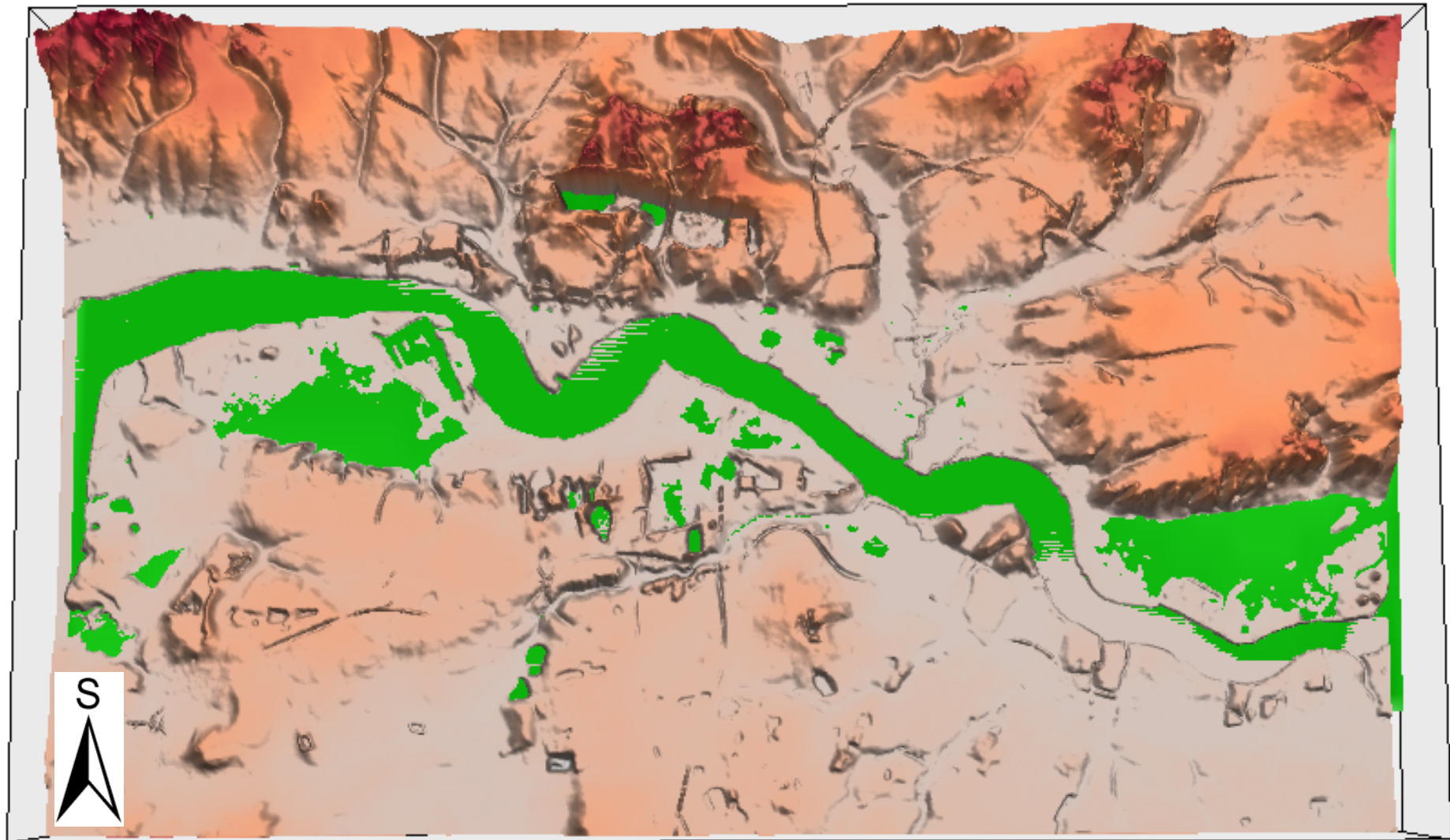


Figure 20 Intersection of simulated groundwater table (green) for October 1997 with DTM within Thames Gateway pilot study area

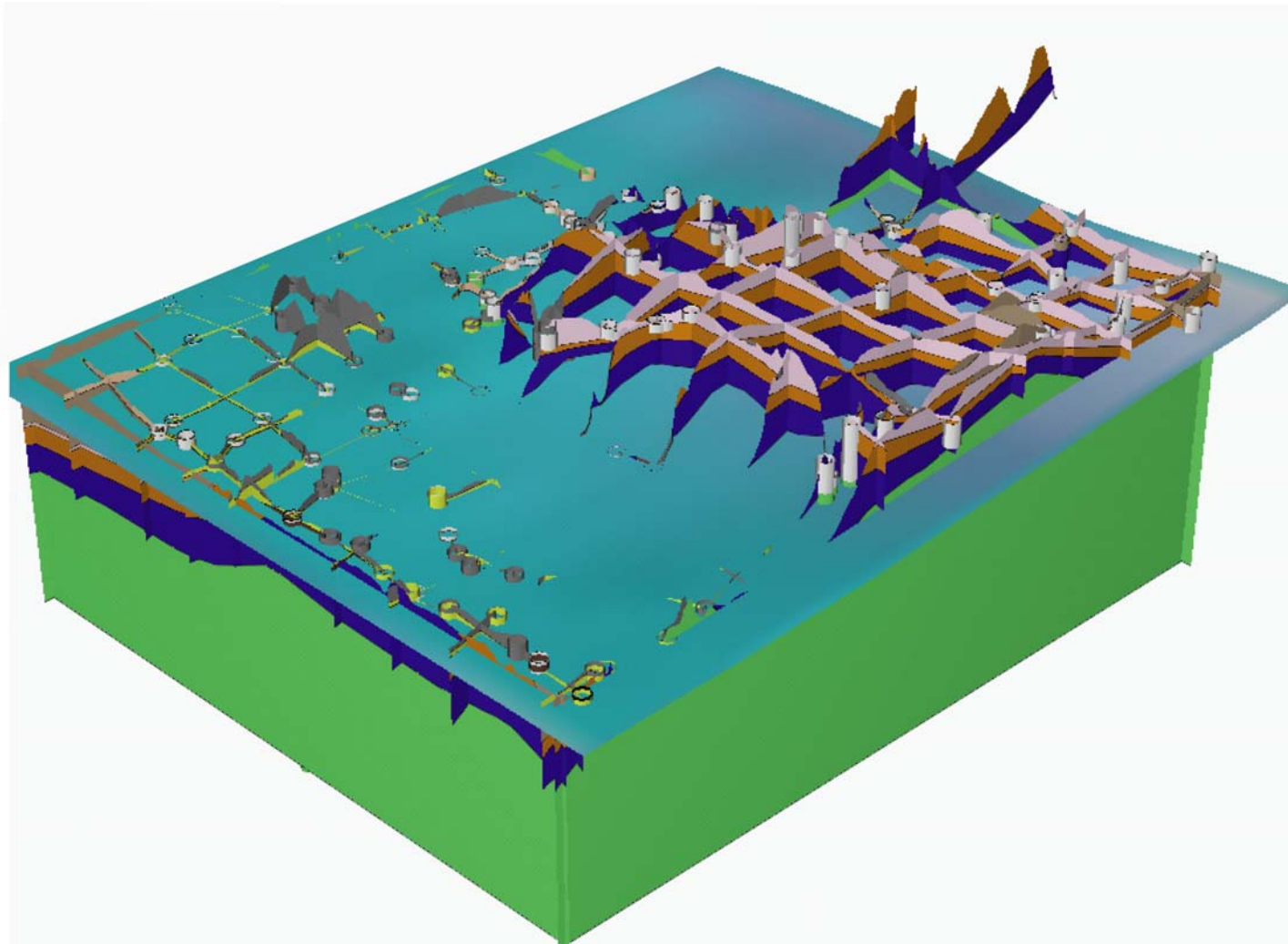


Figure 21 3D GSI3D image showing position of simulated water table for February 1995 in relation to geological sections (fence diagram)

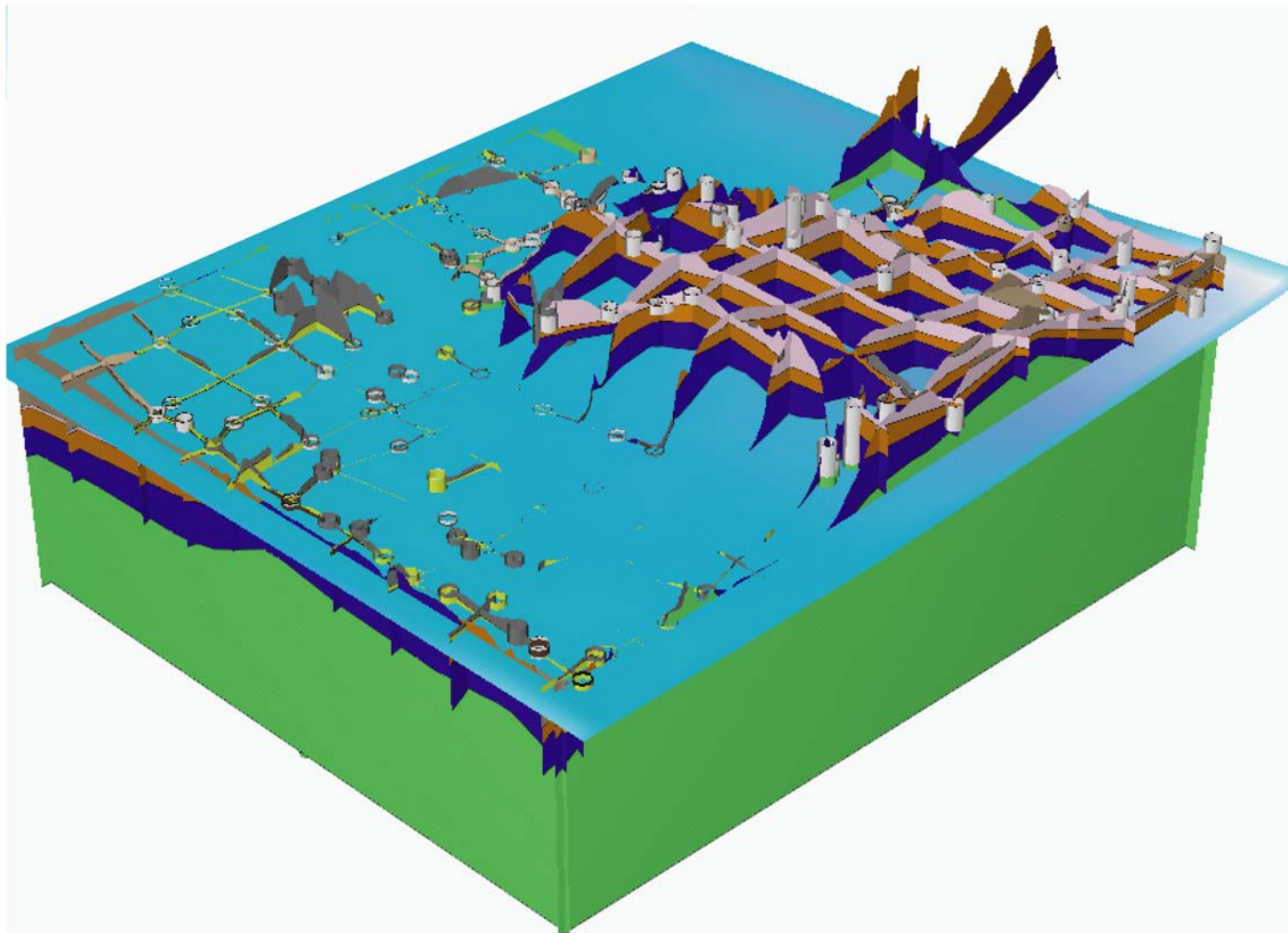


Figure 22 3D GSI3D image showing position of simulated water table for October 1997 in relation to geological sections (fence diagram)

6 Concluding remarks

This project has been a proof of concept as to the ways in which GSI3D can be used to enhance hydrogeological understanding of an area. For this purpose, Area 1 of the Thames Gateway pilot study area has been used in the main, though data searches have been carried out for the whole Thames Gateway area.

The project has shown that GSI3D is a useful tool for:

- Displaying hydrogeological attributes if these can easily be mapped to the lithostratigraphic properties.
- Displaying intersection of the water table/potentiometric surface with lithostratigraphic formations and/or the DTM.

In this study it has been shown that it is possible to incorporate a wide variety of hydrogeological information into GSI3D quickly and this has led to an improved understanding of groundwater system and the development of a better conceptual hydrogeological model. The following hydrogeological information has been incorporated in the Thames Gateway GSI3D model:

- Aquifer type classification (aquifer, non-aquifer).
- Permeability type classification (fractured, mixed or intergranular flow).
- Permeability classification (very high, high, moderate, low or very low permeability).
- Existing groundwater surfaces from groundwater contours maps.
- Geophysical and aquifer properties data.

It has not been possible to incorporate the following information into the GSI3D model because of the paucity of data within the study area.

- Karstic potential.
- New groundwater level surfaces generated using borehole data (e.g. from BGS's WellMaster database).
- Aquifer properties data from borehole core.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

ELLISON, R. (2004). Geology of London - special memoir for 1:50,000 geological sheets 256 North London), 257 (Romford), 270 South London) and 271 (Dartford) (England and Wales)

ENVIRONMENT AGENCY. (1990). Rising groundwater levels in the Chalk-basal sands aquifer of the Central London basin – 1990. Unpublished report.

ENVIRONMENT AGENCY. (2004). Rising groundwater levels in the Chalk-basal sands aquifer of the Central London basin – May 2004. Unpublished report.

JACKSON CR, HUGHES AG, BLOOMFIELD JP AND RUTTER HK. 2003. Numerical modelling of groundwater flow in the Darent catchment and Swanscombe area Chalk aquifer. British Geological Survey Commissioned Report, CR/03/183C.

JACKSON C.R. AND SPINK A.E.F. 2004. User's manual for the groundwater flow model ZOOMQ3D. British Geological Survey Internal Report, IR/04/140.

LEWIS, M. CHENEY, C. AND Ó DOCHARTAIGH. (In press). The National Assessment of permeability indices. British Geological Survey Report.

ROYSE KR, PRICE S, ENTWHISTLE D, LELLIOT M AND TERRINGTON R. 2005. Thames Gateway Pilot Study Results: Is there a need for Urban Geoscience in the Gateway? British Geological Survey Internal Report, IR/05/063.

WATER RESOURCES BOARD. (1972). The hydrogeology of the London Basin. Unpublished report.

Appendix 1 Metadata catalogue

| | |
|---|-----------------------------------|
| Title | |
| Thames Gateway borehole groundwater levels | |
| Summary | |
| Groundwater level time-series for boreholes in Table 1. | |
| Data centre | |
| BGS Wallingford | |
| Project | |
| E2113S83 – Thames Gateway Super Project (Hydrogeology task) | |
| Availability | |
| Through BGS WellMaster database | |
| Thematic programme | |
| Groundwater Management | |
| Internal contact | |
| Andrew Mckenzie | |
| Originator | |
| Chris Jackson | |
| Coordinate reference system | |
| British National Grid | |
| West bounding co-ordinate | East bounding co-ordinate |
| 545000 | 570000 |
| South bounding co-ordinate | North bounding co-ordinate |
| 170000 | 185000 |
| Data quality | |
| Dependent on borehole record | |
| Format | |
| Access database | |

Table 10 Borehole water level records using in Thames Gateway project

| Borehole ID | EASTING | NORTHING | Originating project | Availability |
|--|---------|----------|---------------------|--------------|
| TQ47/102 | 545400 | 179300 | | WellMaster |
| TQ48/63B | 549390 | 182880 | | WellMaster |
| TQ57/10 | 556360 | 173470 | | WellMaster |
| TQ57/118 | 558800 | 179430 | | WellMaster |
| TQ57/12B | 554100 | 170660 | | WellMaster |
| TQ57/61E | 554330 | 172900 | | WellMaster |
| TQ57/61L | 554300 | 172800 | | WellMaster |
| TQ67/86 | 567000 | 179900 | | WellMaster |
| TQ68/1 | 562280 | 180030 | | WellMaster |
| TQ68/4A | 567420 | 182240 | | WellMaster |
| TQ58/2 (Bush Farm Pit) | 556220 | 184080 | | WellMaster |
| Betsham Road | 559940 | 171350 | Swanscombe | WellMaster |
| Church Lane | 568230 | 172510 | Swanscombe | WellMaster |
| Footscray Meadow | 548000 | 171800 | Swanscombe | WellMaster |
| Hurstmere School | 547200 | 173300 | Swanscombe | WellMaster |
| Northfleet East | 561960 | 173380 | Swanscombe | WellMaster |
| Old Mill Farm | 555700 | 171250 | Swanscombe | WellMaster |
| Salisbury Road | 556360 | 173470 | Swanscombe | WellMaster |
| Springhead Nurseries | 561640 | 172830 | Swanscombe | WellMaster |
| Springhead Road | 562370 | 173380 | Swanscombe | WellMaster |
| Tollgate | 564230 | 171710 | Swanscombe | WellMaster |
| Wilmington G School | 552500 | 172300 | Swanscombe | WellMaster |
| Wingfield Bank | 561960 | 173000 | Swanscombe | WellMaster |
| A Western Bean Farm | 558143 | 172333 | Swanscombe | WellMaster |
| B West Drudgeon Farm | 559124 | 171971 | Swanscombe | WellMaster |
| C Mid Drudgeon Farm | 559415 | 172079 | Swanscombe | WellMaster |
| D West Beacon Wood | 558630 | 171777 | Swanscombe | WellMaster |
| E Southfleet EPM | 561161 | 173059 | Swanscombe | WellMaster |
| F Greenhithe EPM | 558702 | 174035 | Swanscombe | WellMaster |
| 1 EA Roman Villa | 556300 | 170600 | Swanscombe | WellMaster |
| 2 EA Salisbury Road | 556370 | 173459 | Swanscombe | WellMaster |
| 3 Football Field Lower | 556624 | 171685 | Swanscombe | WellMaster |
| 4 Football Field Upper | 556810 | 171799 | Swanscombe | WellMaster |
| 5 St Margarets Farm | 557278 | 170230 | Swanscombe | WellMaster |
| 6 Green St. Green | 557340 | 170920 | Swanscombe | WellMaster |
| 7 Stone Pit Diver | 557400 | 174400 | Swanscombe | WellMaster |
| 8 EBH2 Upper West Darenth Wood | 557630 | 172630 | Swanscombe | WellMaster |
| 10 EBH1 Lower West Darenth Wood | 557850 | 173120 | Swanscombe | WellMaster |
| 11 Stone Castle | 558400 | 174000 | Swanscombe | WellMaster |
| 12 SEW Bean Farm | 558522 | 172287 | Swanscombe | WellMaster |
| 13 The Ship Inn | 558597 | 170739 | Swanscombe | WellMaster |
| 14 Old Bean | 558620 | 171750 | Swanscombe | WellMaster |
| 15 Washmills Fissure | 558900 | 173100 | Swanscombe | WellMaster |
| 16 Knockhall School | 559120 | 174755 | Swanscombe | WellMaster |
| 17 EBH6 Eastern Beacon Wood Country Park | 559280 | 171680 | Swanscombe | WellMaster |
| 18 EBH7 Middle Drudgeon Farm | 559425 | 172080 | Swanscombe | WellMaster |
| 19 EBH8 Eastern Drudgeon Farm | 559630 | 172120 | Swanscombe | WellMaster |
| 21 Betsham | 559940 | 171350 | Swanscombe | WellMaster |
| 22 DD17 | 560500 | 173100 | Swanscombe | WellMaster |
| 23 Hook Green Farm | 560855 | 170423 | Swanscombe | WellMaster |
| 24 TWUL Southfleet | 561000 | 172490 | Swanscombe | WellMaster |
| 25 Northfleet Landfill NE004 | 561065 | 173601 | Swanscombe | WellMaster |
| 26 Northfleet Landfill NF007 | 561068 | 174512 | Swanscombe | WellMaster |
| 27 Hook Place Farm | 561178 | 170462 | Swanscombe | WellMaster |
| 28 Beslee Joyce Hall | 561350 | 171970 | Swanscombe | WellMaster |
| 29 Springhead Nurseries | 561680 | 172770 | Swanscombe | WellMaster |
| 30 Northfleet STW | 561960 | 173380 | Swanscombe | WellMaster |
| 31 Beslee Wingfield Bank | 561970 | 173010 | Swanscombe | WellMaster |

| | |
|---|-----------------------------------|
| Title | |
| Thames Gateway groundwater level contours | |
| Summary | |
| Chalk groundwater level contours | |
| Data centre | |
| BGS Wallingford | |
| Project | |
| E2113S83 – Thames Gateway Super Project (Hydrogeology task) | |
| Availability | |
| Storage on corporate server | |
| Thematic programme | |
| Groundwater Management | |
| Internal contact | |
| Chris Jackson | |
| Originator | |
| Chris Jackson | |
| Coordinate reference system | |
| British National Grid | |
| West bounding co-ordinate | East bounding co-ordinate |
| 545000 | 570000 |
| South bounding co-ordinate | North bounding co-ordinate |
| 170000 | 185000 |
| Data quality | |
| Dependent on borehole record | |
| Format | |
| GIS shapefiles | |

| | |
|--|-----------------------------------|
| Title | |
| Geophysical logs in Thames Gateway pilot study area | |
| Summary | |
| Temperature and conductivity geophysical logs | |
| Data centre | |
| BGS Keyworth | |
| Project | |
| E2113S83 – Thames Gateway Super Project (Hydrogeology task) | |
| Availability | |
| Storage on corporate server | |
| Internal contact | |
| Andrew Kingdon | |
| Originator | |
| Andrew Kingdon | |
| Coordinate reference system | |
| British National Grid | |
| West bounding co-ordinate | East bounding co-ordinate |
| 545000 | 570000 |
| South bounding co-ordinate | North bounding co-ordinate |
| 170000 | 185000 |
| Data quality | |
| Good | |
| Format | |
| Text files | |
| Borehole records used | |
| TQ47NE696, TQ47SW139, TQ47SW140, TQ47SW74, TQ48NW253, TQ57NE125 TQ57SW25, TQ57SW28, TQ57SW83, TQ57SW84, TQ62NE3 | |