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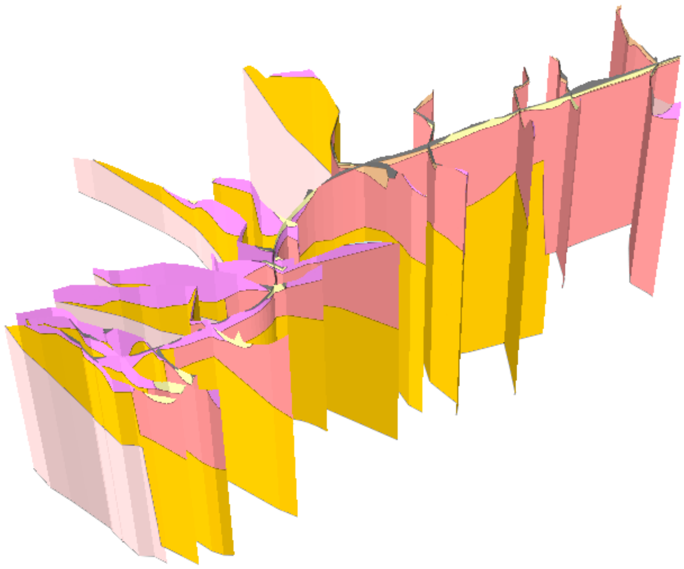
Metadata report for GSI3D cross sections along the HS2 route in Area 9 (Birmingham spur)

Geology and Regional Geophysics Programme

Open Report OR/16/034



BRITISH GEOLOGICAL SURVEY

GEOLOGY AND REGIONAL GEOPHYSICS PROGRAMME

OPEN REPORT OR/16/034

Metadata report for GSI3D cross sections along the HS2 route in Area 9 (Birmingham spur)

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Edits by H Burke & H V Gow

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Map

Sheet 168

Front cover

3D view of modelled cross-section from south

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Summary

This report describes the geological cross-sections of the HS2 (High Speed 2 rail link) Area 9 (Birmingham Spur), created by A. J. M. Barron with support from S. Thorpe. The model was created as part of a set of nine geological models that cover the proposed HS2 rail route from the end of the HS2 London model to Birmingham and the West Coast Main Line near Lichfield. The models were funded from the NERC/BGS Science Budget to promote BGS modelling and geological interpretation services to this important infrastructure project and to test methodologies and procedures for creating geological models by multiple compilers.

The report describes the model construction and purpose, with spatial limits and scale, sources of information, data processing, workflow, decisions, assumptions, rules and limitations, together with images of the model.

1 Modelled volume, purpose and scale

The Area 9 cross-section based model depicts the bedrock, natural superficial deposits and artificially modified ground geology along the western part of the HS2 Birmingham Spur of the proposed route of the High Speed Rail link between London and Birmingham. This is one of an initial group of nine models along the proposed route. These models and cross-sections are suitable for use at scales between 1:100,000 and 1:10,000 to a depth of 30 m below OD. Whereas the models for Areas 1-8 are full 3D models (with geological units represented by surfaces and volumes), the Area 9 model is represented by a network of cross-sections from which no attempt has been made to create geological surfaces.

To constrain the geology along the entire Birmingham Spur between Castle Bromwich and the Birmingham Terminus, nineteen cross-sections were constructed. For the eastern part of the Birmingham Spur, corresponding cross-sections were added to the existing Area 7 geological model. This report describes the cross-sections along the western part of the Birmingham Spur between Castle Bromwich and the Birmingham terminus (Figure 1), with the 'online section' following the proposed HS2 route. Construction of the online section was aided by the compilation of cross sections that intersect it, which enable the integration of borehole data in the vicinity and held by BGS in 2013 to inform the nature and depth/thickness of geological units.

Prior to the cross section construction an assessment of the quality and availability of digital geological linework and existing 3D models of the entire HS2 route between London and Birmingham was undertaken (Barron et al., 2012). Following this review, the geological mapping of this sector was deemed to be adequate, dating from the 1960s to the 1990s. Thus these cross sections are based on geological linework from existing 1:10,000 and 1:50,000 scale DiGMapGB data. The cross sections lie entirely within BGS 1:50,000 Sheet 168 (Birmingham), surveyed between 1978 and 1992, published in 1996 and accompanied by a memoir (Powell et al., 2000).

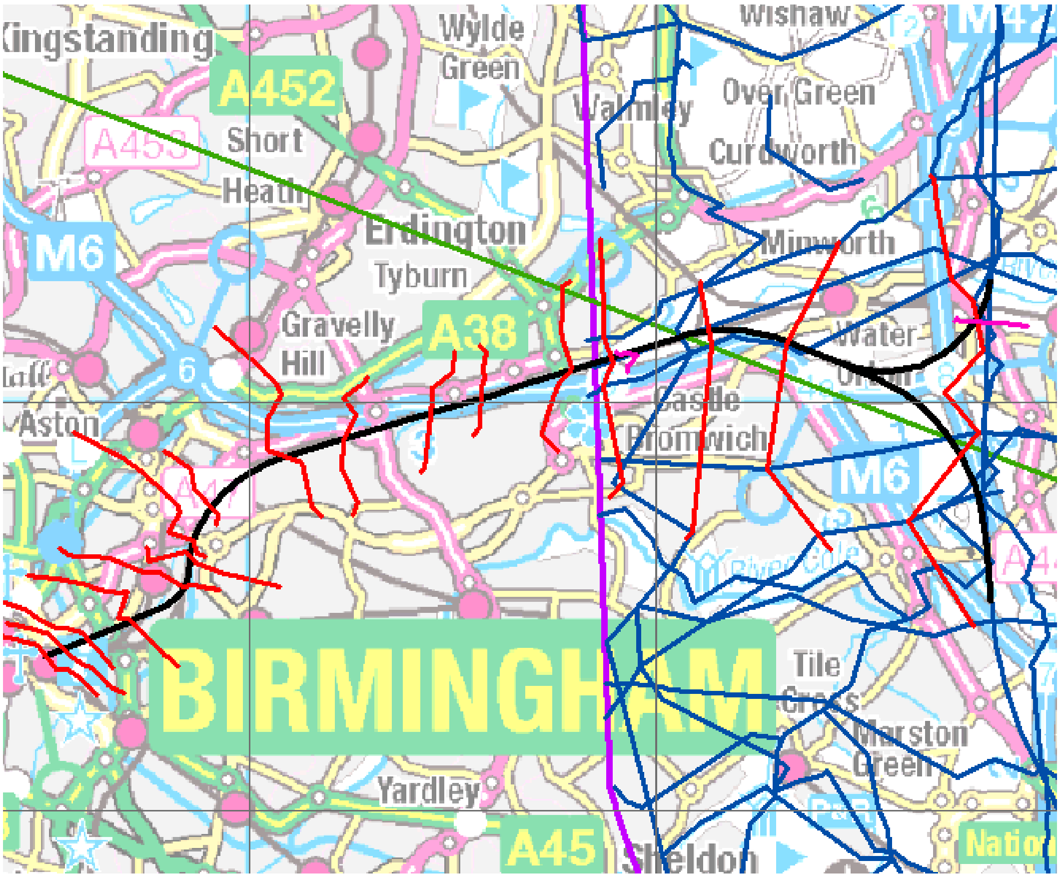

Figure 1. Location of the Birmingham Spur cross section

The cross sections following the proposed route of HS2 Birmingham Spur are shown as black lines; cross sections constructed to inform the geology of the route are coloured red (numbered NS1 to 17 from east to west); Birmingham 1:50,000 sheet cross-section 1 shown in green; Area 7 model area outlined in purple, with Area 7 cross-sections shown in blue. This report describes the cross-sections in Area 9, to the west of Area 7. Contains Ordnance Survey data © Crown Copyright and database rights 2016.

2 Modelled surfaces/volumes

The natural geology of Area 9 sections of the route comprises bedrock units of the Triassic Mercia Mudstone and Sherwood Sandstone groups, together with superficial deposits of glacigenic and fluvial origin. Artificial ground was modelled according to the corresponding 1:50,000 scale geological maps. The level of detail and extent of these units in the model may differ from that shown in other BGS datasets, including 1:50,000 scale geological maps. Table 1 lists the units modelled in the cross-sections and should be used as the legend for viewing images of the cross-sections in this report.

Table 1. Units present in the vicinity of the Birmingham Spur, down to 30 m below OD

Name in model (LEX-RCS)	Description	Comments
WMGR-ARTDP	Worked and Made Ground - Artificial Deposits	
MGR-ARTDP	Made Ground - Artificial Deposits	
ALV-XCZSV	Alluvium – clay, silt, sand and gravel	
HEAD-XCZSV	Head – clay, silt, sand and gravel	
RTD1-XSV	River Terrace Deposits, 1 – sand and gravel	
RTD2-XSV	River Terrace Deposits, 2 – sand and gravel	
GFDMP-XSV	Glaciofluvial Deposits, Mid Pleistocene – sand and gravel	
TILMP1-DMTN	Glaciolacustrine Deposits, Mid Pleistocene, lower – clay and silt	
TSSM-MDSS	Tarporley Siltstone Formation and Sidmouth Mudstone Formation, undifferentiated - mudstone, siltstone and sandstone	
MMG-DLST*	Mercia Mudstone Group – dolomitic siltstone	Also known as 'skerry'. Several thin beds locally mapped in Branscombe Mudstone and Sidmouth Mudstone formations
MMG-MDST	Mercia Mudstone Group - mudstone	
BMS-SDST	Bromsgrove Sandstone Formation – sandstone	Now named Helsby Sandstone Formation
WRS-SDST	Wildmoor Sandstone Formation – sandstone	Now named Wildmoor Sandstone Member of Wilmslow Sandstone Formation
KDM-PESST	Kidderminster Formation – pebbly sandstone	Now named Chester Formation
HPBR-BRSS	Hopwas Breccia Formation – breccia and sandstone, interbedded	
EN-SCSM	Enville Member – sandstone with subordinate conglomerate, siltstone and mudstone	

Units shown in the geological map in Figure 2 but are not represented in the cross-sections are marked *

2.1 BEDROCK GEOLOGY

Mercia Mudstone Group (MMG) lies at geological rockhead beneath the Birmingham Spur throughout its length apart from the extreme west end (Figure 2). It is subdivided into five formations in the West Midlands, in descending order: the Blue Anchor (about 8 m of greenish grey dolomitic mudstone and siltstone), Branscombe Mudstone (20 to 30 m of reddish brown mudstone and siltstone), Arden Sandstone (4 to 10 m of greenish grey and brown mudstone, siltstone and sandstone), Sidmouth Mudstone (SIM, about 250 m of reddish brown mudstone and siltstone) and Tarporley Siltstone (20 to 40 m of reddish brown and greenish grey siltstone, mudstone and sandstone).

The lowest four of these formations are distinguished and modelled in the adjoining Area 7, and three are seen in the extreme southern end of the southern branch of the spur. The two lowest units, Sidmouth Mudstone and Tarporley Siltstone formations, are generally thought to be present in the Birmingham Spur area but were not separately mapped on the Birmingham 1:50,000 scale map sheet and cannot be meaningfully and consistently differentiated in the borehole logs. Thus throughout the Area 9 cross sections, the interval is shown as Tarporley Siltstone Formation and Sidmouth Mudstone Formation undifferentiated (TSSM-MDSS), although it is thought that the Sidmouth Mudstone Formation forms much the greater part and is the unit at rockhead. This is consistent to MMG-MDST and SIM-MDST in the Area 7 cross sections.

The Sherwood Sandstone Group underlies the Mercia Mudstone Group, and is at rockhead west of the Birmingham Fault. It is subdivided into formations on the Birmingham sheet, of which the upper two, the Bromsgrove Sandstone and Wildmoor Sandstone formations are represented in the Area 9 cross sections. However, they are difficult to distinguish in borehole logs (the Bromsgrove Sandstone is pebbly in parts, the Wildmoor Sandstone is fine-grained) and the boundary between them is uncertain.

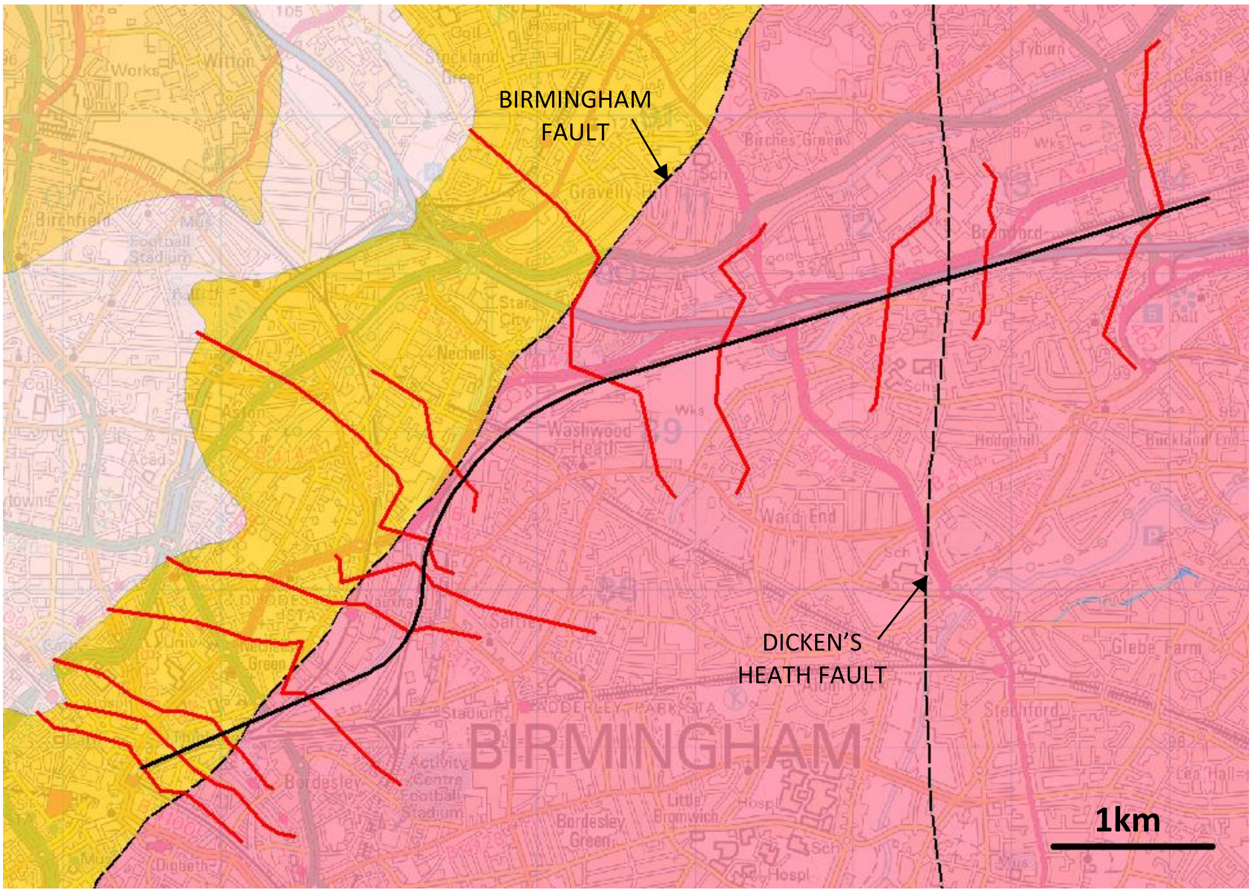

Figure 2. DiGMapGB-50 bedrock geology in Area 9

Black dashed lines are mapped faults; solid black line is the HS2 Birmingham Spur route section; red lines are cross-sections constructed to inform the route section. Key to geology as per Table 1. Contains Ordnance Survey data © Crown Copyright and database rights 2016.

2.2 SUPERFICIAL DEPOSITS

Superficial deposits are extensive in the western part of the Birmingham Spur area (Figure 3). Fluvial deposits associated with the River Tame and River Lea comprise alluvium and river terrace gravels. Glacigenic deposits in the area are dominated by sand and gravel with patches of till. In DiGMapGB-50 v7, most/all of the glacigenic deposits in the district are attributed as Devensian (Late Pleistocene; e.g. GFDUD rather than GFDMP), presumably as a result of recent research, whereas in the memoir (Powell et al., 2000, p. 81), they are inferred to be Anglian/Wolstonian (Middle Pleistocene) in age. However, this re-interpretation is known to be controversial/not yet well substantiated. In the memoir, deep superficial deposit-filled hollows that impinge on the Birmingham Spur are identified, delineated and named in figures 24 and 27 as the Proto-Tame and Gilson ‘palaeovalleys’.

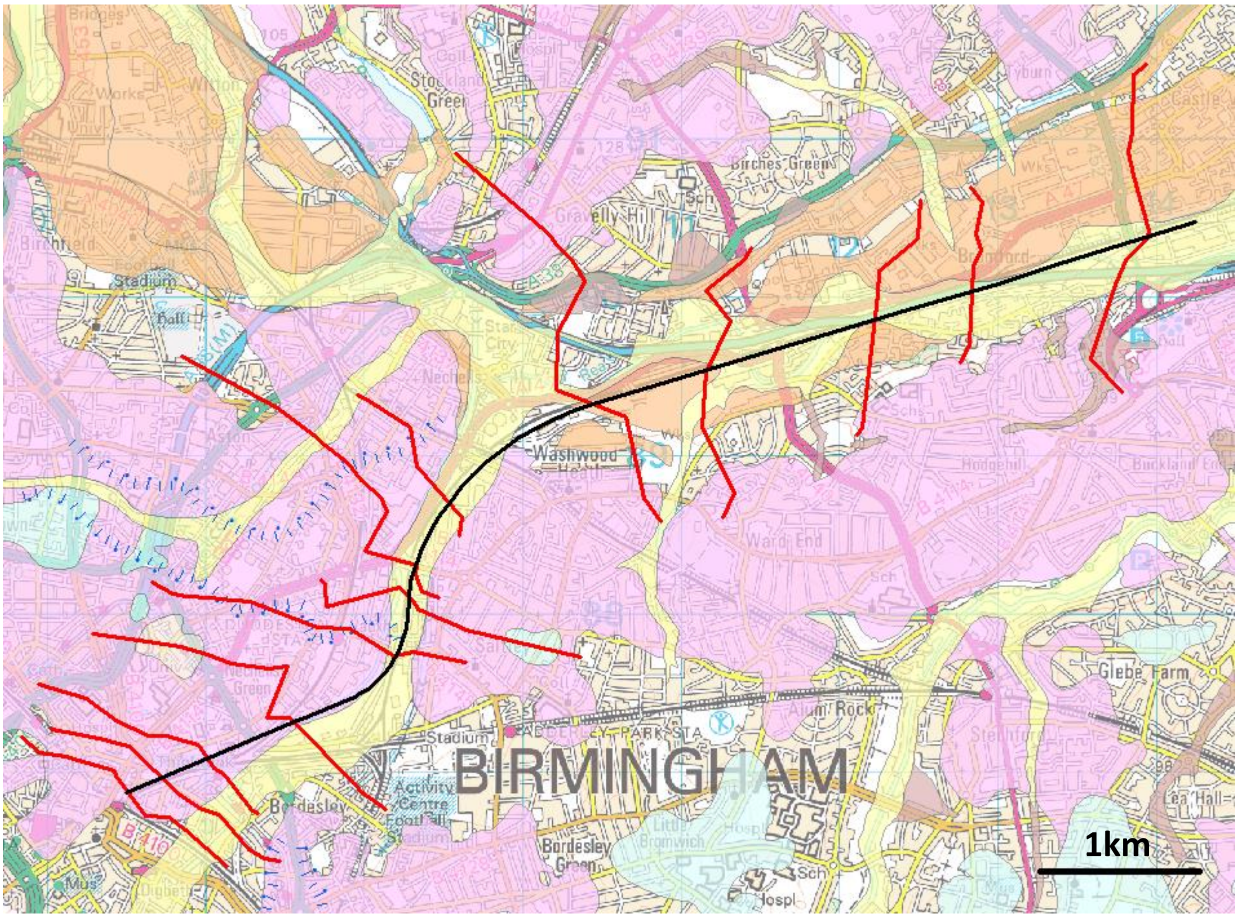

Figure 3. DiGMapGB-50 superficial deposits in Area 9

Black line is the HS2 Birmingham Spur route section; red lines are cross-sections constructed to inform the route section. Blue ticked lines in the west represent the margins of ‘palaeovalleys’ (buried channels). Key to superficial deposits as per Table 1. Contains Ordnance Survey data © Crown Copyright and database rights 2016.

2.3 ARTIFICIALLY MODIFIED GROUND

Extensive areas of artificially modified ground are mapped along the River Tame and River Lea floodplains (Figure 4), which are represented in the cross-sections using available borehole information to inform the thickness/base. This artificially modified ground layer is subdivided into classes, with made ground (areas where the land surface has been artificially raised) and made and worked ground (such as backfilled shallow mineral working) present in the area. Only mapped artificial ground is represented in the cross-sections, although some of the boreholes used record artificial ground where none is mapped.

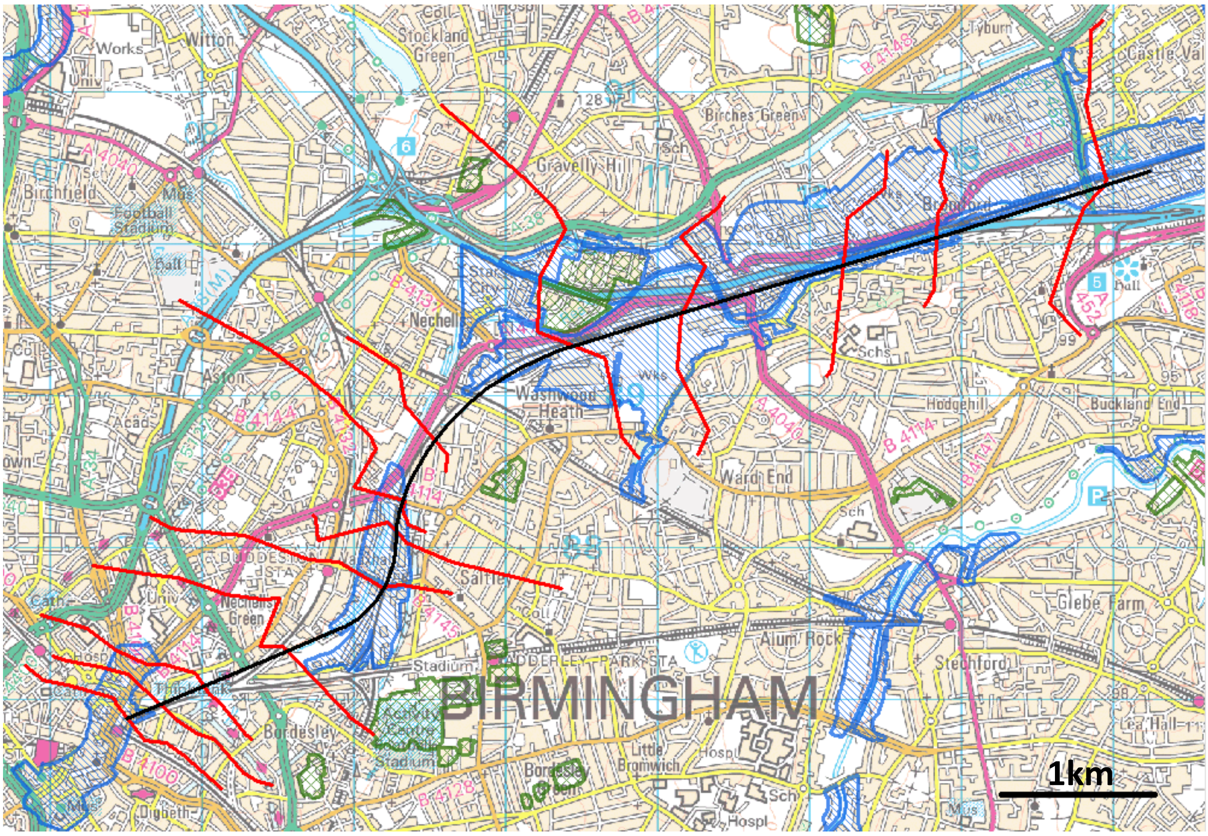

Figure 4 DiGMapGB-50 artificially modified ground in Area 9

Black line is the HS2 Birmingham Spur route section; red lines are cross-sections constructed to inform the route section. Artificially modified ground is shown as hatched areas: made ground is coloured blue and worked and made ground is coloured green. Contains Ordnance Survey data © Crown Copyright and database rights 2016.

3 Modelled Faults

Two major faults with significant throws are present in Area 9, the Birmingham Fault and the Dicken's Heath Fault (Figure 2). These are modelled as fault plane objects, as normal style dipping at a notional 60°, based on mapped surface faults, and are represented as steps in the bases of geological units. Figure 5 shows the Area 9 route cross-section, which passes through both of these faults. Although the route cross section traverses the Birmingham Fault only once, it approaches it elsewhere so that the fault plane may lie below the route at a very approximately estimated -50 m OD around SP 095 887. Note that Powell et al. (2000), p. 102 states that the Birmingham Fault has been observed to comprise at least four planes locally and the presence of multiple planes may be the case with other faults.

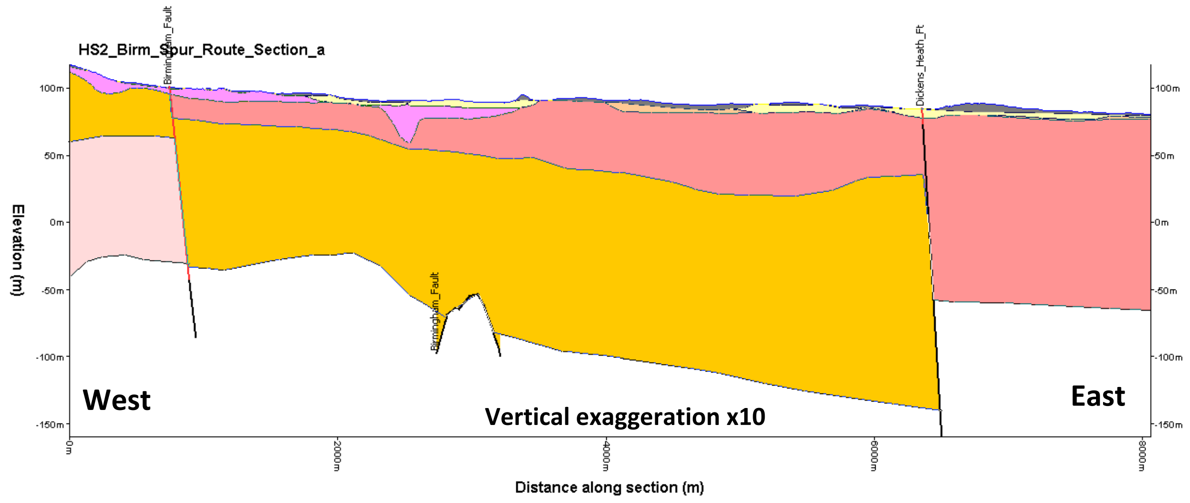

Figure 5 Fault representation in cross-section *HS2_Birm_Spur_Route_Section_a*

4 Model Workflow

The standard GSI3D modelling workflow was followed for this project to the point where cross-sections are cross-correlated. GSI3D software utilises a range of data such as boreholes, digital terrain models (DTM) and geological linework to enable the geologist to construct a series of interlocking cross-sections. Borehole data is represented in GSI3D by two proprietary files: a borehole identification file (.bid) that contains 'index'-level information including location and start-heights; a borehole log file (.blg) that contains the borehole interpretation. Constructing cross-sections is intuitive and flexible, combining borehole and outcrop data with the geologist's experience to refine the interpretation.

In order to control the relative vertical ordering of the units, a generalised vertical section file (.gvs) is established. A proprietary legend file (.gleg) is created to control symbolisation of the cross-sections. The modeller can view all the correlated sections in 3D and iteratively return to any cross-section to make amendments or add further cross-sections to refine the model. This process is a standard methodology within BGS for modelling Quaternary and simple bedrock horizons and is fully documented in Kessler et al. (2009).

5 Model datasets

5.1 GVS AND GLEG FILES

The generalised vertical section (.gvs) and geological legend (.gleg) files were assembled using Notepad or Excel and iterated as the model expanded and new units were encountered. The GVS was based on DiGMapGB-50 data by identifying all those geological units that are within a 5 km area of the HS2 route. However some units occur only in subcrop, so additional units in the GVS had to be appended as modelling progressed. The GLEG files were created using the standard BGS colours from DigMap-50. Overall GVS and GLEG files were created for the whole HS2 route, rather than for each individual model area. Thus the units used in this model are only a subset of those available in the overall HS2 GVS file.

5.2 GEOLOGICAL LINEWORK

All Area 9 cross sections are located within BGS 1:50 000 Sheet 168 (Birmingham), surveyed between 1978 and 1992, published in 1996 and accompanied by a memoir (Powell et al., 2000). The cross-sections use DiGMap 1:50,000 scale geological map data.

5.3 DIGITAL TERRAIN MODEL

The terrain model used in this model was the BGS Bald Earth 20 m DTM obtained from the BaldEarth model and trimmed to the project area (5 km buffer of the route shapefile). A NextMap DTM was also included, but not used for modelling.

5.4 BOREHOLE DATA

Borehole records examined included both Keyworth and Wallingford held logs. Closely clustered sets of boreholes were not all coded but the deepest and most representative were included. Any significant local variation in sequence was also recorded by coding. Entries were all made directly into the corporate BGS *Borehole Geology* database (BoGe). However, many of the boreholes were either very shallow and thus did not provide any data on the bedrock geology, or did not contain sufficient information to be coded in any meaningful way.

After borehole coding was completed, the boreholes were extracted from the BGS *Single Onshore Borehole Index* (SOBI) database using a set of queries. The borehole log file (.blg) needed to be deduplicated and a borehole filter tool was used to address this. A set of priorities were applied to borehole records that were coded by more than one project. Figure 7 shows the distribution of the 105 boreholes used to constrain the Area 9 cross-sections that inform the route section.

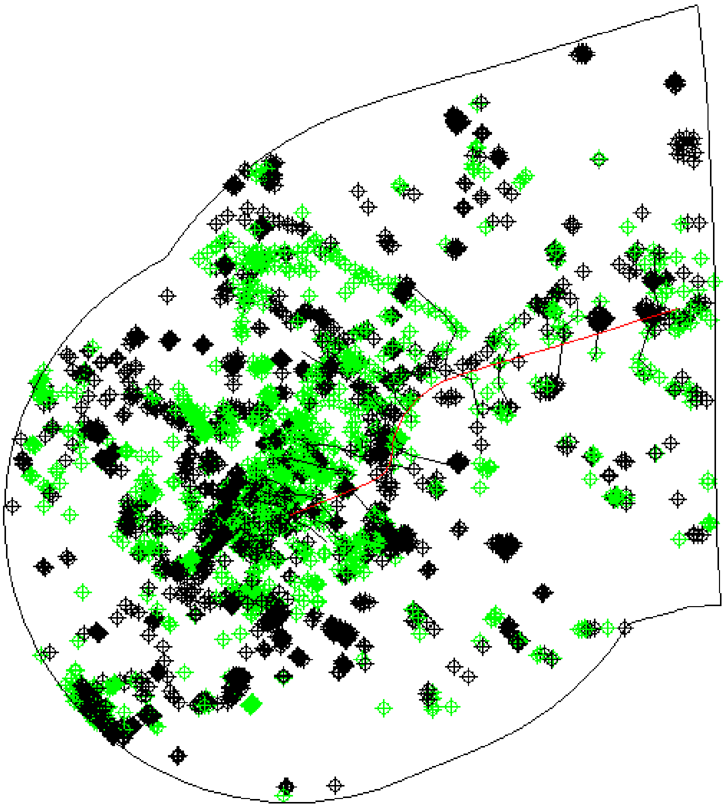

Figure 6 Distribution of available borehole data in Area 9. Black dots have drilled depths up to 10 m and green dots are over 10 m

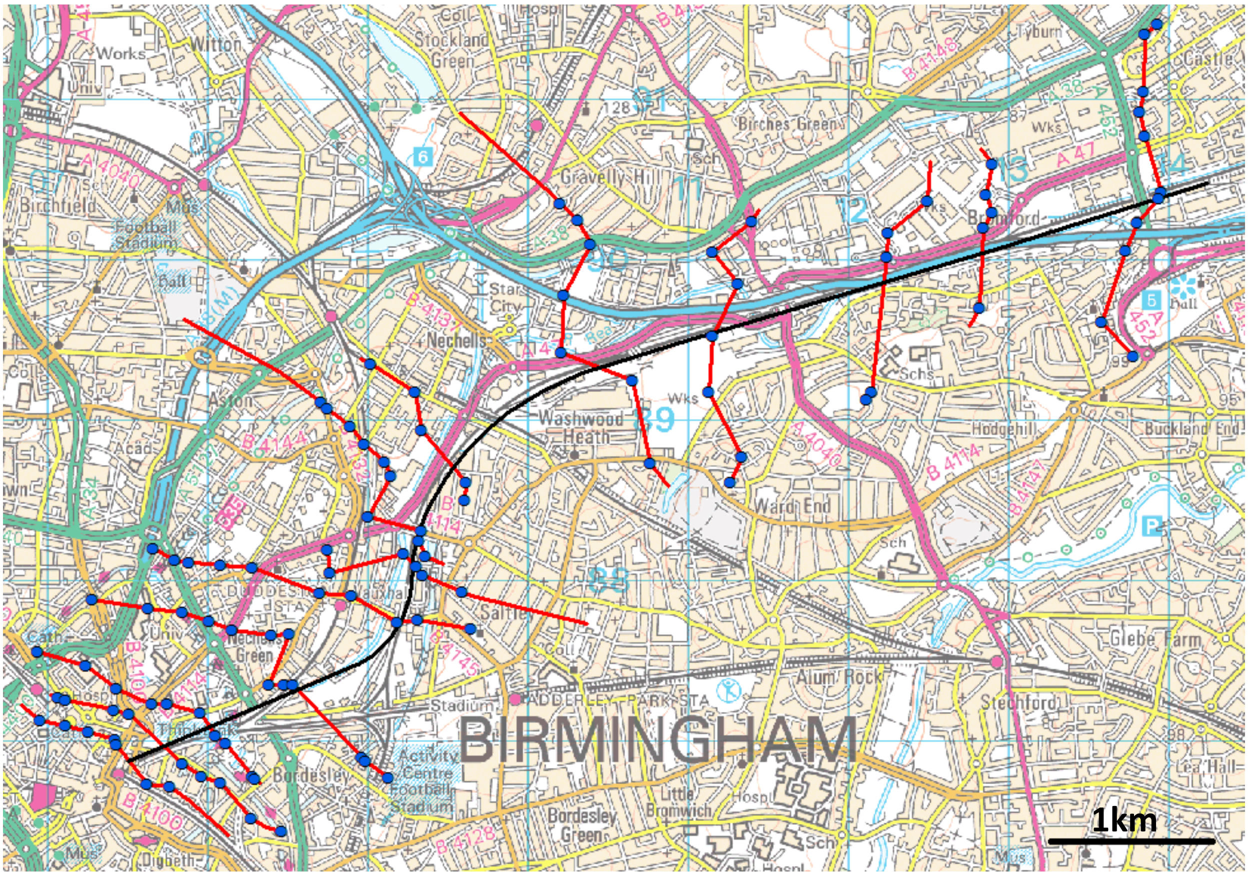

Figure 7 Distribution of borehole data used to constrain the Area 9 cross-sections

Borehole locations are shows as blue dots; black line is the HS2 Birmingham Spur route section; red lines are cross-sections constructed to inform the route section. Contains Ordnance Survey data © Crown Copyright and database rights 2016.

5.5 RASTER IMAGES

Information from BGS Birmingham memoir (Powell et al., 2000), including comments about rock types and unit thicknesses was used to inform the cross-section construction. Memoir figures 20a and 20c (Contour map for the base of the Bromsgrove Sandstone Formation, and for the base of the Mercia Mudstone Group, respectively, covering the west and centre of the Spur) and 27 (Rockhead contours for part of central Birmingham) were georegistered and added to the project (see below).

6 Model Development Log

During the course of the modelling, the modeller kept a running log of the development, changes and decisions made for their designated modelling areas (Figure 8). These records are kept as part of the model storage and metadata (QA) process and can be accessed as needed.

27/6/16: Added Birmingham Fault, dipping SE at a presumed 60°, notionally cut off at -80 m OD. Correlated AMG, superficial deposits and bedrock in cross sections NS13, 14, 7, 8 and 9. Evident that TPSF had not been identified in boreholes or memoir at base of MMG hereabouts, although more recently it is presumed to be present (Howard et al., 2008) so using SIM on BMS is inappropriate, and in the interim MMG was used (see below), v2_13.

Figure 8 Extract from Area 9 Model Development Log

7 Model assumptions, geological rules used etc.

In many cases the borehole data/interpretation conflicted with the memoir figures (Powell et al., 2000), either because the borehole data was not used for the figure or more recently acquired, the present author disagreed with the earlier interpretation, or the figure was poorly drawn or generalized. A judgement was made on the individual case but generally the borehole interpretation took precedence. Nonetheless, the general pattern of structure/rockhead contours in the figures was honoured as far as possible. This continued throughout the modelling.

In the memoir (Powell et al., 2000, p. 81), most/all of the glacigenic deposits in the area are inferred to be Anglian/Wolstonian (i.e. Middle Pleistocene) in age and have been modelled as such in Area 7. However, in DiGMapGB-50 v7 as used in the model shape files, they are attributed as Devensian (i.e. Late Pleistocene; e.g. GFDUD rather than GFDMP), presumably as a result of more recent research, although this interpretation is known to be controversial/not yet well substantiated. To fit Area 7, Middle Pleistocene units are used here, except in NS1 at SP 184 924.

8 Model limitations

8.1 MODEL SPECIFIC LIMITATIONS

The Tarporley Siltstone Formation of the Mercia Mudstone Group cannot be meaningfully and consistently differentiated in the Birmingham Spur area borehole logs from the overlying Sidmouth Mudstone Formation. Thus throughout the cross section, the interval is shown as Tarporley Siltstone Formation and Sidmouth Mudstone Formation, undifferentiated (TSSM-MDSS), although it is thought that the Sidmouth Mudstone forms much the greater part and is the unit at rockhead.

Fault planes are presumed to dip at 60° in the absence of other information.

Figure 6 shows all coded boreholes available in Birmingham Spur and Area 7 (in 2013). Figure 7 shows the boreholes used in cross sections with the lines of cross-sections, indicating where this subsurface data may constrain the model. This gives the model user some idea where the model is most and least certain.

The digital geological map data (DiGMapGB-50) used to inform the surface or subcrop (bedrock under superficial deposits or superficial deposits under artificially modified ground) intercepts in cross section drawing is cartographically generalised for publication of the 1:50,000 scale map. In Area 9 this does not significantly affect the (relatively simple) bedrock polygons. In the superficial layer some minor tracts of deposits (e.g. ribbons of alluvium or head) may be exaggerated or removed. In the artificially modified ground layer, however, some areas recorded at 1:10,000 scale may be omitted in DiGMapGB-50, especially if they are embankments/cuttings associated with existing roads and railways (and therefore shown on the OS topography). The Digital Terrain Model (DTM) used is of 2013 vintage and is subsampled to a horizontal resolution 20 m. Therefore some subtleties of the ground surface may not be correctly represented.

In addition, mapping artificially modified ground in urban areas presents difficulties, even where there is no significant mineral extraction, as it is a result of generations of development, and the evidence can be lost or hidden. The vintage of any borehole data compared with development etc. will affect any interpretation. In addition, the extent and nature of artificially modified ground is constantly changing, and so the distribution that is mapped is a snapshot at the time, utilising the available borehole data. In the case of this cross section, the proposed route partly follows existing transport infrastructure, with its consequent artificially modified ground, and together with the limitations of the DTM, it has not been possible to represent all of this in the model.

8.2 GENERAL MODELLING LIMITATIONS

- Geological interpretations are made according to the prevailing understanding of the geology at the time. The quality of such interpretations may be affected by the availability of new data, by subsequent advances in geological knowledge, improved methods of interpretation, improved databases and modelling software, and better access to sampling locations. Therefore, geological modelling is an empirical approach.

- It is important to note that these geological cross-sections represent an individual interpretation of a subset of the available data; other interpretations may be valid. The full complexity of the geology may not be represented by the cross-sections due to the spatial distribution of the data at the time of their construction and other limitations including those set out elsewhere in this report.

- Best endeavours (detailed quality checking procedures) are employed to minimise data entry errors but given the diversity and volume of data used, it is anticipated that occasional erroneous entries will still be present (e.g. boreholes locations, elevations etc.) Any raw data considered when building geological models may have been transcribed from analogue to digital format. Such processes are subjected to quality control to ensure reliability; however undetected errors may exist. Borehole locations are obtained from borehole records or site plans.

- Borehole start heights are obtained from the original records, Ordnance Survey mapping or a digital terrain model. Where borehole start heights look unreasonable, they are checked and amended if necessary in the index file. In some cases, the borehole start height may be different from the ground surface, if for example, the ground surface has been raised or lowered since the borehole was drilled, or if the borehole was not originally drilled at the ground surface.

- Borehole coding (including observations and interpretations) was captured in a corporate database before the commencement of modelling and any lithostratigraphic interpretations may have been re-interpreted in the context of other evidence during cross-section drawing and modelling, resulting in occasional mismatches between BGS databases and modelled interpretations.

- Digital elevation models (DEMs) are sourced externally by BGS and are used to cap geological models. DEMs may have been processed to remove surface features including vegetation and buildings. However, some surface features or artefacts may remain, particularly those associated with hillside forests. The digital terrain model may be sub-sampled to reduce its resolution and file size; therefore, some topographical detail may be lost.

- Geological units of any formal rank may be modelled. Lithostratigraphical (sedimentary/metasedimentary) units are typically modelled at Group, Formation or Member level, but Supergroup, Subgroup or Bed may be used. Where appropriate, generic (e.g. alluvium – ALV), composite (e.g. West Walton Formation and Ampthill Clay Formation, undifferentiated – WWAC) or exceptionally informal units may also be used in the model, for example where no equivalent is shown on the surface geological map. Formal lithodemic igneous units may be named Intrusions or Dykes or may take the name of their parent (Pluton or Swarm/Centre or Cluster/Subsuite/Suite), or if mixed units Complex may be used. Highly deformed terranes may use a combined scheme with additional rank terms. Artificially Modified Ground units (e.g. Made Ground (undivided) – MGR, Landscaped Ground (undivided) – LSGR) are currently regarded as informal.

- The geological map linework in the model files may be modified during the modelling process to remove detail or modify the interpretation where new data is available. Hence, in some cases, faults or geological units that are shown in the BGS approved digital geological map data (DiGMapGB) may not appear in the geological model or vice versa. Modelled units may be coloured differently to the equivalent units in the published geological maps.

9 Model QA

In order for a geological model to be approved for publication or delivery to a client a series of QA checks is carried out. This includes visual examination of the modelled cross-sections to ensure that they match each other at cross-section intersections and fit the borehole and geological map data used. The naming convention of the modelled geological units is checked to ensure that recognised entries in the BGS Lexicon of Named Rock Units (http://www.bgs.ac.uk/lexicon/home.html) and the BGS Rock Classification Scheme (http://www.bgs.ac.uk/bgsrcs/) are used as far as possible.

Any issues found in the QA checking process are recorded and addressed before delivery/publication of the model.

10 Model images

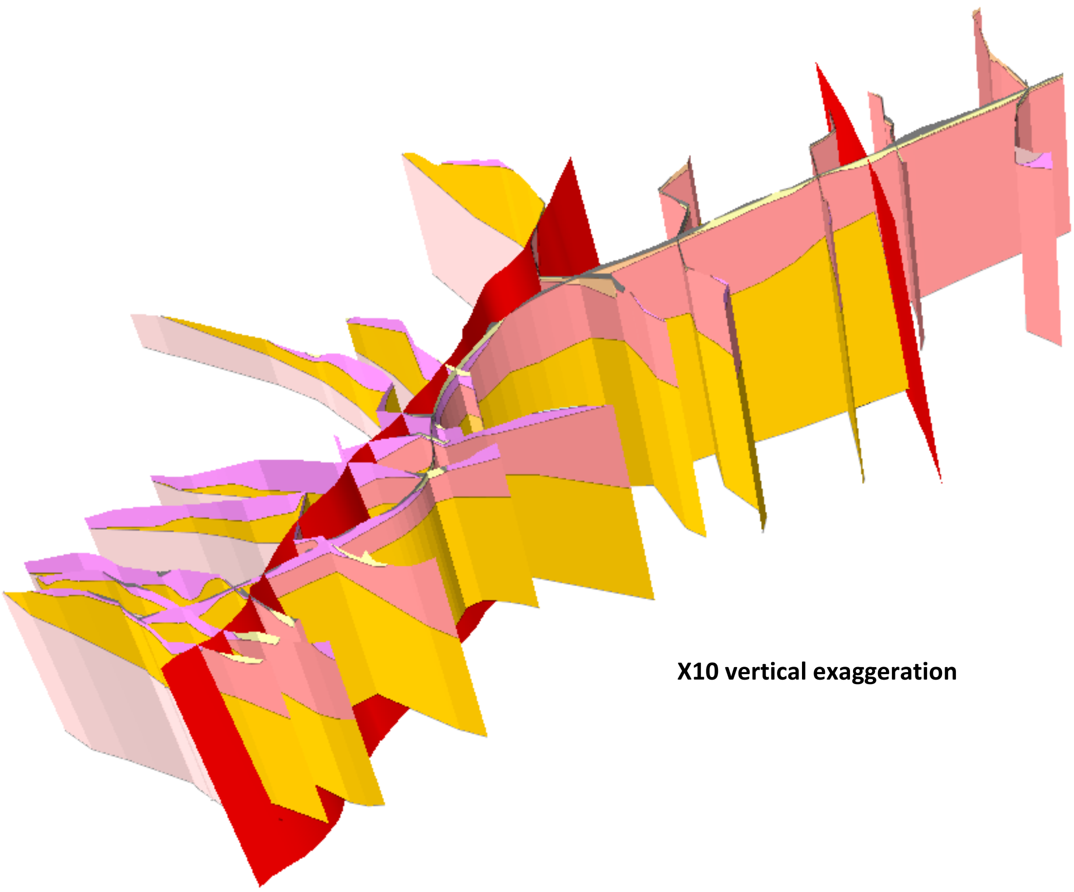

Figure 9. 3D view of the Area 9 Birmingham Spur route cross-sections with fault planes (red), looking from the south). Key to geology as per Table 1.

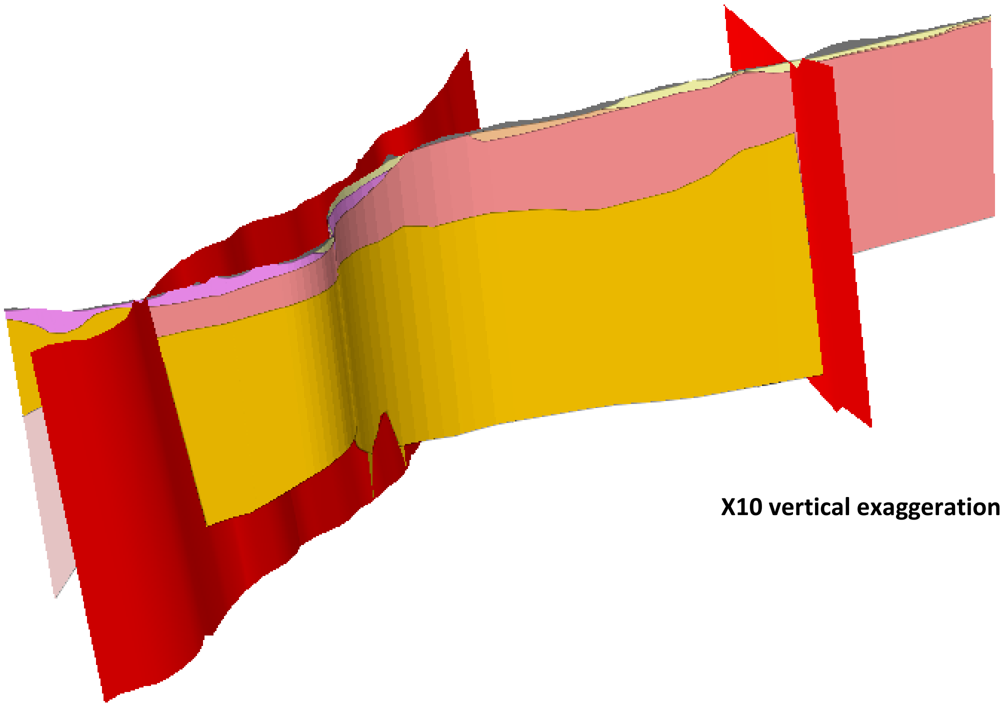

Figure 10. 3D view of the Area 9 Birmingham Spur route cross-section with fault planes (red), looking from the south. Key to geology as per Table 1.

11 References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

BARRON, A J M, THOMPSON, J, and POWELL, J H. 2012. *Assessment of BGS maps and 3D models along the proposed HS2 route*. British Geological Survey Internal Report IR/12/043.

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 & geosciences*, Vol. 35, 1311-1321.

POWELL, J H, GLOVER, B W, and WATERS, C N. 2000. Geology of the Birmingham area. Keyworth: Nottingham, Memoir of the British Geological Survey. **Sheet 168 (England and Wales)**.