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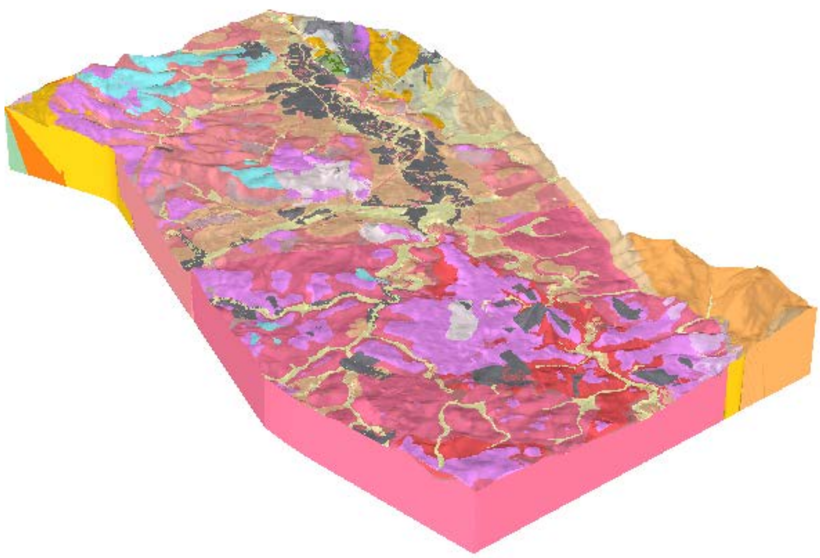
GSI3D model metadata report for HS2 Area 7 (Hampton in Arden to Drayton Bassett)

Geology and Regional Geophysics

Open Report OR/15/073



BRITISH GEOLOGICAL SURVEY

GEOLOGY AND REGIONAL GEOPHYSICS PROGRAMME

OPEN REPORT OR/15/073

GSI3D model metadata report for HS2 Area 7 (Hampton in Arden to Drayton Bassett)

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Map

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Summary

This report describes the 3D geological model of HS2 (High Speed 2 rail link) Area 7 (Hampton in Arden to Drayton Bassett), created by Keith Ambrose with support from Steve Thorpe and borehole coding by John Powell. 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 model purpose was to model the bedrock, superficial and artificial ground following part of the proposed High Speed Rail link between London and Birmingham (HS2). This model is of the bedrock, natural superficial deposits and artificially modified ground geology of a 25 km stretch of the proposed route in Warwickshire, between Hampton in Arden in the south and Drayton Bassett in the north, in Warwickshire, including a 5 km buffer either side of the route (Figure 1). The bedrock geology of this section of the route comprises sedimentary rocks of Cambrian, Carboniferous and Triassic age, igneous intrusions of probable Ordovician age, together with superficial deposits of glacigenic and fluvial origin, and artificial deposits. This is one of an initial group of nine models along the planned route. Area 6 to the south west was modelled by Oliver Wakefield and Area 8 to the north was modelled by Keith Ambrose. All of these models have been matched to ensure integrity across the project as a whole. This model is suitable for use at scales between 1:100,000 and 1:10,000 to a depth of 30 m below Ordnance Datum (OD).

Prior to the modelling work, an assessment of the quality and availability of the digital geological linework and existing 3D models of the whole HS2 route between London and Birmingham was undertaken (Barron et al., 2012). As a consequence of this review, the geological mapping of this sector, dating from the 1980s and 90s, was deemed to be in need of some revision. Therefore some changes have been necessary. For example, the unmapped Triassic Tarporley Siltstone Formation has been added and the outcrop of the Arden Sandstone Formation has been completed and some modification made, such as adding and extending faults, as the unit is continuous. Major modifications were also made to the river terrace deposits and artificial deposits in the northern part of the River Thame valley where quarries had been enlarged, new workings opened up and others backfilled. Thus this 3D model is based on geological line work from existing 1:10 000 and 1:50 000 scale DiGMapGB data to which modifications have been made.

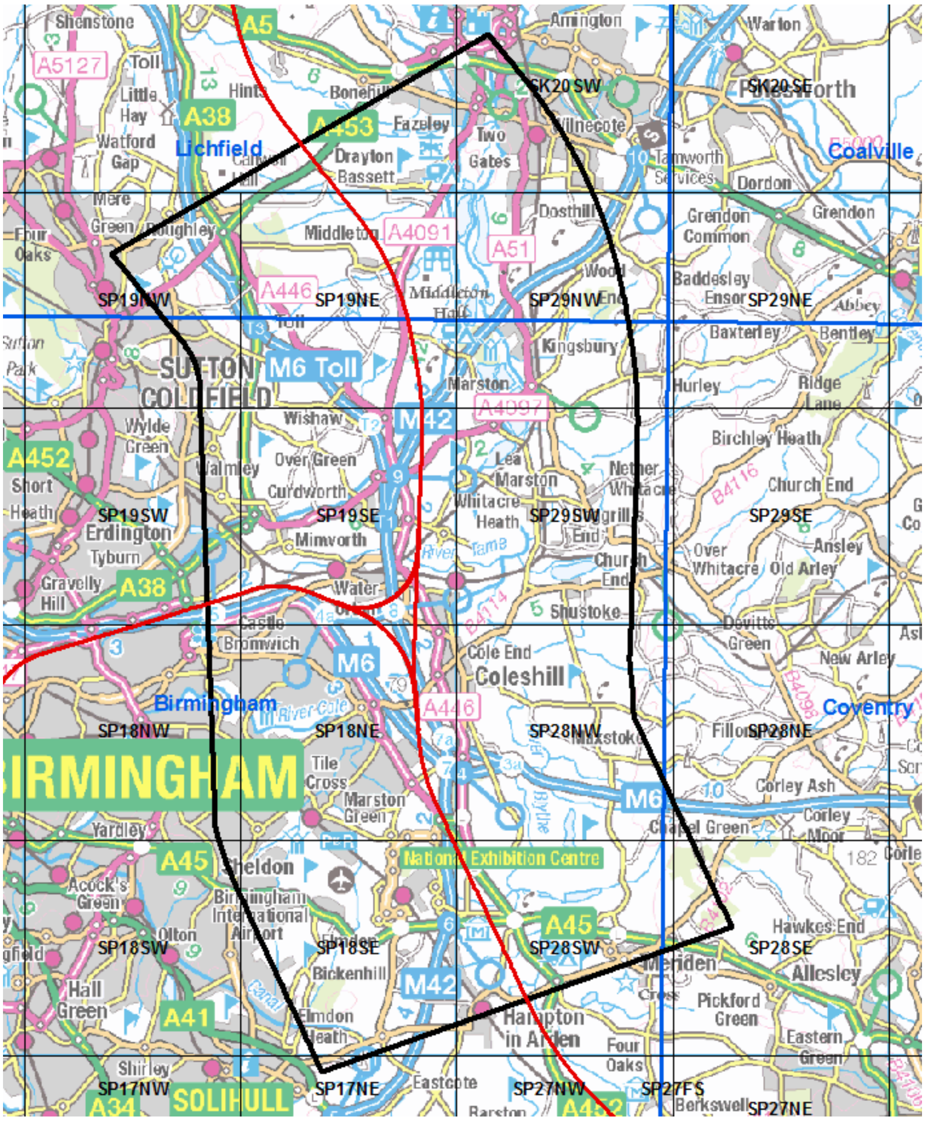

Figure 1. Location of the Area 7 model outlined in black, proposed HS2 route shown in red. BGS 1:10,00 scale map sheet areas are shown in black, 1:50,000 scale in blue.

2 Modelled Surfaces/Volumes

The modelled bedrock, superficial and artificial deposits are listed in Table 1 in the relative stratigraphic order used in the model. Brief descriptions of the geological units are given here, but more detail can be found in the BGS Lexicon of Named Rock Units. The level of detail and extent of the natural geology in the model may differ from that shown in other BGS datasets. Artificial ground was modelled according to the corresponding 1:50,000 scale geological maps. Table 1 should be used as the legend for viewing images of the model in this report.

Table 1. Units modelled in Area 7

LEX-RCS	Lex_Description	Comments and included units in DiGMapGB-50
WMGR-ARTDP	Worked and Made Ground	Variable composition
MGR-ARTDP	Made Ground	Variable composition
WGR-VOID	Worked Ground	Variable composition
LSGR-UKNOWN	Landscaped Ground	Variable composition

ALV-XCZSV	ALLUVIUM	Clay, silt, sand and gravel
HEAD-XCZSV	HEAD	Clay, silt, sand and gravel
PEAT-P	PEAT	Peat
RTD1-XSV	RIVER TERRACE DEPOSITS, 1	Underlies alluvium very extensively. Sand and gravel
RTD2-XSV	RIVER TERRACE DEPOSITS, 2	Sand and gravel
RTD3-XSV	RIVER TERRACE DEPOSITS, 3	Sand and gravel
GFDUD-XSV	GLACIOFLUVIAL DEPOSITS, DEVENSIAN	Sand and gravel
GFTMP-XSZ	GLACIOFLUVIAL TERRACE DEPOSITS	Age uncertain. Sand and silt.
GFDMP-XSV	GLACIOFLUVIAL DEPOSITS, MID PLEISTOCENE	Sand and gravel
GLLMP1-XCZ	GLACIOLACUSTRINE DEPOSITS, MID PLEISTOCENE	Clay and silt
TILMP-DMTN	TILL, MID PLEISTOCENE	Till (includes single polygon of Thrussington Till present within the area)
GFDMP0-XSV	GLACIOFLUVIAL DEPOSITS, MID PLEISTOCENE	Sand and gravel
BCMU-MDST	BRANSCOMBE MUDSTONE FORMATION	Mudstone
AS-SDSM	ARDEN SANDSTONE FORMATION	Original mapped outcrop showed some discontinuities but is known to be continuous. Boundary has been adjusted to take this into account with some fieldwork; some faults have been added and others extended. *Important to note that in Area 6 this was originally modelled as AS-SISM, due to differences in lithology being mapped. This was subsequently changed to AS-SDMS to match Area 7 (in Nov 2017).*
SIM-MDST	SIDMOUTH MUDSTONE FORMATION	Mudstone
TPSF-MDSA	TARPORLEY SILTSTONE FORMATION	This unit was not originally mapped but has been added with the aid of fieldwork. Four former outcrops of Bromsgrove Sandstone have been reclassified as Tarporley Siltstone Formation.
MMG-MDST	MERCIA MUDSTONE GROUP	Modelled at group level in the northern half of the model where component formations are not separated on the geological maps
BMS-SDST	BROMSGROVE SANDSTONE FORMATION	Outcrops in south east of Area 7 have been reduced from 5 to 1 with fieldwork. This unit has been renamed the Helsby Sandstone Formation
WRS-SDST	WILDMOOR SANDSTONE FORMATION	Sandstone
KDM-PESST	KIDDERMINSTER FORMATION	Pebbly sandstone
HPBR-BRSS	HOPWAS BRECCIA FORMATION	Interbedded breccias and sandstone
ASY-ARSC	ALLESLEY MEMBER	Interbedded argillaceous rocks, subordinate sandstone and conglomerate
KRS-ARSC	KERESLEY MEMBER	Originally mapped with sandstone subdivisions but combined into a single lithology for modelling. Interbedded argillaceous rocks, subordinate sandstone and conglomerate
WIT-MDSD	WHITACRE MEMBER	Originally mapped with sandstone subdivisions but combined into a single lithology for modelling. Mudstone and sandstone
ALY-MDSD	ALVELEY MEMBER	Originally mapped with sandstone subdivisions but combined into a single lithology for modelling. Mudstone and sandstone
HA-MDSS_1	HALESOWEN FORMATION	Mudstone, siltstone and sandstone
HA-SDST	HALESOWEN FORMATION	Sandstones in Halesowen Formation retained for modelling
HA-MDSS	HALESOWEN FORMATION	Mudstone, siltstone and sandstone
HA-SDST_0	HALESOWEN FORMATION	Basal sandstone unit in Halesowen Formation. May not be distinguished throughout the model
ETM-MDSC	ETRURIA MARL FORMATION	Mudstone, sandstone and conglomerate
WAWK-MDSS	WARWICKSHIRE GROUP	Used in north west of Area 7 where individual subdivisions of the Group cannot be identified

PMCM-MDSS	PENNINE MIDDLE COAL MEASURES FORMATION	Mudstone, siltstone and sandstone
PLCM-MDSS	PENNINE LOWER COAL MEASURES FORMATION	Mudstone, siltstone and sandstone
MG-SDST	MILLSTONE GRIT GROUP	Sandstone
MMI-LMPY	MIDLANDS MINOR INTRUSIVE SUITE	Lamprophyre
MVSH-MDST	MEREVALE SHALE FORMATION	Mudstone
MPSH-MDST	MONKS PARK SHALE FORMATION	Mudstone

The Hopwas Breccia Formation, Kidderminster Formation, Wildmoor Sandstone Formation and Bromsgrove Sandstone Formation are part of the Sherwood Sandstone Group. Recent work has renamed units from the Kidderminster Formation upwards respectively as the Chester Formation, Wilmslow Sandstone Formation and Helsby Sandstone Formation (Ambrose *et al.* 2014).

Units from the Tarporley Siltstone Formation up to the Branscombe Mudstone Formation are all part of the Mercia Mudstone Group, all of which are Triassic in age. These are modelled as individual units in the south of the model where they are separated out in the geological maps. These units are modelled as Mercia Mudstone Group is used in the north of the model where the geological maps do not separate the individual formations.

The Alveley Member (ALY), Whitacre Member (WIT), Keresley Member and Allesley Member (ASY) are part of the Salop Formation. The Etruria Marl Formation (ETM), Halesowen Formation (HA), and Salop Formation are all part of the Warwickshire Group (WAWK). Both are of Carboniferous age. The Monks Park Shale Formation (MPSH) and Merevale Shale Formation (MVSH) are part of the Stockingford Shale Group, of Cambrian age.

3 Modelled Faults

There are three major faults within Area 7. The Western Boundary Fault and Maxstoke Fault run along virtually the entire eastern side; the Birmingham Fault clips the north-west corner, running north-east into Area 8 and south westwards away from the area. These faults form a graben that links the Needwood Basin to the north with the Knowle Basin to the south. These basins and the graben were active during the Triassic, resulting in synsedimentary movement during the Permian and Triassic and a much thicker (c. 1000 m) sequence of these deposits within the graben. The Carboniferous Warwickshire Group and Pennine Coal Measures rocks that crop out on the upthrow sides of the faults are absent in the floor of the graben.

Warwickshire Group rocks cropping out in the east of Area 7 show several faults with throws of less than 60 m. Other faulting is limited in Area 7 and affects the Mercia Mudstone Group sediments mainly in the south of the area. Several small faults, most with throws of less than 20 m occur and are modelled with fault plane dips of around 60° for drawing guidance, based on mapped surface fault traces (Figure 2).

Modifications were made to the Maxstoke Fault, lengthening its outcrop in order for the model to fit. A number of new faults with downthrows of less than 20 m have been added and existing faults modified in order to create a model for the Sidmouth Mudstone, Arden Sandstone and Branscombe Mudstone Formations. These formations were incomplete on the current geological sheet 168 (Birmingham).

The faults were modelled using the GSI3D superficial engine (see section 4, model workflow) as steps in the geological surfaces rather than as a faulted bedrock model where the unit is in contact across the fault.

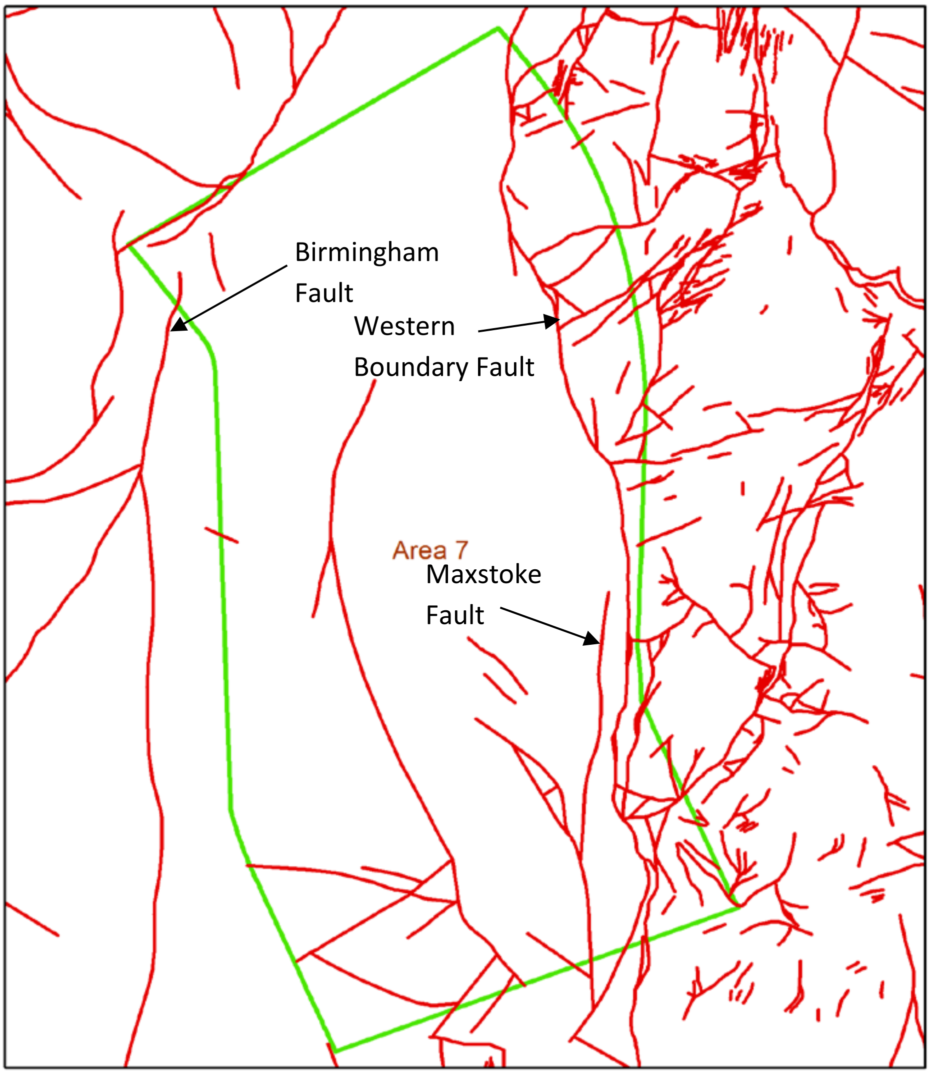

Figure 2. Area 7 project area outlined in green with revised geological fault network shown in red. Faults within the project area are represented in the model

4 Model Workflow

The standard GSI3D modelling workflow was followed for this project. 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.

Using both the information from the cross-sections and the distribution of each unit a calculation algorithm creates the triangulated surfaces for the top and base of each unit. In order to control the relative vertical ordering of the calculation, a generalised vertical section file (.gvs) is established. A proprietary legend file (.gleg) is created to control symbolisation of the cross-section and model. The modeller can view all the units in 3D and iteratively return to the 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).

In Areas 6, 7 and 8, to aid the calculation of bedrock units in faulted areas, scattered data points were created for the geological units that intersect the base of the model. This was then manipulated in GSI3D so that it could be applied to the respective geological units. This process aided the calculation of the geological units to the basal model limit.

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 generated based on DiGMapGB-50 data by identifying all those geological units that are within a 5km 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 Geological Legend files (.gleg) were generated 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

The geology of the area is described in Powell *et al.*, (2000), Barrow *et al.*, (1919) (northern part) and Bridge *et al.*, (1998) (south east corner). The model is matched to 10 newly revised 1:10 000 scale geological maps, which supersede the existing 1:50 000 scale geological map data. The revised 1:10 000 scale geological maps are: SK10SE, SK20SW, SP17NE, SP18NE, SP18SE, SP19NW, SP19NE, SP28NW, SP28SW and SP29NW (Figure 3). These geological maps were displayed in the workspace as raster images.

The following revisions were made to the geological interpretation in these areas:

Undivided Mercia Mudstone group covers most of Area 7 as the subdivisions identified by Howard *et al* (2008) postdate the existing geological mapping. The only subdivision shown was the Arden Sandstone Formation, which was incomplete in some areas. Completion of this unit allowed the Sidmouth Mudstone and Branscombe Mudstone Formation subdivisions to be delineated in the model. Several geological faults needed to be added or existing ones extended.

Significant areas of the river terrace gravels in the Tame valley and its tributaries have been worked and other areas backfilled since the original geological mapping had been undertaken. This necessitated the removal of extensive areas of the river terrace deposits (mainly First Terrace) and the insertion of many areas of worked and infilled ground to the geological maps and this model. Another issue was that several areas of worked or infilled ground had not been delineated on the map face and were shown as bedrock. These were corrected and added to the model.

On some rivers the mapped alluvium stopped at the edge of the River Terrace Deposits. It was continued across the terrace to join up with the alluvium of the River Tame.

Problems were noted in the south east corner of Area 7 and the north east corner of Area 6, where five outcrops of Bromsgrove Sandstone Formation had been mapped in two fault blocks, but overlying the Mercia Mudstone Group with no Tarporley Siltstone delineated. The necessitated a field visit to map in the Tarporley Siltstone. The area within the fault block was re-mapped as Tarporley Siltstone, apart from the middle outcrop of Bromsgrove Sandstone south of the village of Meriden, which was retained. The outcrop of Bromsgrove Sandstone to the north east of Balsall Common was changed to Tarporley Siltstone on the evidence of boreholes and a measured section in a railway cutting.

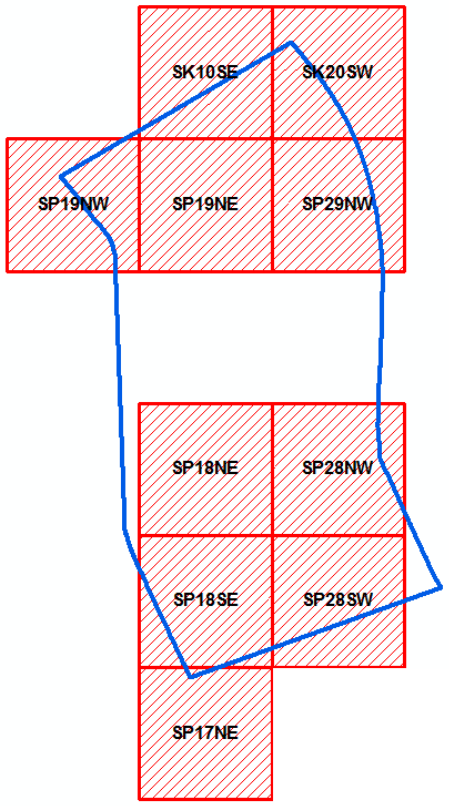

Figure 3 Plot of revised 1:10,000 scale maps used in the model. Area 7 model area outlined in blue, map sheets shown with red cross-hatching

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

A review of borehole records in the BGS *Single Onshore Borehole Index* (SOBI) in the model area was carried out and those that held sufficient geological information were selected for coding in the BGS *Borehole Geology* database (BoGe). A plot of borehole logs in the model area and the cross-sections constructed from them are shown in Figure 4.

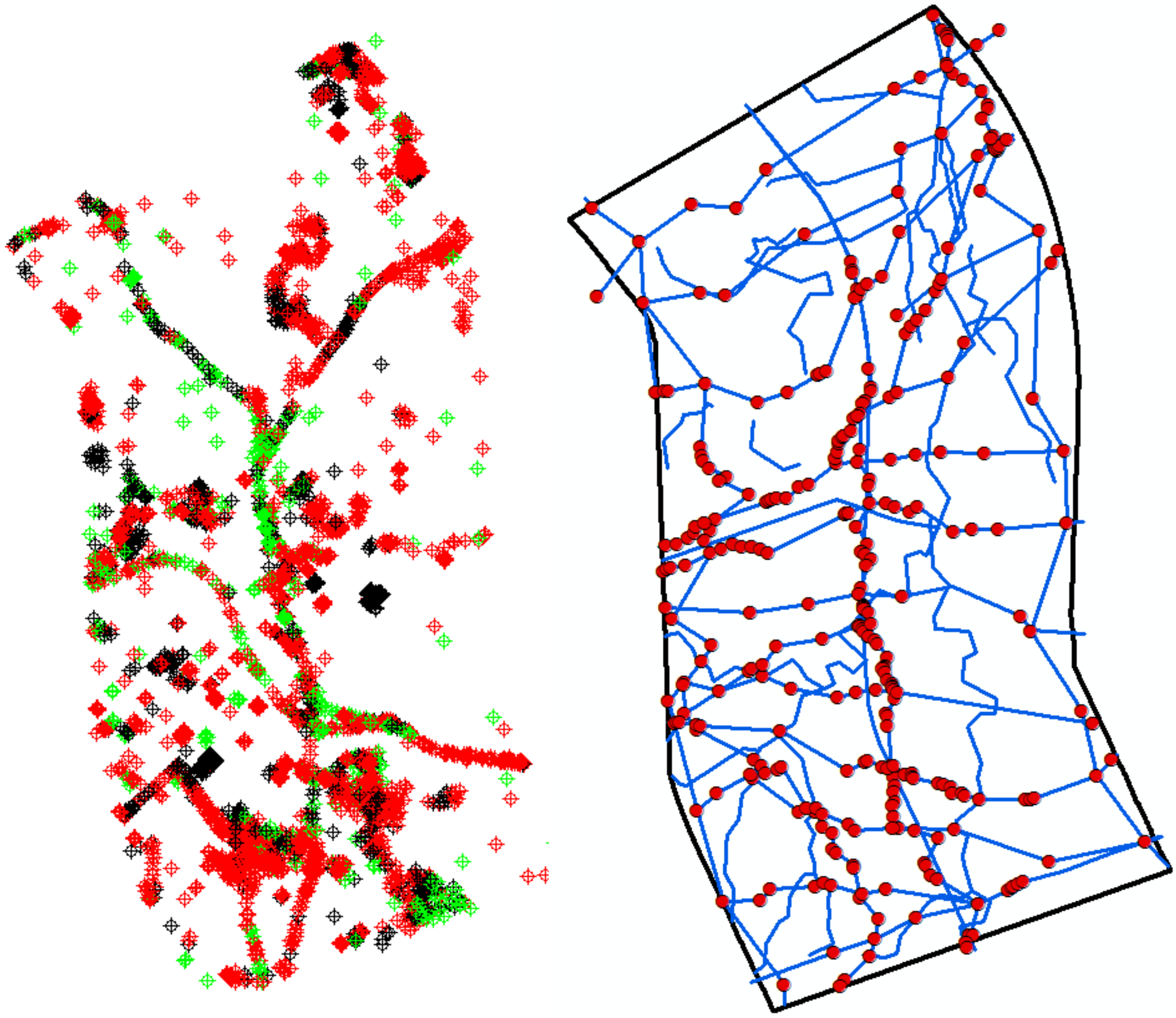

Figure 4. Left: Plot of all boreholes within the Area 7 model area. Coded boreholes with drilled depths of 10 m and over are coloured green, under 10 m in black. Red boreholes are not coded. Right: Plot of boreholes used (red dots) in the 39 cross-sections (blue lines) constructed to constrain the model. Model area outlined in black

After borehole coding was completed, the boreholes were extracted from the BGS *Single Onshore Borehole Index* (SOBI) database for use in the 3D modelling software using a set of queries. Two boreholes had been coded slightly outside of the project area so these were manually added to the BID/BLG files. 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. The records at the top of this list have a higher priority and the filter tool keeps these records and discards other matching records. Some records in the list contained entries that were used to 'fill-in' units that were missing, for example TPSF Tarporley Siltstone Formation. To allow a single combined log to be created the Content-Code and Interpreter have been altered to match the rest of the recorded entries. This left a total of 1549 boreholes coded out of a total borehole count of 4205.

5.5 OTHER DATASETS

Raster images of revised 1:10 000 scale geological maps were displayed in the model in order to match the model to them. These maps are listed in section 5.2 (Geological Linework). Some of the borehole logs were interpreted from gamma ray logs.

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 5). These records are kept as part of the model storage and metadata (QA) process and can be accessed as needed.

KA added 10 cross sections to the model

KA created the polygons for each of the geological units

KA finalised cross sections and calculation 17/3/14

KA checked cross sections after calculations from 24/3/14 to 10/4/14

Minor amendments to cross sections; checking all snap points on map and cross sections

Figure 5. Example of development log text

7 Model Assumptions, Geological Rules Used etc.

First order river terrace deposits (RTD1-XSV) are modelled beneath alluvium where the two units are adjacent to each other. Figure 6 shows the distribution of modelled alluvium and RTD1-XSV in the floodplain of the River Tame in the middle of the model area. Alluvium is displayed with a transparency, which allows the underlying RTD1-XSV to be seen. Irregular shaped white areas show areas of sand and gravel extraction, where both alluvium and RTD1-XSV have been removed. The alluvium polygons have been simplified to aid the model calculation.

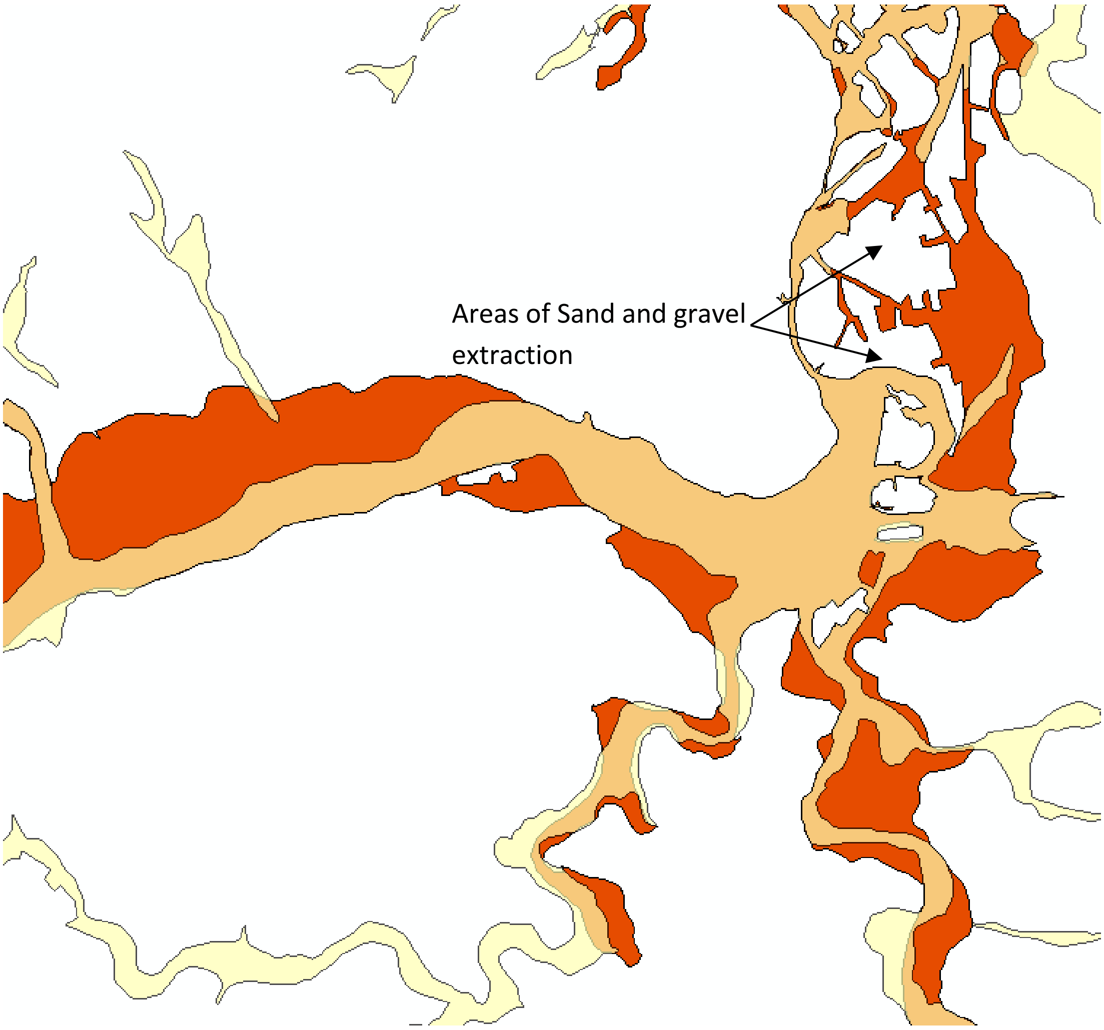

Figure 6 Modelled distribution of first order river terrace deposits (orange) beneath alluvium (pale yellow). Orange areas indicate where alluvium and first order river terrace deposits are present in the model. Areas of sand and gravel extraction can also be seen.

Similarly, the glacial deposits have been extended beneath younger units in the sequence. For example, mid-Pleistocene glaciofluvuial deposits (GFDMP-XSV) are modelled beneath alluvium, second order river terrace deposits (RTD2-XSV) and mid-Pleistocene till (TILMP-DMTN). Mid-Pleistocene glaciolacustrine deposits (GLLMP1-XCZ) are modelled beneath GFDMP-XSV. Figure 6 shows both units, with a transparency on GFDMP-XSV to show modelled extent of the underlying GLLMP1-XCZ.

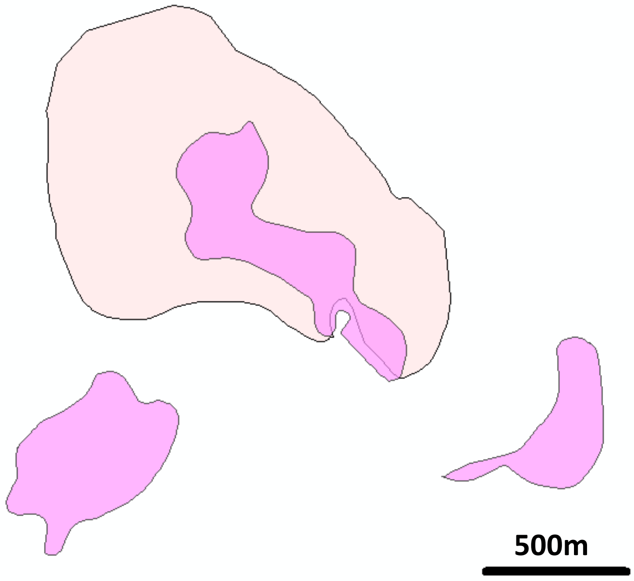

Figure 7. Extension of GLLMP1-XCZ beneath GFDMP-XSVin the middle of the model area around Coleshill

In the bedrock a mapped sandstone unit in the Kersley Member (labelled KRS-SDST on the geological maps) that occurs in the east of the model area has been modelled as Kersley Member (KRS-ARSC). Similarly, mapped sandstone units in the Whitacre Member are not separated out in the model.

The geological mapping only enables the Mercia Mudstone Group to be subdivided into its constituent formations in the southern half of the model; in the northern half only Mercia Mudstone Group is modelled.

8 Model Limitations

8.1 MODEL SPECIFIC LIMITATIONS

Although faults were drawn and modelled dipping at around 60° for modelling, all correlated lines are stepped across, either to join into the same unit in the footwall, or if absent there, to join the edge of the envelope at the surface.

Figure 4 shows all boreholes available in Area 7 with those over 10 m deep coloured green. This figure also shows the boreholes chosen as possibly useful in cross-sections where this subsurface data may constrain the model. This gives the model user some idea where the model is most and least certain.

Some of the deep boreholes have not distinguished the Tarporley Siltstone Formation. However, it is known to be present everywhere at the base of the Mercia Mudstone Group (Warrington *et a.*, 1980). It has been modelled in the southern half of the model (the northern half is modelled as Mercia Mudstone Group with no further subdivision) with an approximate thickness in places and only east of the fault around 424000, 282950. The use of MMG creates a discordancy with the units modelled in Area 8 but with a paucity of data, it is necessary. The continuity of the Arden Sandstone Formation across the country is known (Warrington *et al.* 1980). The current outcrop as shown is discontinuous in places and has had been made continuous. This was done as desk based work using *Geovisionary* software and clearly marked topographic features. However, there may be some errors in this interpretation. Additionally, the lithological variation mapped in DiGMap50k has not been retained between the Area 7 model and the Area 6 model and both areas are modelled as AS-SDSM.

For ease of modelling, the lithological subdivisions/beds of the Arsley Member (ASY), Kersley Member (KRS), Whitacre Member (WIT) and Alveley Member (ALY) of the Salop Formation have been removed in the model. Sandstone units in the Halesowen Formation have been modelled where they can be separated out. A subsurface area of the Warwickshire Group in the north west corner of Area 7 has not been subdivided into formations or members owing to lack of useful stratigraphic information.

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 this 3D geological model represents 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 model due to the spatial distribution of the data at the time of model 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 model calculation is checked to ensure that all units calculate to their full extent within the area of interest and the modelled geological surfaces are checked for artefacts such as spikes and thickness anomalies. 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

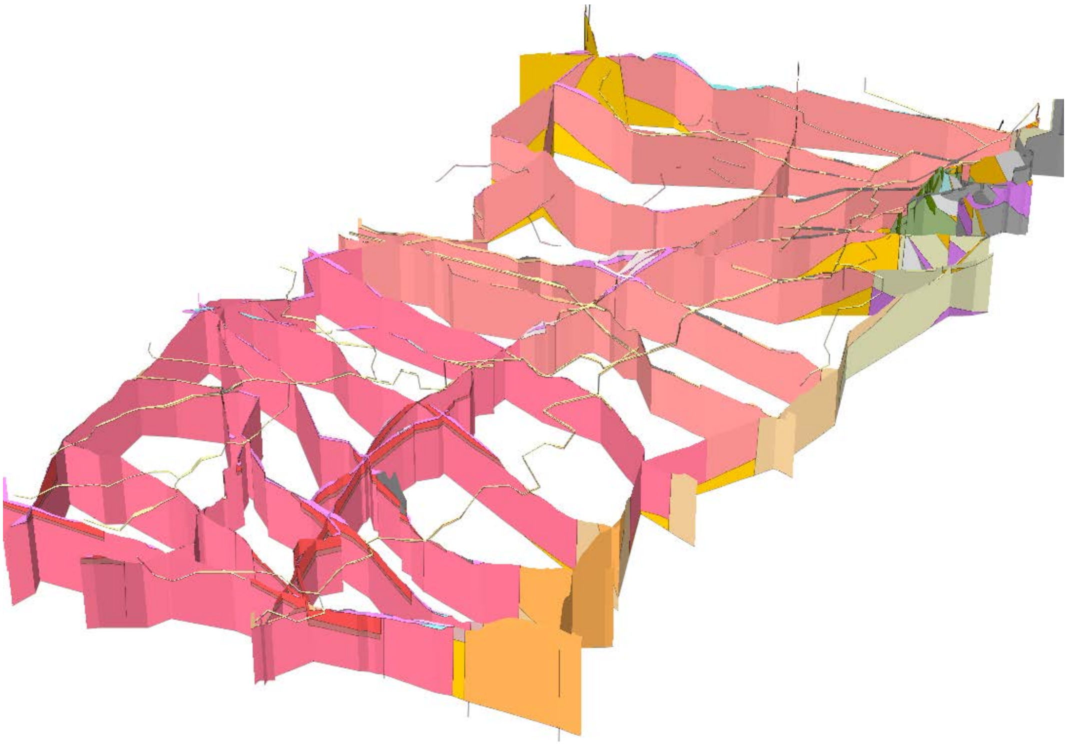

Figure 8. 3D view of all Area 7 cross sections from the south east (vertical exaggeration x10). Key as Table 1.

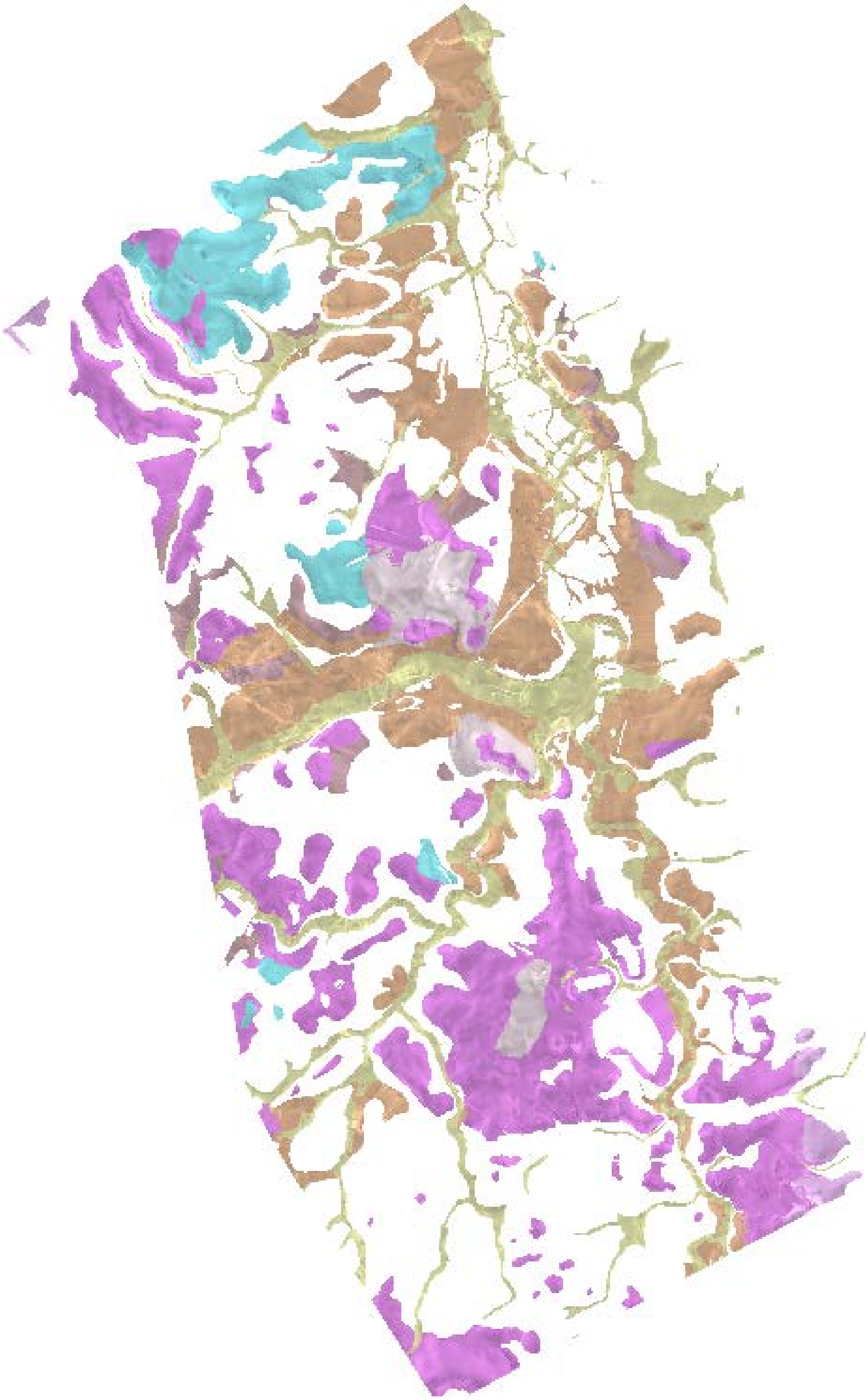

Figure 9. 3D view of all superficial deposits in Area 7. Alluvium is coloured yellow, river terrace deposits are pale orange, till is blue, glacial gravels are coloured pink. White areas indicate bedrock at surface. Key as Table 1.

Figure 10. 3D view of all artificial deposits (grey) in Area 7 with ALV (yellow) and RTD 1 (pale orange). This shows the extent of floodplain sand and gravel workings in the area. Key as Table 1.

Figure 11. 3D view of the modelled Permo-Triassic formations volumes, from the south-west. Vertical exaggeration x10. Key as Table 1.

Figure 12. 3D 'exploded' view of the Carboniferous units in Area 7 from the west (vertical exaggeration x10)

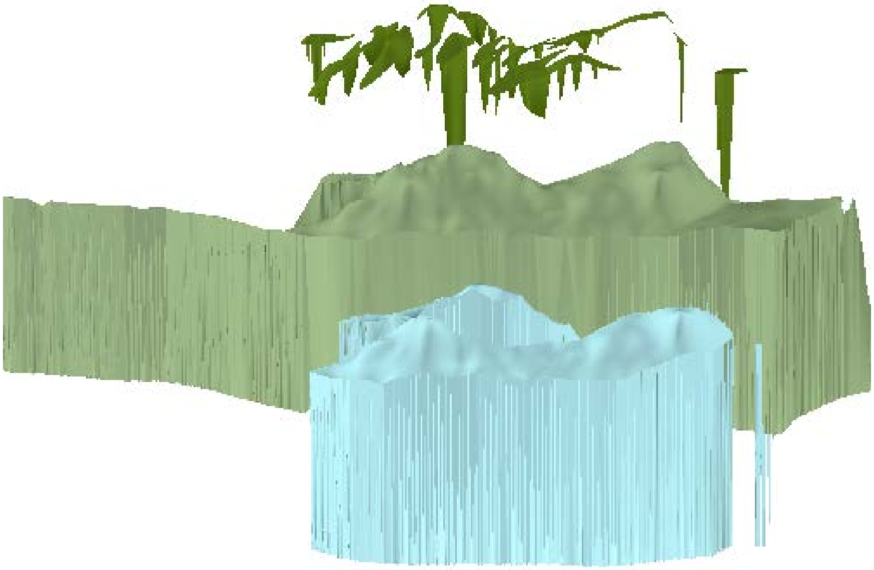

Figure 13. 3D 'exploded' view of the Cambrian units in Area 7, viewed from the west (vertical exaggeration x10). Key as Table 1.

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.

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