British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Metadata report for the Knowsley 3D geological model

Engineering Geology Programme

Open Report OR/15/020

BRITISH GEOLOGICAL SURVEY

ENGINEERING GEOLOGY PROGRAMME

OPEN REPORT OR/15/020

Metadata report for the Knowsley 3D geological model

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Summary

This report describes the construction of a 3D geological model for the Environment Agency (EA) in the Knowsley area in NW England. The buried sewerage network presents a potential source of pollution to the underlying Triassic Sherwood Sandstone Group aquifer in the Knowsley Industrial Park area. Weakly permeable superficial deposits beneath the site may provide a barrier to potential pollution of groundwater in the aquifer. The aim of the study was to develop and apply a 3D model of the superficial deposits beneath the park to a qualitative assessment of the vulnerability of the underlying aquifer to potential pollution. The study also aimed to devise a method for the integration of the 3D geological model of the shallow sub-surface with the buried utility network.

7 Superficial units were modelled in the area. Glacial till, comprising clay and silt, was the only weakly permeable deposit identified. Other deposits were interpreted as permeable. The underground utility network was integrated in 3D with the geological model. Those utilities overlying less than 2.5 m of till were interpreted to represent the most vulnerable parts of the underlying aquifer. The greatest relative vulnerability to the aquifer occurred in the south and south-west of the project area.

The study identified a novel method for the integration of a 3D geological model and a buried sewerage network. The identification of these utilities prioritised the areas of highest relative vulnerability of the Sherwood Sandstone aquifer to potential pollution from utility leakage. This approach enabled the development of a hazard identification and prioritisation scheme for future improvements to the buried sewerage network serving Knowsley Industrial Park.

1 Modelled volume, purpose and scale

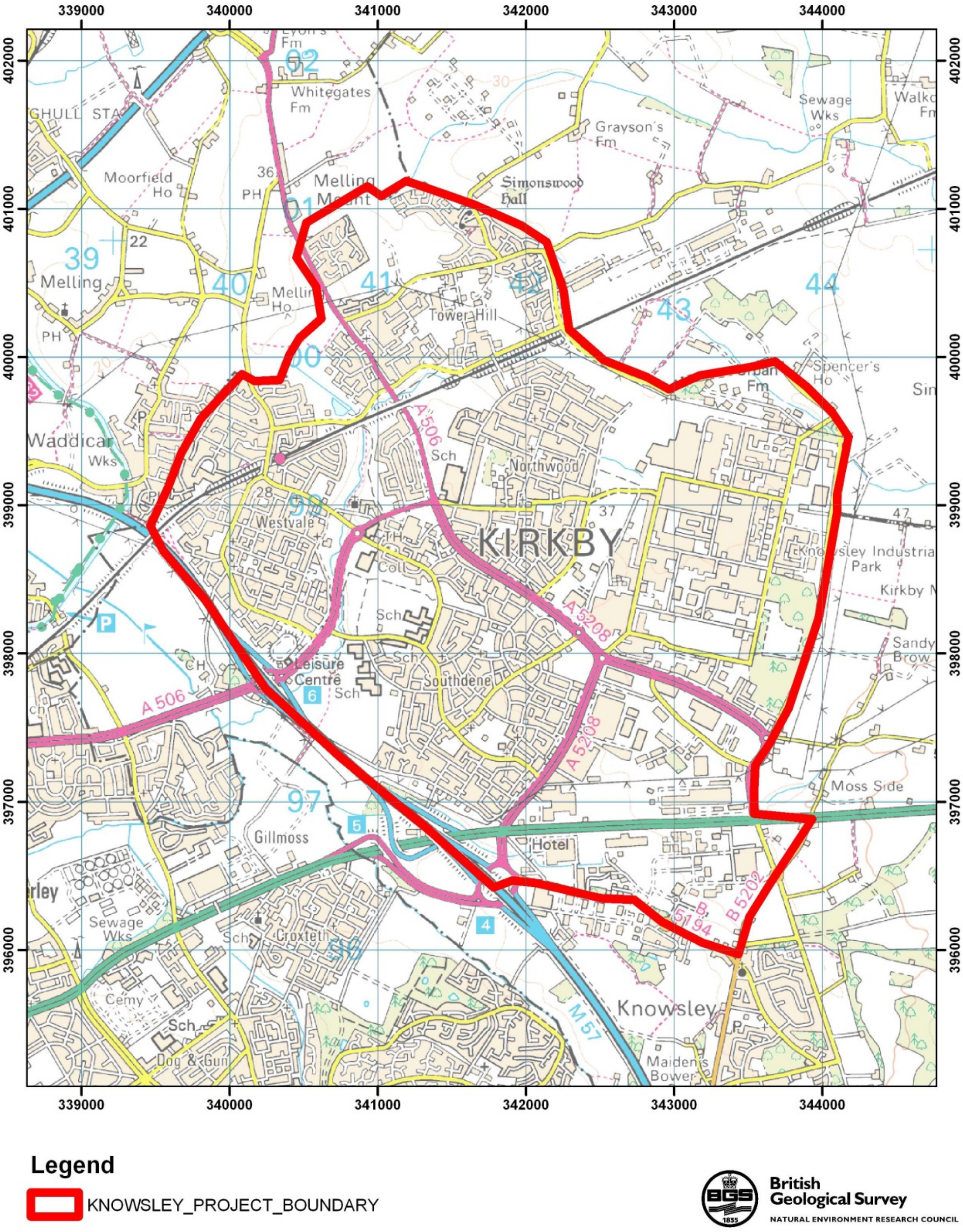


Figure 1 Model area (in red)

The model incorporates the town of Kirkby and the Knowsley Industrial Park located in the northwest of the project area. This industrial area lies on a sequence of superficial deposits comprising glacial, post-glacial and artificial deposits overlying the Sherwood Sandstone Group, that in places are deeply weathered to form loose sand (Price et al., 2008). The Sherwood

Sandstone Group is an important source of groundwater and identifying the vulnerability of the aquifer to potential pollution from the buried sewerage network was the driver for the project. United Utilities supplied the pipeline network for foul and surface water drainage, and the EA provided boreholes which were incorporated into the geological model. A detailed 3D geological model of superficial and artificial deposits was constructed based on the existing borehole data held by the BGS and that supplied by the EA. Once the model surfaces were calculated, they were interrogated in a GIS against the sewerage network data. This spatial data assessment was used to highlight the relative spatial vulnerability of the underlying Sherwood Sandstone Group aquifer to potential pollution based on the thickness and distribution of permeable and weakly-permeable superficial deposits.

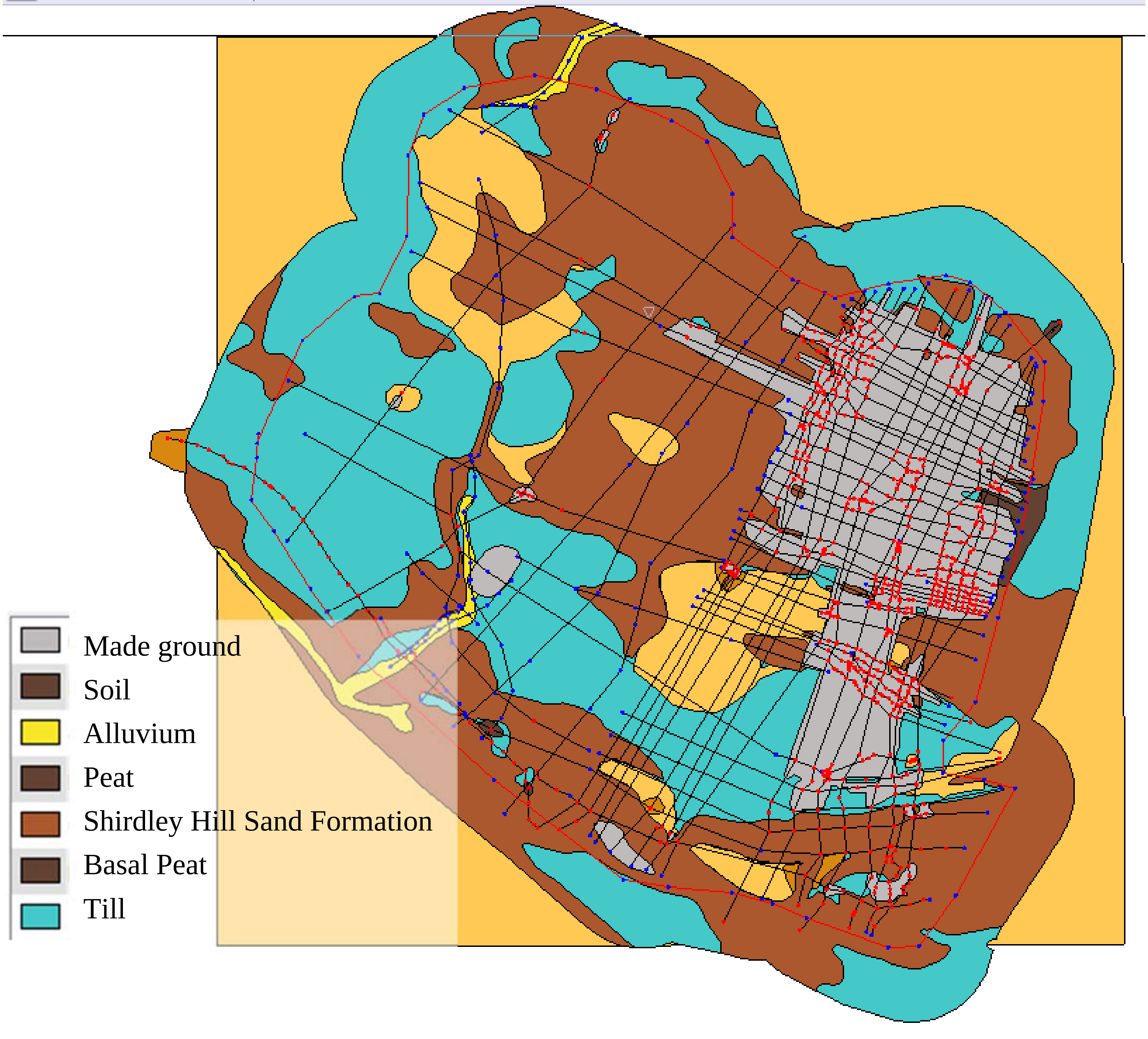


Figure 2 - Distribution of cross-sections and geological units at outcrop viewed in GSI3D

2 Modelled surfaces/volumes

7 superficial geological units and 5 glacial lenses were modelled and surfaces generated for each. The interpreted weathered top of the Sherwood Sandstone Group was modelled as a separate unit. The Sherwood Sandstone Group was the basal unit in the model and was given an arbitrary elevation of approximately -10 mOD. The geological model comprised the following units:

Name of modelled unit	Stratigraphy Description	Lithology Description

mgr	Made Ground (Undivided). Includes colliery spoil and industrial and commercial waste	Artificial/Manmade deposits
alv_1	Alluvium	East of tidal sluice river dominated processes depositing mainly silt, clay and sand. West of sluice active channel comprising mainly sand and gravel.
peat_1	Main peat deposit at surface	Peat
ssa	Shirdley Hill Sand Formation	Sand
peat_4	Buried Peat	Peat
till_1	Main till sheet	Gravelly, sandy, silty Clay
gfic_b	Subtill Glaciofluvial Ice Contact Deposits	Gravelly sand
w_ssg	Weathered Sherwood Sandstone Group	Gravelly sand
ssg	Sherwood Sandstone Group	Sandstone
gfic_l13_t	Intratill Glaciofluvial Ice Contact lens, base above 35m OD. In EA Knowsley Model	Gravelly sand
gfic_l13	Intratill Glaciofluvial Ice Contact lens, base above 35m OD	Gravelly sand
gfic_l14_t	Intratill Glaciofluvial Ice Contact lens, base above 35m OD. In EA Knowsley Model	Gravelly sand
gfic_l14	Intratill Glaciofluvial Ice Contact lens, base above 35m OD	Gravelly sand
gfic_l100_t	Intratill Glaciofluvial Ice Contact lens, base above 25m OD. In EA Knowlsey Model	Gravelly sand
gfic_l100	Intratill Glaciofluvial Ice Contact lens, base above 25m OD	Gravelly sand
gfic_l101_t	Intratill Glaciofluvial Ice Contact lens, base above 40m OD. In EA Knowlsey Model	Gravelly sand
gfic_l101	Intratill Glaciofluvial Ice Contact lens, base above 40m OD	Gravelly sand
gfic_l102_t	Intratill Glaciofluvial Ice Contact lens, base above 40m OD. In EA Knowlsey Model	Gravelly sand
gfic_l102	Intratill Glaciofluvial Ice Contact lens, base above 40m OD	Gravelly sand
gfic_l103_t	Intratill Glaciofluvial Ice Contact lens, base above 41m OD. In EA Knowlsey Model	Gravelly sand
gfic_l103	Intratill Glaciofluvial Ice Contact lens, base above 41m OD	Gravelly sand

Table 1 List of codes used in this model with their descriptions

3 Model datasets

DTM

The DTM source was NEXTMap (Intermap Technologies Inc) at a 25m cell size resolution. The date of the DTM extraction was not recorded but it is assumed to be the date that modelling commenced – Sep 2007

Borehole data

Borehole information was downloaded from the BGS corporate databases – Single Onshore Borehole Index and Borehole Geology. Additionally, over 300 paper borehole records were provided by the Agency from previous environmental site investigations carried out in the industrial park and were coded into the BGS databases. In total, 1279 coded boreholes were considered in the study. Of these, 733 were used to construct 58 geological cross-sections (Price et al., 2008). One site investigation containing 11 boreholes had subsequently been found to contain boreholes whose start height was based on a local survey. These boreholes sit approximately 26m above the model DTM, and for these the boreholes were hung from the DTM in order to use their data in drawing the sections.

Map data

The 1:50 000 DigMapGB-50 digital geological data (natural superficial deposits and bedrock) which was used to guide the cross-section drawing and creation of the geological unit distributions was extracted from version 4.16 in 2008 and was derived from the 1930s survey of the Wigan sheet which did not include artificially modified ground. Although modelling then took place approximately concurrently with resurvey of the district (1999-2010) any consequent revisions from the latter were not fed into the shapefiles that were utilised within the model. In addition, the Made Ground envelope drawn for the model differs in detail from the survey. Thus there are discrepancies from the final map data published in the Wigan 1:50 000 sheet in 2013 (and to be included in DiGMapGB-50 v8) which are only partly due to generalisation. Incorporating the updated natural superficial deposits and bedrock data into the model and the Made Ground into DiGMapGB-50 would require further intervention that for the moment cannot be justified [A J Mark Barron and S Thorpe, 09/03/2015]

GVS and GLEG Files

The generalised vertical section (.gvs) (see Table 1 and Appendix) and geological legend (.gleg) (see Appendix) 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 the project boundary. 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.

4 Software Used and Model workflow

4.1 SOFTWARE USED

- GSI3D V2.6
- ArcGIS 9.3
- MS Excel

4.2 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* ((Kessler, 2004)).

The interrogation of the pipeline data with the modelled surfaces was then completed using a series of spatial queries in ArcGIS (for more details see (Price, 2007))

5 Model Limitations

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.

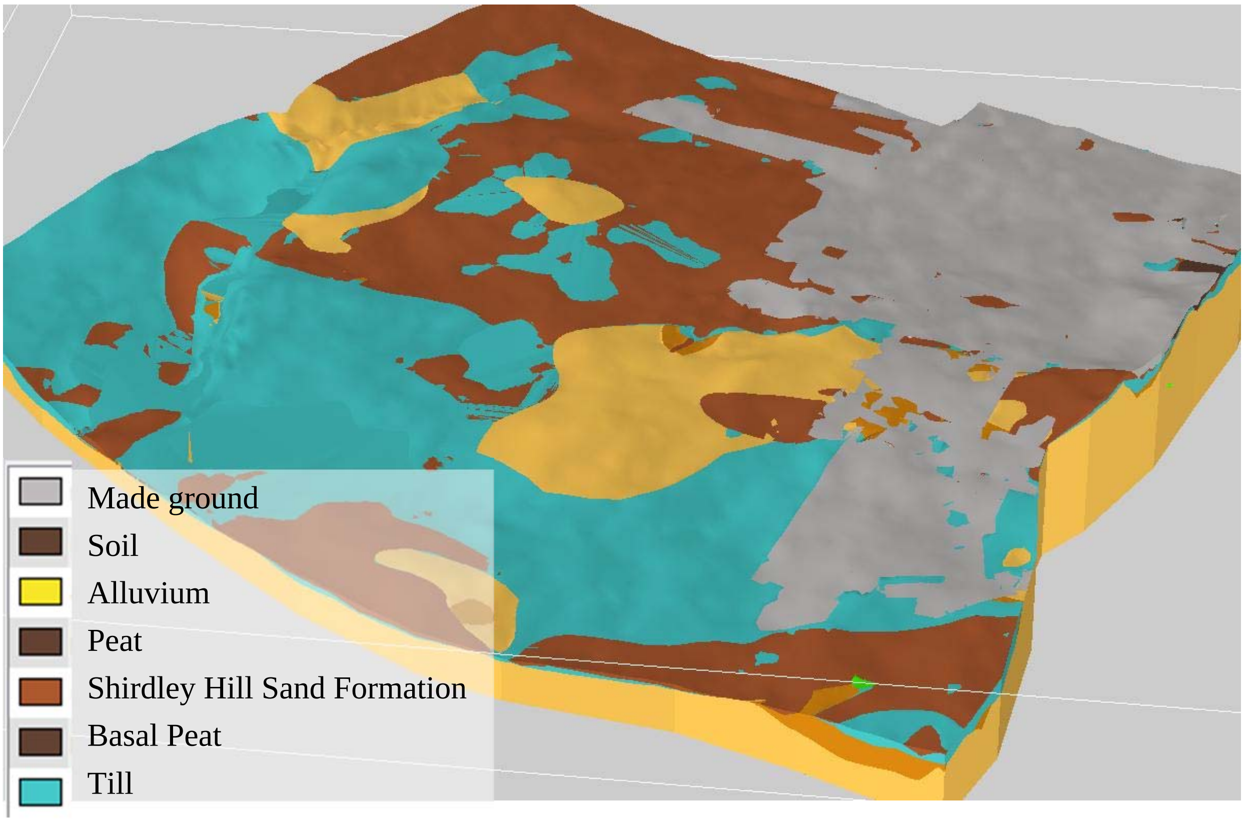
- Borehole coding (including observations and interpretations) was captured in a corporate database before the commencement of modelling and any lithostratigraphic interpretations may have been re-interpreted in the context of other evidence during cross-section drawing and modelling, resulting in occasional 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 informal units may also be used in the model, for example where no equivalent is shown on the surface geological map. 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.

6 Model image



7 Reference List

KESSLER, H, and MATHERS, S. 2004. GSI3D - The software and methodology to build systematic near-surface 3-D geological models - Version 1.5.

PRICE, S J, CROFTS, R G, TERRINGTON, R L, and THORPE, S. 2008. A 3D geological background for Knowsley Industrial Park and surrounding area, NW England. *Commisioned Report*.

Appendix

Key review of model

During a further review process in Feb 2015 some small modelling errors came to light. These included a site investigation whose boreholes had been entered into the BGS corporate system using a site datum without being converted to the correct level above Ordnance Datum (SI 44928 – corrected on 9th March 2015). One borehole in particular did not fit the geological understanding of the area. This borehole was located at an intersecting junction between two cross-sections shown below as Figure 3.

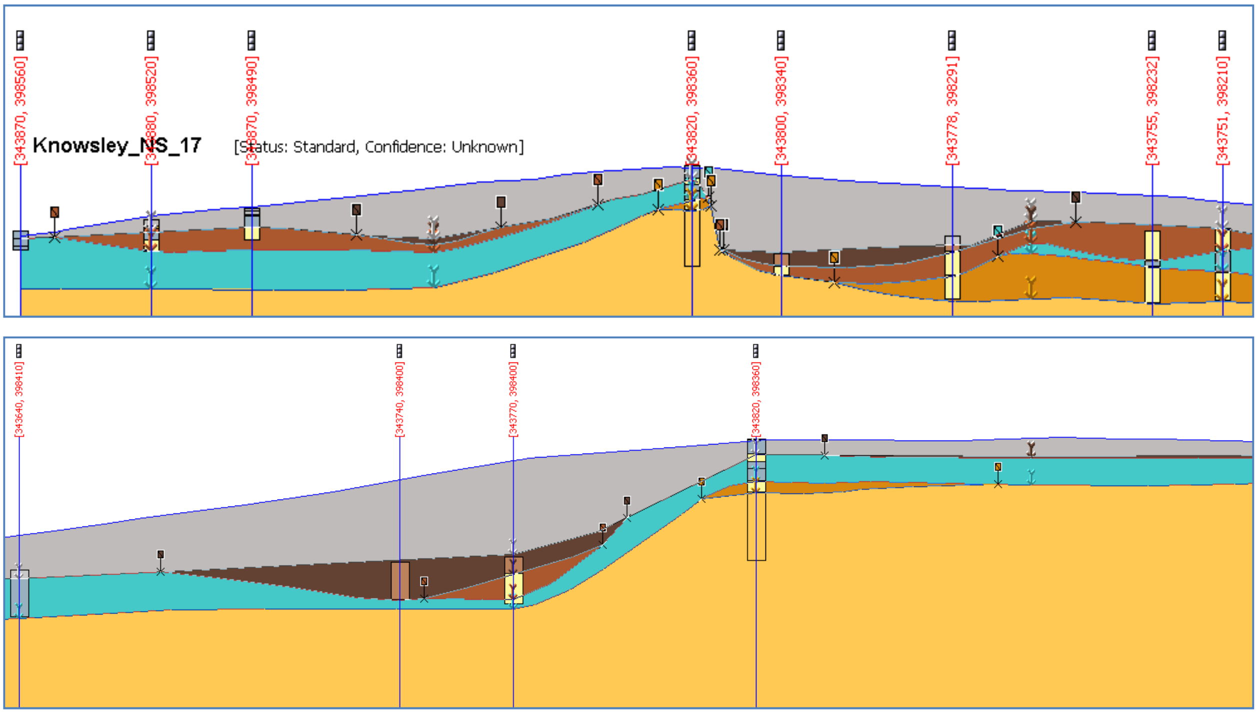


Figure 3 - Sections showing erroneous borehole start heights

As is clear, the borehole in question (SJ49NW1122.) appears to have ‘forced’ the superficial geology to a higher elevation than the surrounding geological units. Upon investigation it was revealed that this borehole was not located in the correct position by at least 1000m. The cross-sections were amended to exclude this false borehole information and this in turn altered the geological envelopes for the Peat_1 (dark brown – but transparency is set to 50% which allows the other units to show through), Shirdley Hill Sand (in dark orange) and the Weathered Sherwood Sandstone (in orange). The original project is shown on the left, and the amendments are shown on the right.

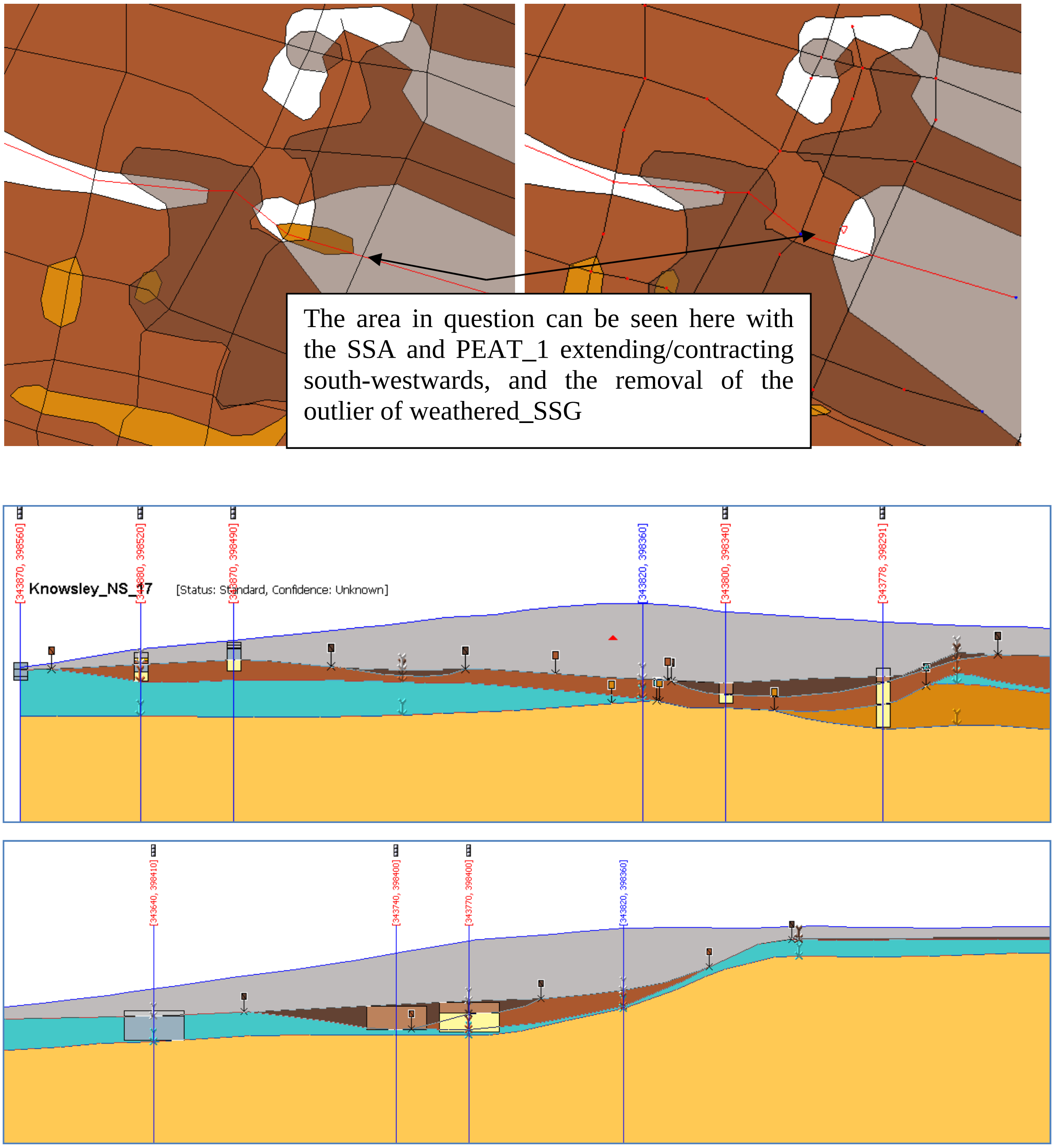


Figure 4 - Corrected sections after removing erroneous borehole

Some cross-sections show correlation lines that appear to be above the DTM. This may be because the original model was produced using a version of GSI3D which did not store the DTM. Therefore when the model was taken through the corporate check process a new DTM may have been introduced which was a higher resolution. The sections have been modified to represent a better fit to this more recent DTM (derived from the BaldEarth DTM model).

Below is a specific example of the changes made:

<u>Knowsley_WE_16</u>

This section shows the MGR line 'floating' above the DTM, the corrective action is shown in the Figure 6

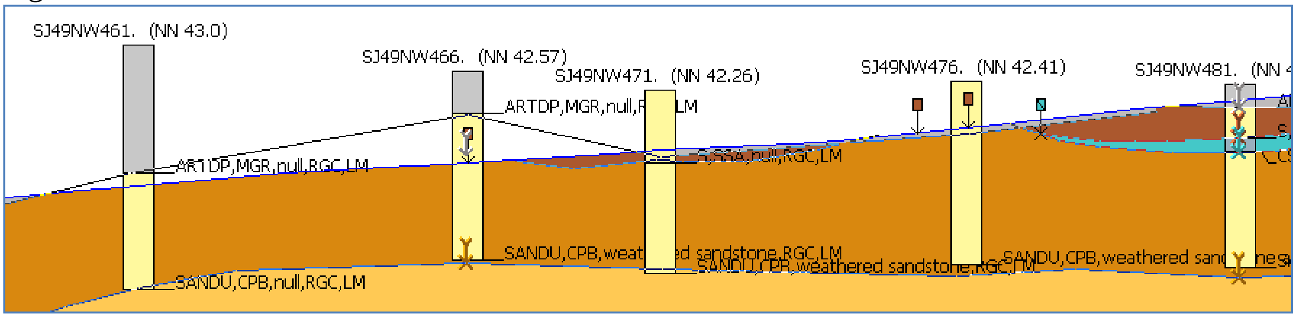


Figure 5 Cross-section Knowsley WE 16 before corrective amendments

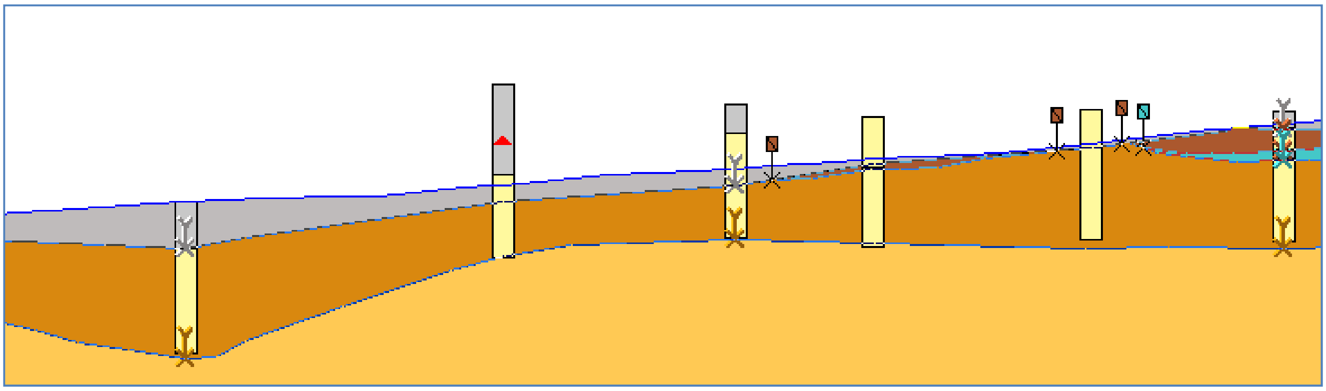


Figure 6 Cross-section Knowsley WE 16 after corrective amendments

GVS file

name	id	Stratigraphy	LEX_RCS	RCS	Age	Description
mgr	10	MGR	MGR-ARTDP	ARTDP	Holocene	Made Ground (Undivided). Includes colliery spoil and industrial and commercial waste
soil	31	SOIL	SOIL-SOIL	SOIL	Holocene	Soil
alv_1	33	ALV	ALV-ZCV	ZCV	Holocene	Alluvium. East of tidal sluice river dominated processes depositing mainly silt, clay and sand. West of sluice active channel comprising mainly sand and gravel.
peat_1	45	PEAT	PEAT-P	P	Holocene	Main peat deposit at surface
ssa	70	SSA	SSA-S	S	Devensian	Shirdley Hill Sand Formation
peat_4	72	PEAT	PEAT-P	P		
till_1	100	TILL	TILL-CZSV	CZSV	Devensian	Main till sheet

gfic_b	105	GFIC	GFIC-SV	SV	Devensian	Subtill Glaciofluvial Ice Contact lens
w_ssg	123	W_SSG	W_SSG-SV	SV		Weathered Sherwood Sandstone Group. Sand and Gravels
ssg	125	SSG	SSG-SDST	SDST		Sherwood Sandstone Group. Sandstone
gfic_l13_t	-713	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 35m OD. In EA Knowsley Model
gfic_l13	713	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 35m OD
gfic_l14_t	-714	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 35m OD. In EA Knowsley Model
gfic_l14	714	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 35m OD
gfic_l100_t	-800	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 25m OD. In EA Knowsley Model
gfic_l100	800	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 25m OD
gfic_l101_t	-801	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 40m OD. In EA Knowsley Model
gfic_l101	801	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 40m OD
gfic_l102_t	-802	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 40m OD. In EA Knowsley Model
gfic_l102	802	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 40m OD
gfic_l103_t	-803	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 41m OD. In EA Knowsley Model
gfic_l103	803	GFIC	GFIC-SV	SV	Devensian	Intratill Glaciofluvial Ice Contact lens, base above 41m OD

GLEG file

ALV	DESCRIPTION	248	231	40	255	TEXTURES\black.jpg
ARTDP	DESCRIPTION	200	200	200	255	TEXTURES\black.jpg
CZSV	DESCRIPTION	153	176	190	255	TEXTURES\CZV.jpg
GFIC	DESCRIPTION	50	250	0	255	TEXTURES\black.jpg
MGR	DESCRIPTION	191	187	187	255	TEXTURES\black.jpg
P	DESCRIPTION	188	130	92	255	TEXTURES\P.jpg
PEAT	DESCRIPTION	188	130	92	255	TEXTURES\P.jpg

S	DESCRIPTION	255	249	158	255	TEXTURES\S.jpg
SDST	DESCRIPTION	255	201	84	255	TEXTURES\SV.jpg
SSA	DESCRIPTION	171	88	46	255	TEXTURES\black.jpg
SSG	DESCRIPTION	255	201	84	255	TEXTURES\black.jpg
SV	DESCRIPTION	255	249	158	255	TEXTURES\SV.jpg
TILL	DESCRIPTION	68	200	200	255	TEXTURES\black.jpg
W_SSG	DESCRIPTION	217	136	15	255	TEXTURES\black.jpg
ZCV	DESCRIPTION	206	212	174	255	TEXTURES\ZCV.jpg