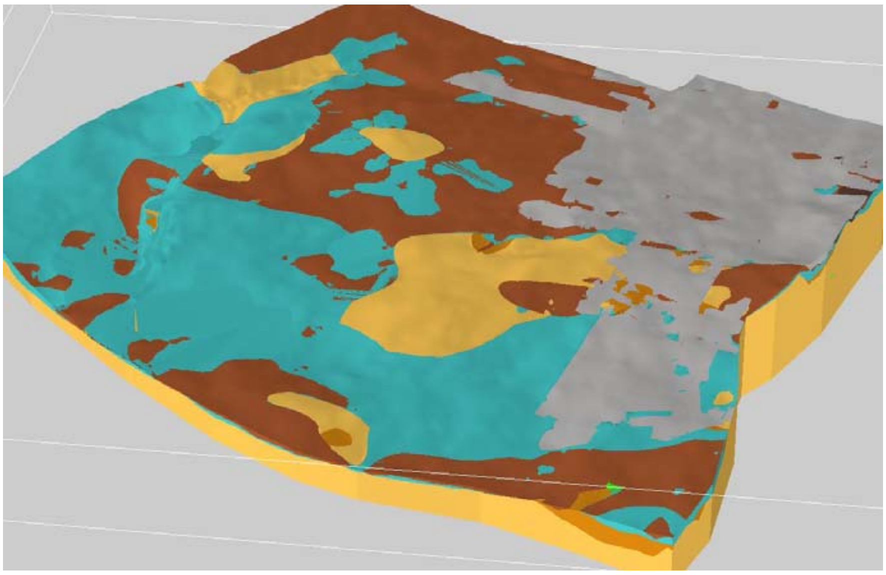
A 3D geological background for Knowsley Industrial Park and surrounding area, NW England

Physical Hazards Programme

Commissioned Report CR/07/203 N

Report prepared for the Environment Agency by the British Geological Survey



BRITISH GEOLOGICAL SURVEY

PHYSICAL HAZARDS
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A 3D geological background for Knowsley Industrial Park and surrounding area, NW England

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Foreword

This report is the published product of a study by the British Geological Survey (BGS). The project was undertaken following a request by Keith Seymour, Senior Technical Specialist at the Environment Agency NW and Kerry Diamond, (Technical Specialist, Environment Agency NW) to provide a scope for a study to enable the Agency to assess the potential pollution risk to the Sherwood Sandstone Aquifer from potentially leaking sewers.

Acknowledgements

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Jon Ford (BGS) is gratefully acknowledged for his advice and assistance on adapting the methodology for point inspection of pipeline data against grids derived from the 3D geological modelling.

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Summary

This report describes the results of a study carried out by the British Geological Survey (BGS) on behalf of the Environment Agency NW to investigate the underlying geology beneath Knowsley Industrial Park, Merseyside, NW England. The overarching aim of the project was to establish a 3D geoscience framework beneath the Knowsley Industrial Park to enable the Environment Agency (the Agency) to assess the vulnerability of the underlying Sherwood Sandstone aquifer. The vulnerability of the aquifer to pollution from current and historic contamination of land, potentially leaking foul sewers and contaminated surface water drains could then be assessed by reference to the underlying geology.

In addition to the 3D geological model, United Utilities pipeline data for foul and surface water drainage was provided by the Agency. This pipeline information was analysed and integrated with the geological data to provide an assessment of the potential linkage between the pipes and the underling bedrock or superficial geology in which they are sited.

Over 300 additional paper borehole records were provided by the Agency from previous environmental site investigations carried out in the industrial park and incorporated into the BGS databases. In total, 1279 coded boreholes were used in the study. Of these, 733 were used to construct 58 geological cross-sections.

The 3D geological model revealed a sequence of superficial deposits across the site comprising glacial, post-glacial and artificial deposits overlying the Sherwood Sandstone Group, that in places are deeply weathered to form loose sand. In the south-east and north-west of the site, rocks belonging to the Sherwood Sandstone Group crop out at surface. The vulnerability of the Sherwood Sandstone aquifer beneath the site, to pollution from contaminated water, depends in part on the distribution and thickness of weakly permeable superficial deposits such as clay or silt. The geological model has revealed that till is the only clay dominated unit present beneath the site and for this reason, invert levels of foul and surface water pipes were compared to this geological deposit as it may influence the potential vulnerability of the underlying aquifer. Invert levels represent the elevation of the base of the pipe.

4722 pipeline segments were analysed and classified according to their minimum invert level (representing the maximum depth below ground level) recorded for each segment. This information was used to identify pipeline segments that occurred above, below or within till. Pipeline segments interpreted to lie within or above the till were subdivided according to whether they were underlain by greater or less than 2.5 m of till. 2.5 m represents the average thickness of till calculated from the 3D geological model. Pipeline segments whose invert level occurs beneath the till will lie directly within the Sherwood Sandstone aquifer or sand and gravel dominated superficial deposits and therefore the relative hazard potential may be higher than those where clay dominated superficial deposits occur between them and the underlying aquifer.

In general, the results indicate that the northern part of Knowsley Industrial Park and the north-western part of the wider project area are underlain by greater than 2.5 m of till and that pipelines lie above the top surface of the till or within it. In contrast, the southern part of Knowsley Industrial Park and the south-western part of the wider project area are underlain generally by less than 2.5 m of till and pipeline segments occur below the till or directly within the Sherwood Sandstone aquifer.

This information can be used as a preliminary screening or prioritisation tool. It can identify potential areas where the Sherwood Sandstone aquifer is most vulnerable to pollution from contaminated groundwater from poor condition, potentially leaking sewers and drains in the subsurface.

Introduction and background

Project background provided by the Agency:

Knowsley Industrial Park is one of the largest industrial parks in Europe. The site was occupied by a Royal Ordnance Factory (ROF) from the 1930s to approximately 1960. Since then the area was developed as an industrial park. It is currently home to a wide variety of commercial and industrial organisations and a number of authorised processes and activities take place.

Most of the land is owned by the Local Authority. The infrastructure on many of the sites is known to be in a poor condition and there is potential for pollution of groundwater from historic contamination of land within the estate. Specifically, there are concerns over the condition of the public and private drains and sewers within the estate. The Agency has initiated a project to co-ordinate activities within the estate and to develop a strategic approach to future work. This will include:

- Approaches to the sewerage provider to assess and improve the condition of drainage infrastructure within the estate.

- Approaches to the local authority and other landowners to improve infrastructure within individual sites.

- Pollution prevention visits to individual premises.

Where possible, the most vulnerable areas of the estate should be dealt with first. It is envisaged that by developing a geological model of the subsurface conditions at the estate, the prioritisation process can take account of risks to the deeper aquifer. The information will also assist the Agency in prioritising its efforts in responding to planning consultations.

There is data available on superficial deposits and shallow groundwater from a number of site investigations, carried out for a variety of purposes. These include the support of planning applications, for IPPC permitting purposes and those provided voluntarily by occupiers. It would appear that protection of the deeper aquifer is patchy. Shallow groundwater, where present, appears to be at a similar level to drains and sewers and in places there appears to be considerable interaction between the shallow groundwater and the drainage system. Shallow groundwater is polluted in many parts of the estate.

1.1 AIM AND OBJECTIVES

The Agency required the BGS to produce a refined grid of cross-sections showing the superficial deposits within the area centred around Knowsley Industrial Park to complement cross-sections produced as part of the ongoing Lower Mersey Basin and North Merseyside Aquifer groundwater resources study within the Agency. The cross-sections were used to construct a 3D geological model.

The main objective of this focused study is to provide the Agency with a better understanding of:

- the hydrogeological relationship between deeper and shallow groundwater in the superficial deposits

- the vulnerability of and potential recharge to the Sherwood Sandstone aquifer that underlies the industrial park from current and historic contaminative land use

Specifically, the objectives of the work were:

- To code the remaining boreholes within the project area describing the detail within the superficial deposits
- To construct a minimum of 28 cross-section in the central region of Knowsley Industrial Park and 6 wider local sections around the site
- To illustrate the relationship between buried infrastructure (drains and sewers) and the superficial deposits or bedrock with which they may be in contact

Project area

The project area is shown in Figure 1. Knowsley Industrial Park is situated near the town of Kirkby approximately 6 km north-west of Liverpool City Centre, NW England. The Knowsley area is bounded to the west by the Knowsley Expressway (M57), to the south by the East Lancs Road (A580) and to the north by the M58 motorway. The eastern part of the area is generally rural and characterised by areas of peat, locally called “Moss”, including Simonswood Moss.

Topographically, the area lies between 20 and 45 m OD, with a gentle slope across the project area from east to west towards the tributaries of the River Alt. The River Alt flows northwards beyond the project area to drain into the Irish Sea, south of Formby.

The project area comprises Knowsley Industrial Park and part of Knowsley Business Park to the east. The central and western parts of the area are dominantly residential areas or public open space.

Geological background

1.2 GEOLOGICAL OVERVIEW

The study area lies within North Merseyside close to the edge of the Permo-Triassic East Irish Sea Basin, which is bounded on its eastern edge by the Western Boundary Fault. The bedrock is the Sherwood Sandstone Group, which is Triassic in age. The sandstone is most probably from the lower part of the Chester Pebble Beds Formation and underlain by the Kinnerton Sandstone Formation. These beds are generally poorly exposed throughout the area due to an extensive cover of natural and man-made superficial deposits of Devensian to Holocene age. An overview of regional geology can be found in Jones *et al*, (1938) and Aitkenhead *et al*, (2002). A summary geological map of the area is provided in Figures 2 and 3.

1.2.1 Sherwood Sandstone Group

The Sherwood Sandstone Group is considered to be represented by the Chester Pebble Beds Formation that comprises well-sorted, medium-grained, red-brown and orange-yellow sandstone with small-scale, low-angle trough cross-bedding with angular to sub-angular sand grains. Small extraformational rounded quartzite pebbles and mudstone clasts may be present in part. The unit was deposited as large fluvial, subaqueous bars in a major braided river system. The sandstone is exposed in Hewitt’s Lane Quarry [4405 9725] and the nearby Knowsley Brook. There were numerous exposures of pebbly sandstone in a number of small quarries in the Kirby area, for example on County Road (formerly Delf Lane) [4225 9820], that are now backfilled. Buildings constructed of this local sandstone show random, but generally rare, pebble inclusions in about 10% of the building blocks. The sandstone has a proven thickness of 300 m in the Pilkington Simonswood (SJ49NW/2) borehole.

1.2.2 Bedrock Structure

The Permo-Triassic rocks lie in the post-Varsican rift basin of the West Lancashire Basin, a landward extension of the East Irish Sea Basin (Kirby *et al*, 2000 and Aitkenhead *et al*, 2002). The Permo-Triassic rocks lie unconformably on Carboniferous strata. The eastern margin of the West Lancashire Basin is defined by a syn-depositional normal fault, namely the Western Boundary Fault on which the present day cumulative throw is in excess of 1000 metres. Within the West Lancashire Basin the dip is generally northwards.

1.2.3 Superficial Deposits

Much of the study area is covered by extensive spreads of superficial deposits. These can be divided into three major categories:

- Glacial deposits (mainly till), but including coversands (Shirdley Hill Sand Formation), presumed to be mainly of late Devensian age
- Fluvial, Holocene (post-glacial) age deposits associated with development of the headwater streams of the river Alt, and peat
- Anthropogenic deposits, recording man's modification of the surface in the last fifty years.

The area is likely to have suffered a number of glaciations during the Pleistocene epoch. However, most of the current superficial deposits present in the area are likely to have been deposited during Late-Devensian time, when ice streams radiating from centres in the Lake

District and adjoining Irish Sea Basin. The general pattern of ice movement, based on glacial striae and till fabrics (Worsley, 1968 and Longworth, 1985) supports movement into the area from this north-westerly direction, with subsidiary streams from a northerly direction constrained to the east by the Pennine escarpment. Buried valleys identified in the district (Grayson, 1972 and Howell, 1973) are sub-parallel to the direction of ice movement. The project area lies on the “interfluve” between two of these buried channels.

The depositional products of the glaciation are dominated by till, which forms a cover of variable thickness over most of the study area. During the last phase of the Devensian glaciation large volumes of meltwater were released sub and supra-glacially. At the close of the Devensian period, coversands were deposited across much of the Lancashire Plain (Wilson *et al*, 1981) between the current day Mersey and Ribble valleys. During the post-glacial (Holocene) period large areas of peat developed on the Lancashire Plain and the modern river systems developed. As sea levels recovered marine deposits were deposited around the edges of the Lancashire Plain.

1.3 DESCRIPTION OF SUPERFICIAL GEOLOGICAL UNITS

The distribution of the geological units across the area is based on surveys carried out in 1930 by L H Tonks. This survey had the great advantage of being conducted when the area was completely rural in nature. In recent times a large number of boreholes and trial pits have been sunk to accompany development of the industrial and business parks, residential areas and associated infrastructure projects. The records of these provings have all been examined during this project and the correspondence of positive fit with the 1930 map is estimated to be greater than 95%. However, as boreholes are normally located prior to development, any subsequent removal or disturbance of ground during foundation construction or site levelling is likely to have disturbed the natural juxtaposition of the superficial deposits.

Additionally, as a number of these deposits are thin in nature (e.g. Shirley Hill Sand Formation) or potentially problematical to construction (e.g. peat) it is likely they have been removed or significantly disturbed from their last know natural distributions. Furthermore, many industrial sites have large areas of constructed hardstanding, most probably created, in a large part, by “cut-and-fill” techniques, bringing about further disruption of the surface deposits. Any modern attempt to geologically remap the area of Kirby is therefore reliant to a great extent on the scrutiny of additional data such as boreholes and trial pit records. The basis for the distribution of superficial deposits for this project in the Kirby area is, therefore, taken as the 1930 mapped boundaries as currently shown on BGS approved 1:10 560 scale County Standards. Only the extent of made ground within the boundary of the Knowsley Industrial and Business Parks has been amended on a significant scale. This assumes a skin of made ground has been produced during the development of these sites. Elsewhere in Kirby, local additions of made ground have been added by recent resurvey, for example noise barriers adjacent to residential areas on Valley Road [4080 9825] and embankments for the Kirkby Stadium [4040 9800].

A summary of the geological succession beneath the site is provided in Table 1.

1.3.1 Made Ground (mgr)

In the last 50 years Kirby has developed from a small, rural south Lancashire hamlet to a small town with the planned growth of residential, industrial and business premises. During this development a widespread cover of anthropogenic (artificial) deposits, proved in over 80 per cent of boreholes in the project database, has been established. In urban areas, the deposits often have no well-defined landform, and the boundaries are ill-defined or gradational. More organised spreads of made ground are often associated with waste from specific industries for example quarrying at Old Rough Road [4575 9900] and brick making on Cut Lane [4480 9740], or the backfilling of marl pits as on Ribbler’s Lane [4125 9715]. However, and more significantly, large scale industrial developments initiate large areas of made and disturbed ground. In this project, therefore, the extent of made ground has been taken to include all the area contained within the boundary of the Knowsley Industrial and Business Parks. In addition, most sites within Knowsley Industrial Park are built on a gently sloping surface. Thus, in order to provide a level surface, a proportion of each site is probably a combination of cut-and-fill construction, i.e. partly worked ground (cut) and partly made ground (fill). In this report we refer to all these areas as “made ground” with the assumption that a skin of made ground has been produced during the development of the industrial and business sites. This may equally hold for the residential and recreational areas of Kirby. However because of the limited borehole coverage in these areas this assumption is unconfirmed for these latter areas.

None of the current study area was mapped at a time when the survey systematically recorded areas of made and worked ground. Now however, four categories of deposit are normally recognised at the mapping level:

- **Made Ground-** where material is known to have been placed on the pre-existing land surface
- **Worked Ground-** where the pre-existing land surface is known to have been excavated
- **Infilled Ground-** where the pre-existing land surface has been excavated (Worked Ground) and subsequently partially or wholly backfilled (Made Ground).
- **Landscaped Ground -** where the pre-existing land surface has been disturbed, typically for large, modern industrial and residential developments such as Kirby.

In the current project area any area of made ground is likely to consist of a combination of these categories and to comprise reworked site material and “waste” products imported for the surrounding district. Generally, thicknesses are between zero and 2 m but locally thickness in excess of 5 m may be established as for example in borehole SJ49NE/1101.

1.3.2 Peat (peat_1 and peat_4)

The Lancashire Plain has the second largest extent of lowland peat in the UK (Shimwell, 1985). Peat development began about 8,000 years ago and at one time may have formed an almost continuous cover over much of the study area. Extensive deposits remain in the area immediately to the east of the project area on Kirkby Moss and Simonswood Moss. The extent of the peat deposits is likely to have diminished in extent and thickness since the deposits were mapped in the 1930 due to subsequent peat cutting and/or removal prior to development. Peat cutting was active in 1930 as indicated on BGS field slips for the western edge of Kirkby Moss. The current mapped area may therefore not be true reflection of its current day distribution. Due to drainage, the peat is now often very compacted and original thicknesses of more than 5 m may now be reduced to less than 3 m.

1.3.3 Alluvium (alv_1)

Narrow strips of alluvial deposits are associated with the headwater streams of the River Alt, namely Croxteth Brook [4195 9600] and Bank or Simonswood Brook [4050 9990]. The deposits are Holocene in age and generally comprise up to 3 m of yellow-grey to grey silt and sandy silt with a thin, basal gravel lag up to 0.3 m thick.

1.3.4 Shirdley Hill Sand Formation (ssa)

The Shirdley Hill Sand Formation has accumulated in a flat spread over much of the Kirkby area. The deposits comprise loose, clean, fine- to medium-grained sand. Small mounds, possibly relict dunes, were noted in the 1930 geological survey and recorded on BGS field slips for the areas now covered by the Northwood and Southdene areas of Kirkby town. The height of some dunes may have exceeded 5 m. The "dunes" in the Kirkby area show a preferred west-north-west – east-south-east orientation (Jones *et al*, 1938). However, due to development across the whole Kirkby area, no sign of these mounds now exists and any mounds were, most likely, spread over the surrounding surface. The deposit now rarely exceeds 2 m in thickness. Exceptionally, 4.5 m was proved at the southern end of section NS_12. The sand is believed to be aeolian in origin (Wilson *et al*, 1981) and derived from glaciofluvial sheet deposits (sandur) deposited in the Irish Sea during lower sea levels and blown by winds from a north-westerly quarter. The deposits are likely to have accumulated in the late glacial period between about 15 000 and 8 000 years ago.

1.3.5 Glaciofluvial Ice-Contact Deposits (gfic_b, gfic_l3, gfic_l4, gfic_l101, gfic_l102 and gfic_l103)

Glaciofluvial Ice-Contact Deposits are generally found in an intimate relationship with till. They commonly have a lenticular form and can be found beneath, within and overlying till deposits. They usually consist of sand, but gravel rich deposits may also occur and these often have a very variable clay content. The thickness of the deposits is also highly variable, being anywhere between tens of centimetres to tens of metres thick. It is generally difficult to correlate these bodies over any distance, even where there area a large number of closely spaced boreholes. The thickest development in this area occurs beneath the north-western corner of the Knowsley Industrial Park to the west of Marl Road [4320 9935] (see for example Knowsley sections **WE_3** and **NS_4**). Here, the deposit comprises up to 9 m of red-brown and orange-brown sand with some pebbles and thin, rare clayey horizons. These deposits are likely to have originated as meltwaters passed over, within or under the ice sheet, eroding the local soft Triassic bedrock. In particular, the area here may have formed as a moulin kame (Benn and Evans, 1998) with water cascading down a vertical fissure (crevasse) in the ice as a "waterfall". The impact of the falling water would erode the soft sandstone, and then carry the debris only a short distance before it is rapidly redeposited. Those Glaciofluvial Ice-Contact Deposits found within till are generally water saturated, and may contain perched water tables.

1.3.6 Till (till_1)

Till within the study area is a product of the Devensian Glaciation. It generally comprises firm to stiff reddish brown and greyish brown clay with pebbles and cobbles of Carboniferous sandstone and limestone, and sedimentary and igneous rock from the Lake District massif. The clay matrix is predominantly derived from mudrocks of Permo-Triassic age. The till is generally massive but may contain shear planes that relate to the mode of deposit associated with the temperate warm based ice sheets (Paul, 1983). The upper 3 m or so of the till is often decalcified, and fissuring may also extend to a similar depth. The fissures are generally tight but may open wider in prolonged dry periods.

The thickness of the till within the project area is extremely variable. Approximately 630 boreholes within the project area contain material interpreted as till and were used to define its thickness and geometry within the 3D geological model (Section 4). Of these, approximately 400 boreholes prove the full thickness of the till where the drilled depth of borehole terminates in deeper superficial or bedrock units below it. Figure 5 shows the distribution of boreholes that terminate within Sherwood Sandstone bedrock.

A minimum proved thickness of the till is provided by the remaining 230 boreholes where its base is not intersected. The thickness information provided by the inclusion of additional boreholes recording the minimum thickness of till is an essential part of the modelling process that reduces uncertainty and enhances confidence in the resulting model. These data act as further control points during model calculation. They provide valuable thickness information in areas that would have no data at all if only boreholes proving rockhead were used. If a model was calculated based on the latter, the calculated till thickness may be less than that proved as a minimum thickness in a borehole record. Inclusion of the borehole records where a minimum thickness is recorded therefore reduces uncertainty and increases confidence in the modelled unit. Further details of the 3D modelling methodology are provided in Section 4.

Over most of the area till is less than 5 m thick, thinning to a feather edge against bedrock outcrops as for example on **Section NS_5** approaching Gores Road [4300 9805].

Till thickness exceeding 7 m is uncommon. Borehole SJ49NW/1025 m proved a maximum thickness of 11 m as shown on **Section NS_11**. This may be within an isolated hollow in the bedrock surface. A cluster of boreholes at the junction of Moss End Way and Woodward Road [4380 9940] e.g. boreholes SJ49NW 841-843 proved at least 9 m of till as shown in **Section WE_1**. Overall, the boreholes available for the project suggest a general increase in thickness in a north-westerly direction across Knowsley Industrial Park as shown in a number of north-south section e.g. **Section NS_8** and **_11**.

1.3.7 Weathered Sherwood Sandstone Group (w_ssg)

In this area the Sherwood Sandstone Group shows weathering from sandstone bedrock to an unconsolidated sand. Generally, where concealed by natural superficial deposits, this is to depths of between 1.5 and 3 m as shown for example on **Section NS_8**. Previously, this phenomena was often considered to be a glaciofluvial in origin. However, it is now firmly established that weathering in Permo-Triassic sandstones is the norm below glacial deposits. Where the sandstone is exposed, as at the junction of Arbour Lane and County Road [4235 9820], weathering to a depth of 1.4 m has been recorded.

	Map Unit	Model Unit	Lithology	Environment (inferred)	Model Code of Geological object
Holocene	Made Ground	Made Ground	Mixed	Anthropogenic (Artificial Deposits)	mgr
	Alluvium	Alluvium	Sand or peaty sand	Fluvial	alv_1
	Peat	Peat	Peat	Organic	peat_1
	Shirdley Hill Sand Formation	Shirdley Hill Sand Formation	Sand	Aeolian	ssa
	NA	Buried Peat	Peat	Organic	peat_4
Pleistocene (Devensian)	Glaciofluvial Ice-contact Deposits	Intra-till lenses	Sand and gravel	Sub-glacial and supra-glacial drainage associated with glacial ice	gfic_l3, gfic_l4, gfic_l101, gfic_l102, gfic_l103
	Till	Till	Pebbly clay, thin interbedded sands and silts	Sub-, supra- and intra glacial	till_1
	Basal glaciofluvial Ice-contact Deposits	Basal glaciofluvial deposits	Sand and gravel	Sub-glacial drainage	gfic_b
Bedrock	N/A	Weathered Sherwood Sandstone Group	Sand with some angular sandstone gravel		w_ssg

Table 1 Generalised Vertical Section (GVS) for project area

3D geological modelling and cross-section construction

Geological modelling of superficial deposits in the project area was carried out using GSI3D™ modelling software (Kessler *et al*, 2004). The software and its workflow allow the user to create 3D geological models by combining interpreted digital borehole data, Digital Terrain Models (DTMs), digital geological maps and other data to construct an intersecting grid of cross-sections. From the series of intersecting cross-sections, the surface and sub-surface distribution of each geological deposit is then defined and the geological model is calculated to derive the 3D distribution and geometry of each geological deposit.

Importantly, the 3D geological model is based on the geological interpretation and correlation of cross-sections made by the user using all the available data and information. GSI3D™ provides the flexibility to include the geologist's interpretation of the geometry and thickness of each geological unit using all available data to support it.

1.4 3D MODELLING WORKFLOW

The modelling workflow in GSI3D™ consists of four main stages:

- digital borehole coding and interpretation,
- cross-section construction and correlation,
- definition of surface and sub-surface distribution of units (based on correlation in stage 2)
- 3D model calculation and iteration.

1.5 BOREHOLE CODING AND INTERPRETATION

Lithological and lithostratigraphical interpretations of boreholes were derived from scanned paper records held within the National Geoscience Data Centre at the BGS and additional records provided by the Agency. In total, 344 additional boreholes were received, sited, scanned and digitally coded for the Knowsley Industrial Park area.

1279 coded boreholes were available for use in Knowsley Industrial Park and the wider area, including an additional 344 boreholes provided by the Agency. The location of all non-confidential boreholes (and Agency boreholes) used to create the cross-sections is shown in Figures 4 and 5.

Most borehole information was concentrated in relatively small, dense areas in the eastern parts of the site associated with multiple phases of site investigation within Knowsley Industrial Park. In contrast, the central and western parts of the area are characterised by more widely spaced boreholes.

1.5.1 Borehole coding methodology

Boreholes were digitally coded according to the description of the down-hole lithology recorded on the borehole log. The quality of the original description varied according to the age of the record and the purpose for which the borehole was drilled (e.g. site investigation, water abstraction or coal exploration). In addition to the lithological interpretation, a relevant stratigraphic code was applied where possible by the coder and with reference to the published, digital DiGMap50 geological dataset. The stratigraphic codes used for the project were derived from the BGS Stratigraphic Lexicon (http://www.bgs.ac.uk/lexicon/lexicon.html).

Sites of all boreholes can be obtained from the BGS website at http://www.bgs.ac.uk/geoindex/home.html

The lithological codes for the superficial deposits were derived from the BGS Superficial Deposits Coding Scheme (Cooper *et al*, 2005). The scheme uses six letters to denote the primary lithology of a deposit and is shown below in Table 2.

Lithological Units	**Code**
Peat	P
Sand	S
Silt	Z
Clay	C
Gravel	V
Cobbles	L
Boulders	B
For Made Ground	FILLU

Table 2 Unlithified deposits lithological coding scheme component codes

Where more than one lithological unit is present, the letters can be combined in descending order of importance from left to right, to reflect the complete lithological description of the material. In the case of sandy clay for example, the lithological code would be CS, where clay is the primary lithology and sand the second. The coded lithological and stratigraphic information was added to the BGS Borehole Geology database to be retrieved subsequently for correlation.

1.5.2 Borehole elevation

Each borehole was referenced to an elevation with respect to Ordnance Datum (OD). This information is not always included on borehole records however. If the elevation was recorded it was added to the database. If missing, the elevation was either derived manually from Ordnance Survey contours and spot heights or automatically from the NEXTMap Digital Terrain Model. Where present, mismatches between DTM and borehole start heights may be due to anthropogenic changes in the ground level since the borehole drill date such as excavations or made ground and inherent errors in the DTM itself.

1.6 CROSS-SECTION CONSTRUCTION AND CORRELATION

58 cross-sections were constructed and geologically correlated within GSI3D™ and their locations are shown in Figure 6. Coded borehole data, digital elevation models, scanned and georegistered map images and digital geological maps were imported and used to define the distribution and geometry of the superficial deposits along the lines of section. The Sherwood Sandstone Group bedrock was represented schematically with its base shown on the cross-sections at -10 m aOD.

NEXTMap (Intermap Technologies Inc) 25 m cell size DTM data was used to provide the top layer or "cap" to the cross-sections. Digital, coded boreholes were imported into GSI3D™ from the BGS Borehole Geology database in their correct spatial positions. From the complete database of coded boreholes, the highest quality logs were selected for inclusion in the cross-sections. The selection process was based a number of key criteria, including depth (preferably boreholes reaching rockhead) and quality of the description.

Cross-sections were constructed by selecting boreholes after this assessment. As successive boreholes are added, the line of section is created.

In general, north-east–south-west and north-west–south-east lines of section were created to allow the most representative geological cross-sections across Knowsley Industrial Park and the surrounding Kirkby area, to be identified.

1.6.1 Cross-section correlation

Cross-sections displaying borehole information are displayed in GSI3D™. Correlation lines are digitised between boreholes corresponding to individual geological units proved within them. Geological units are correlated based on their order of superposition and relative age. This order defines which geological deposits can occur stratigraphically above or below others and is stored in a model file called a Generalised Vertical Section (GVS). A summary of the GVS used in the project is shown in Table 1.

Importantly, each correlation line is made up of a series of nodes digitised by the geoscientist. When all of the cross-sections are combined, the lines and nodes for every geological unit provide the basis for the calculation of the model. This method of on-screen digitisation, using boreholes and digital geological map data to constrain the surface and sub-surface distribution and geometry of the geological units, allows a detailed 3D conceptual model of the geological history of the area to be developed by the geoscientist.

Consequently, the GSI3D™ methodology provides the flexibility to incorporate the geoscientist's interpretation where borehole or other data, may be uncertain. For example, where boreholes do not penetrate rockhead, the geoscientist is able to enhance the 3D model, by using surrounding borehole data or local knowledge, to define the thickness or geometry of the deposit that provides additional information to the minimum level of data provided by the borehole. The resulting 3D model therefore does not rely on borehole data alone.

In general, uncertainty in the thickness and geometry of the modelled geological units is greatest in data poor areas. Confidence is highest in data rich areas. Data rich areas are represented by dense areas of closely spaced boreholes.

In addition, regional cross-sections created for the Lower Mersey/North Merseyside Aquifer – Superficial and Bedrock Geology study (Crofts *et al*, 2006) were incorporated to provide a regional geological framework from which to work in the present study.

1.6.2 Cross-section export and pipeline intersections

36 selected cross-sections are provided in Appendix 3. The same cross-sections at 1:10 000 scale are provided as A1 plots on the associated project CD and folded as part of the report. The cross-sections were exported from GSI3D™ with a vertical exaggeration of 10. For the purposes of cross-section presentation, an arbitrary depth cut-off of -10 m OD was used to define the bedrock level for presentation purposes. This allowed the proportional display of superficial deposits on cross-sections that contained boreholes many hundreds of metres deep. The borehole depths presented on the cross-sections therefore may extend to a deeper level than shown.

For the purposes of the project, the surface intersection of all foul sewers and surface water drains are shown on the cross-sections. The thickness of each line corresponds to the absolute recoded diameter of the pipeline segments derived from the pipeline dataset "Outline of KIP projectSEWERS_polyline" provided by the Agency and sourced from United Utilities. This information provides a visual assessment of the 2D surface relationship of pipeline locations and the underlying geology. It does not represent the relationship between the modelled geology and the true depth position of the pipeline. The latter was assessed using a method described in Chapter 5.0.

1.7 DISTRIBUTION OF SUPERFICIAL GEOLOGICAL UNITS

1:50 000 scale digital geological data (DiGMapGB50) was used to aid correlation and provide an initial assessment of the surface distribution of the superficial deposits beneath the project area. In addition, scanned and geo-registered 1:10 560 scale County Series geological maps provided higher resolution information on the information of those geological units that crop out at the surface. Geo-registration ensures that scanned map data appears in the correct spatial position "on the ground".

Information from the correlation lines on cross-sections provided evidence for the sub-surface distribution of each geological unit, including those units for which there is no evidence at the surface. Envelopes defining the combined surface and sub-surface distribution of each geological unit were constructed.

1.8 MODEL CALCULATION

The 3D geological model was calculated by combining the correlated units present on cross-sections with the envelopes defining the distribution of those units. The modelling calculation in GSI3D™ uses a proprietary Triangular Irregular Network (TIN) algorithm to create a series of surfaces representing the top and base of each geological unit from the individual nodes along correlation lines. The model is calculated "top-down" beginning at the ground surface and working downwards from younger to older geological units. This stack of surfaces forms the geological model from which the top and base elevation and thickness of every geological unit can be calculated and exported. An example of an exported grid showing the calculated thickness of till is shown in Figure 7. All digital grids in ASCII and ESRI format are provided on the associated project CD.

1.9 MODEL EXPORT

The calculated geological model was exported as ASCII grids with a 10 m cell size. Each ASCII grid representing the top and base elevation and thickness of each geological unit, rockhead elevation and thickness of superficial deposits was then converted to ESRI format grids. The grids representing the top and base elevation of the till and its thickness were subsequently used to inspect the elevations of foul and surface water drains relative to each grid.

1.9.1 Rockhead Elevation

The rockhead elevation grid (Figure 8) represents the elevation of bedrock either beneath superficial deposits, weathered Sherwood Sandstone or at ground surface.

1.9.2 Thickness of Superficial Deposits

The thickness of superficial deposits is shown in Figure 9. It includes weathered Sherwood Sandstone sediments as they are principally composed of sand or gravelly sand and therefore behave as an unconsolidated superficial deposit.

1.10 QUALITY CONTROL

Overall Quality Control for the 3D geological model, including cross-sections, envelopes and derived outputs, was undertaken by Dick Crofts, District Geologist for Lancashire and Cheshire.

Drains and sewers

Attributed GIS data relating to the distribution of foul sewers, surface water drains and combined sewers was provided to BGS by the Agency. The data was originally sourced from United Utilities and prepared for the Environment Agency by Entec Ltd in 2004. The two datasets of relevance that showed depth and geometry of buried pipeline assets beneath Knowsley Industrial Park and Kirkby were:

- **Outline of KIP projectSEWERS_polyline**. This data vector layer contained information including spatial distribution of foul and surface water pipes (held as individual pipeline segments of variable length), pipe diameter for x and y dimensions (millimetres), the invert level of the start and end of the pipe below ground level (metres) and relative to Ordnance Datum (metres) and classification as foul, surface or combined.
- **Outline of KIP projectWWNO_elipse**. This point data layer contained attributes relating to manhole covers, including diameter for x and y dimensions (millimetres) and depth to node (metres). Depth to node was interpreted as equivalent to depth to pipeline.

These two datasets are shown in Figure 10.

Pipeline data was used within the study area to assess the potential vulnerability of the Sherwood Sandstone Aquifer to pollution from potentially contaminated water leaking from sewers and drains.

1.11 DATA TYPE AND FORMAT

The data was supplied as ESRI GIS shapefiles and MapInfo polygons representing 4722 individual foul sewer (F), surface drains (S) or combined (C) pipeline segments and 4549 manhole covers of variable length. Information on the subsurface position of the pipelines, either recorded as depth below ground level or as an elevation in metres relative to Ordnance Datum (m OD), was of highest importance for use within the project.

For the pipeline data, 1010 records did not contain information on the start and end depth below ground level of the pipeline and 1037 did not contain values for the start and end invert level relative to OD. For 23 records, data on start and end depth below ground level was recorded but no corresponding values are recorded for start and end invert elevation. For 30 records, data on start and end invert elevation are recorded where there are no corresponding values for start and end depth below ground level.

For approximately 600 records, only one value corresponding to start or end depth below ground level or elevation relative to OD was recorded. In these cases only a start or end level invert level for the pipeline was recorded.

In total, 2488 records contained data for start invert elevation, end invert elevation, start depth below ground level and end depth below ground level combined.

1.11.1 Data modelling

A number of techniques were tested to model the pipeline data in 3D in order to integrate them into the 3D geological model. A 3D model of the pipeline data was created successfully for pipelines where elevation data was available in a 3D modelling package called GoCAD™. However, it was not possible to integrate the 3D pipeline model with the 3D geological model. Therefore, It was not possible to show the pipelines at their correct elevation within the geological cross-sections.

In order to illustrate the spatial relationships between the surface position of the pipes and the underlying geology, the surface intersections of the pipeline segments were shown against the geological cross-section. (See Section 4.3.2). The thickness of the pipes on the cross-sections reflects the angle at which the cross-section intersects it. This may vary from true thickness (where the cross-section intersects the pipe at right angles) to a larger apparent thickness where the pipe is intersected at an oblique angle.

1.11.2 Data classification

Two levels for either depth below ground level or elevation relative to OD are recorded for each pipeline segment. One invert level represents a start level and the second represents the end level. The pipeline data was classified based on the lowest elevation level recorded as this represented the maximum depth of the pipeline segment below the ground surface. The invert level relative to OD of each foul, surface water drain and combined pipeline segment was classified into ten classes, including those where no data was recorded and the result is presented in Figure 11.

1.12 INTEGRATION WITH OUTPUTS OF 3D GEOLOGICAL MODEL

The vulnerability of an aquifer to a source of pollution depends in part on the distribution and thickness of weakly permeable sediments that broadly correspond to those whose primary lithology is either clay-rich or silt-rich (Lelliott *et al*, 2006). These sediments or sediment assemblages may reduce the vulnerability of an aquifer to potential pollution by acting to inhibit or reduce lateral or vertical flow towards the aquifer. A qualitative assessment of the vulnerability of an aquifer to potential pollution can therefore be made with reference to the thickness and distribution of weakly permeable superficial deposits overlying the aquifer. Within Knowsley Industrial Park and the surrounding area, potentially leaking sewers and drains are considered a possible source of pollution to the underlying Sherwood Sandstone Aquifer.

Glacial till represents the only superficial deposit whose primary lithology is either clay or silt. The composition of the till is variable however. Within the till, clay or silt is present as a matrix with sand and gravel commonly present as lenses or as secondary or tertiary components of the till matrix (see Chapter 3.0). For the purposes of the project however, till has been attributed as a weakly permeable unit for the qualitative assessment of aquifer vulnerability within Knowsley Industrial Park. Further assessments of the hydrogeological properties of the superficial deposits along with groundwater flow paths, were beyond the scope of this study.

1.12.1 Pipeline elevation relative to till elevation

2488 pipeline segments contained complete attributes for start and end invert depths below ground level and elevation relative to OD. For the purposes of comparison to till, other pipeline data that contained null values for depth below ground level or elevation relative to OD were excluded.

The extent of the calculated top and base elevations and thickness of till exported from the 3D model of superficial deposits were compared to the positions of surface drains and foul sewers. Pipeline segments whose invert level occurs beneath the base of the till will lie directly within the Sherwood Sandstone aquifer or sand and gravel dominated superficial deposits. Similarly, pipeline segments that lie beyond the extent of the modelled till surface are interpreted to lie within the Sherwood Sandstone aquifer or other underlying or overlying permeable deposits. Pipeline segments that lie above the top surface of the till or within it, may pose a lower relative hazard from pollution to the underlying aquifer, compared to those that lie beneath it, depending on the thickness of the till.

Pipeline segments stored as lines were initially converted to points representing the end points of each segment. It was assumed that the direction of digitising in the original dataset was carried out in the direction of decreasing invert elevation so that the end point corresponds with the lowest elevation. The minimum invert elevation (maximum depth) was selected and compared against three surfaces derived from the 3D superficial deposits model. The surfaces represented the top and base elevation of the till and its thickness.

A query was then designed to assign values of "Above_Till", "Below_Till" and "Within_Till" to indicate the relative elevations above OD of each point to the till. The points were then appended to the pipeline segments and classified (Figure 12).

1.12.2 Pipeline elevation relative to till thickness

For those pipeline segments that lie above or within till, the degree to which till will provide some protection to the underlying aquifer is dependant partly on its thickness. Where these pipelines overly thin till, the relative hazard may be greater than where they overly thick till. It is therefore necessary to assess the pipelines classified in Section 5.2.2 in relation to the thickness of the till and provide a qualitative assessment of the relative hazard where pipelines overlies thin till.

The terms "thick" and "thin" till are relative. Previous studies (Lelliott *et al*, 2006) have used a thickness value of 5 m to classify till as permeable or weakly permeable. This is because thin till, close to the ground surface may be affected by weathering and flow may be enhanced as result of the creation of fractures and fissures. It was beyond the scope of this study to interpret the weathering state of till beneath Knowsley Industrial Park. To provide a qualitative assessment of the relationship between pipelines and till thickness, the average thickness of till was calculated as 2.5 m and used to define "thick" and "thin" till, (Figure 13). Thick till is defined as till greater than 2.5 m thick and thin till is defined as less than 2.5 m thick.

1.12.3 Discussion of pipeline relationship to till

926 pipeline segments occur below the basal surface of the till (Figure 12). Where pipeline segments occur beneath the base of the till it is interpreted that they lie within weathered or un-weathered Sherwood Sandstone bedrock or Glaciofluvial sand and gravel. These pipeline segments may therefore be considered a greater potential hazard than the 1059 segments that lie either above the top surface of the till or within it (Figure 13).

The potential hazard exhibited by the pipeline segments that lie either above the top surface of the till or within it, is partly dependant on the thickness of the till that underlies or surrounds them. Of those segments that lie above or within till, 558 overlie greater than 2.5 m of till while 501 overlie less than 2.5 m of till.

1.12.4 Uncertainty

Only pipeline segments containing a full record of pipeline invert levels below ground level and relative to OD were used. Errors in depth below ground level or elevation relative to OD may be present but the data has been used as presented to avoid the introduction of any further errors. For example, pipeline segment 33239847 to the north-east of the project area records an elevation of 67.64 m OD and may represent an error. Consequently, each pipeline segment invert level should be checked when using the data in any further analysis or derived data.

In addition, it was assumed that pipelines were digitised in the direction of decreasing elevation when the original dataset was created by United Utilities. If this was the case then the end points used to derive the relative elevation of pipeline segments to the elevation of the till would be correct. If not, there will be uncertainty in the part of the pipe that represents the lowest elevation, and the deepest below ground surface.

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Appendix 1 Borehole data supplied

This table provides a summary of borehole data associated with sites supplied by the Environment Agency with corresponding BGS borehole registration numbers. For some sites boreholes were not registered. Where this is the case the reason for not siting the boreholes is given in the table.

SITE_REFERENCE	SITE_NAME	REGISTRATION NO'S	COMMENTS	REGISTRATION_COMMENTS
CL6/KN/1055B	YORKSHIRE COPPER TUBE - TOPHAM	SJ49NW 803-813		
CL6/KN/1010	FORMER KME SITE	DUPLICATE		NOT SCANNED NOT INCLUDED IN ACCESSION - DUPLICATE OF SI'S 16868 & 23633 SJ49NW 455 - 533
CL6/KN/1056	DELTIC WAY	UNSITED		POOR BH LOC PLAN
CL6/KN/1017	KNOWSLEY COLLEGE CHERRYFIELD DRIVE KIRBY	UNSITED	POOR SITE MAP	POOR BH LOC PLAN
CL6/KN/1018	CHARLEY WOOD ROAD	SJ49NW 814-832		
CL6/KN/1008	FORMER MOD SITE GORES ROAD	DUPLICATE		NOT SCANNED NOT INCLUDED IN ACCESSION - DUPLICATE OF SI 32617 SJ49NW 667 - 681, 683 - 702
CL6/KN/1036	FORMER CLARIAN SITE KIRBY	SJ49NW 833-868		
NO REFERENCE NUMBER	BAKER PETROLITE	SJ49NW 869-922		
CL6/KN/1057	NEWS INTERNATIONAL	SJ49NW 923-931		
CL6/KN/1064	CARLTON FUELS	SJ49NW 932-961		
CL6/KN/1059	SITE OFF ACORNFIELD ROAD	UNSITED		2 UNSITED, 1 DUPLICATE
CL6/KN/1045	LAND OFF JAMES HOLT AVE	SJ49NW 962-965	COOPER ASSOCIATES DATA ONLY	1 SITED, 1 UNSITED NO BH LOC PLAN
CL6/KN/1019	QVC HOMHOUSE LANE	SJ49NW 966-988	CAPITA SYMONDS POOR QULAITY SITE MAP. OTHER BOREHOLE RECORDS ATTAHCED IN FOLDER BUT APPEARS TO BE DUPLICATE OF ANOTHER SITE	1 SITED, 1 UNSITED
CL6/KN/1051	KODAK	SJ49NW 989-1032		
CL6/KN/1030	KITLING ROAD	SJ49NW 1034-1039		
CL6/KN/1041	REAR OF 120 ARBOUR LANE	SJ49NW 1040-1054		
CL6/KN/1049	OVERBROOK LANE	SJ49NW 1055-1066		
CL6/KN/1027	NORTH MERSEY BUSINESS PARK DEPOT ROAD	UNSITED	POOR SITE PLAN PLUS OTHER EXISTING BOREHOLES IN AREA	POOR BH LOC PLAN

CL6/KN/1029	ROBERT HERBERT GARAGES	SJ49NW 1067-1074		
CL6/KN/1053	LAND BETWEEN ST IVEL AND YORKSHIRE METAL	SJ49NW 1075-1079	POOR SITE MAP	
CL6/KN/1083	W G SEARCH	UNSITED	POOR SITE MAP	POOR BH LOC PLAN
CL6/KN/1040	HENRY BATH AND SON	SJ49NW 1080-1082		1 SITED, 1 UNSITED - SUBMITTED SITE PLAN DOES NOT MATCH RECORDS
CL6/KN/1055B	YORKSHIRE COPPEER TUBE	SJ49NW 1083-1118		
CL6/KKN/1033	N EXPRESS SOLUTIONS	UNSITED	NO SITE PLAN. COVER NOTE REFERS TO KODAK SITE BUT CANNOT DISTINGUISH BOREHOLES	UNCERTAIN RELATIONSHIP BETWEEN SUBMITTED SITE PLAN AND BOREHOLE RECORDS
CL6/KN/1021	CAPITOL PARK KIRBY BANK ROAD	SJ49NW 1119-1120		
CL6/KN/1020	GLADESWOOD ROAD	SJ49NW 1121-1125		
NO REFERENCE NUMBER	RENTOKILL INITIAL SUPPLIES	SJ49NW 1126-1148	POOR SITE MAP	

Appendix 2 Figures

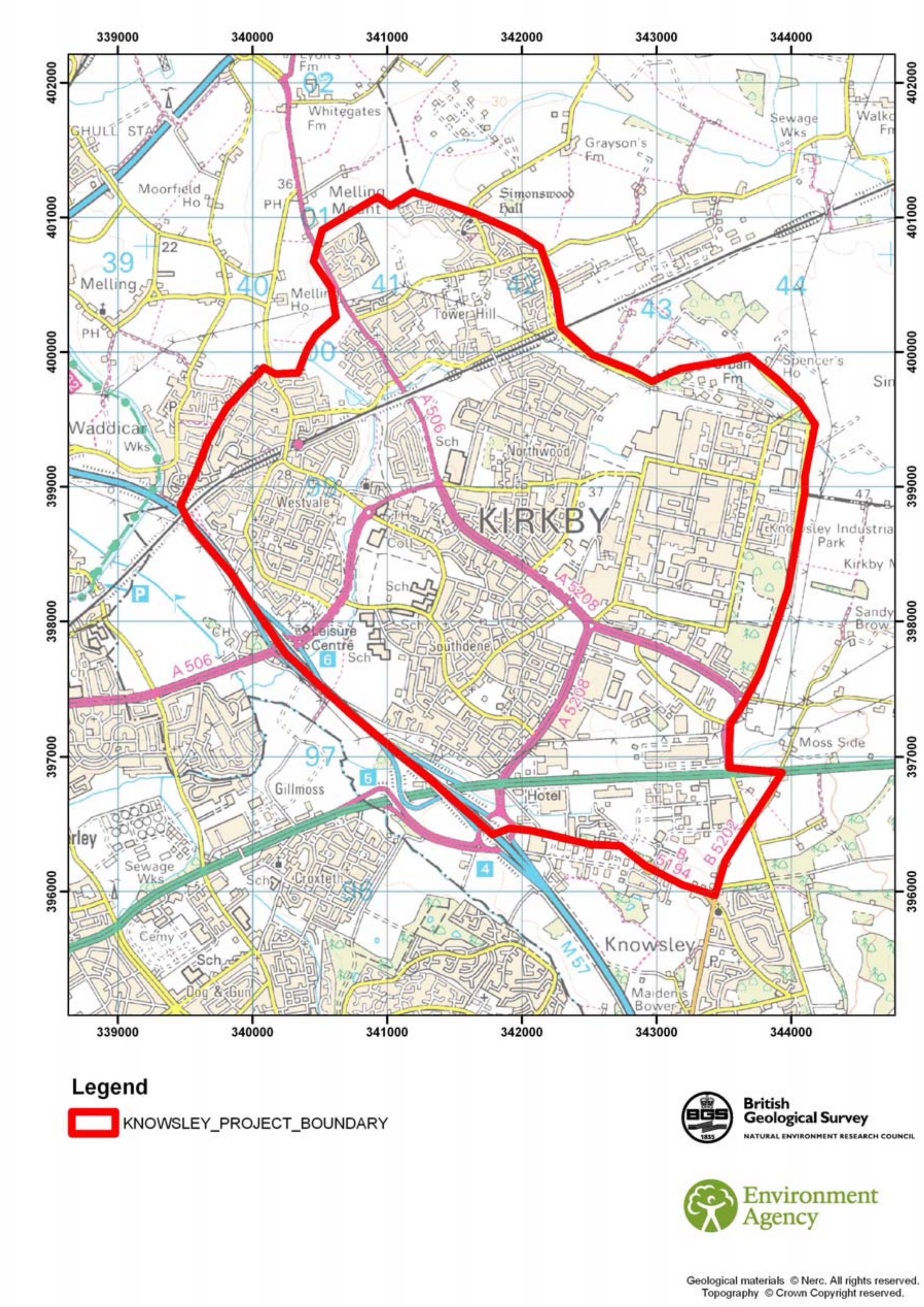


Figure 1 Location of project area

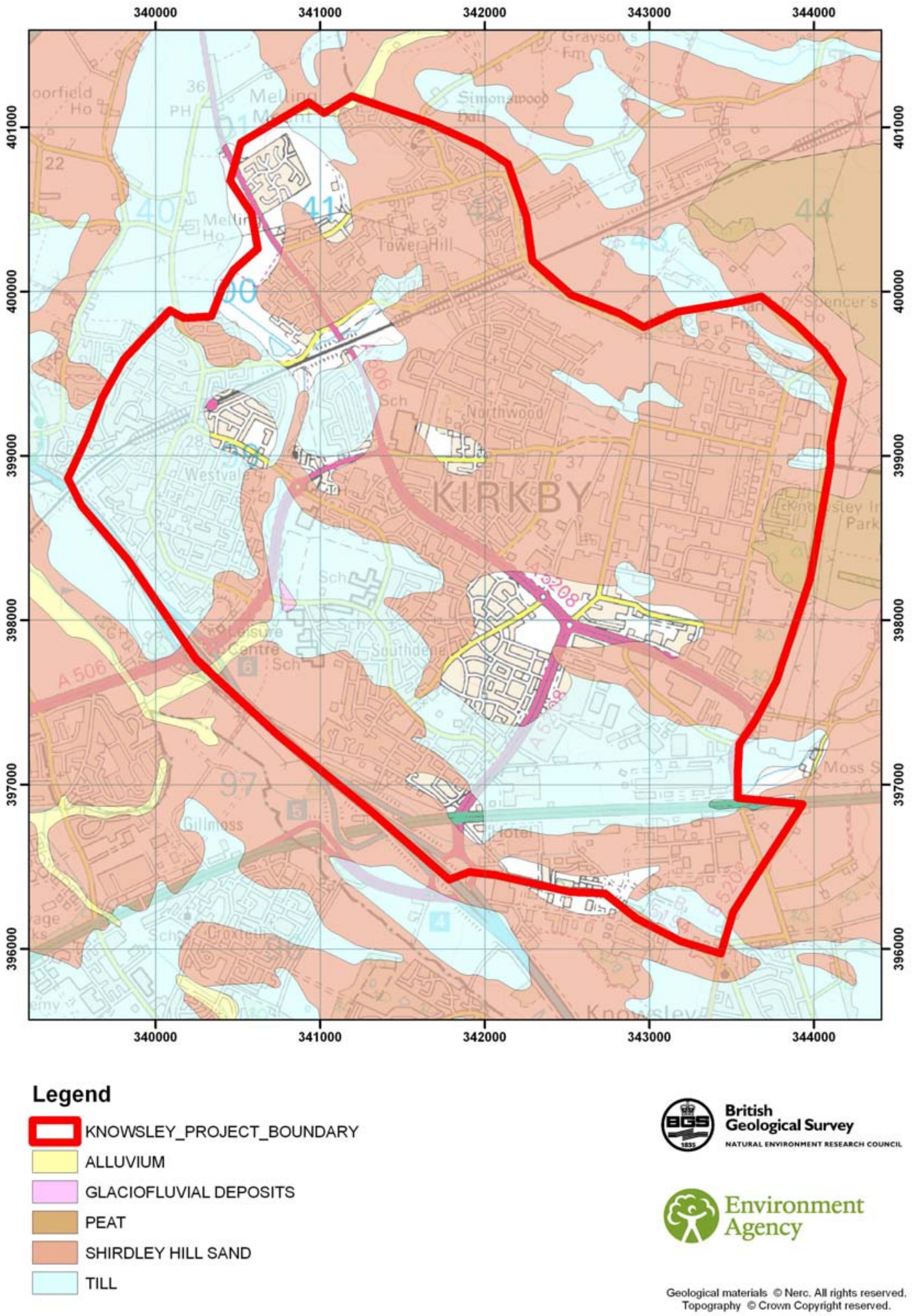


Figure 2 Superficial geology derived from DiGMapGB50

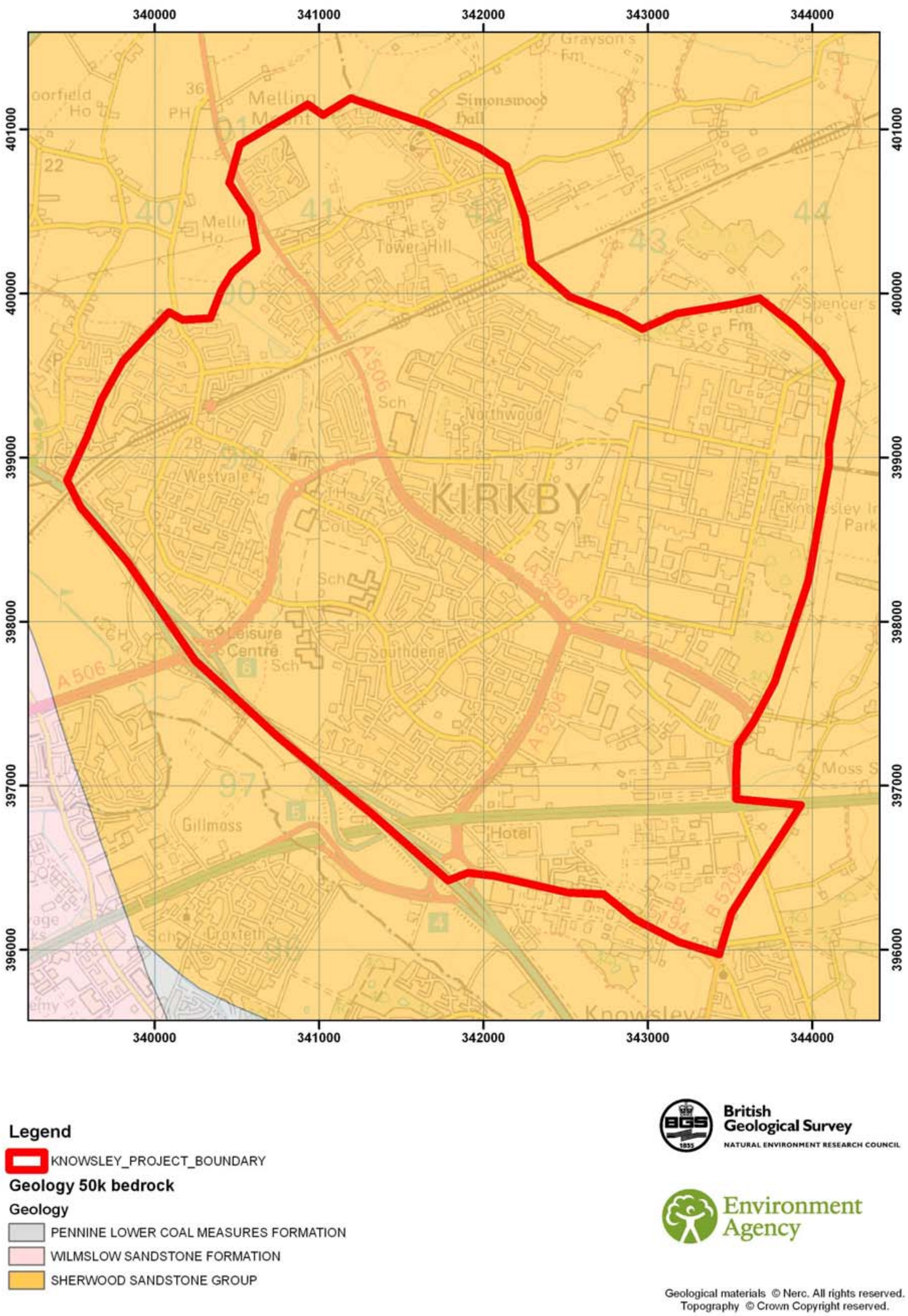


Figure 3 Bedrock geology derived from DiGMapGB50

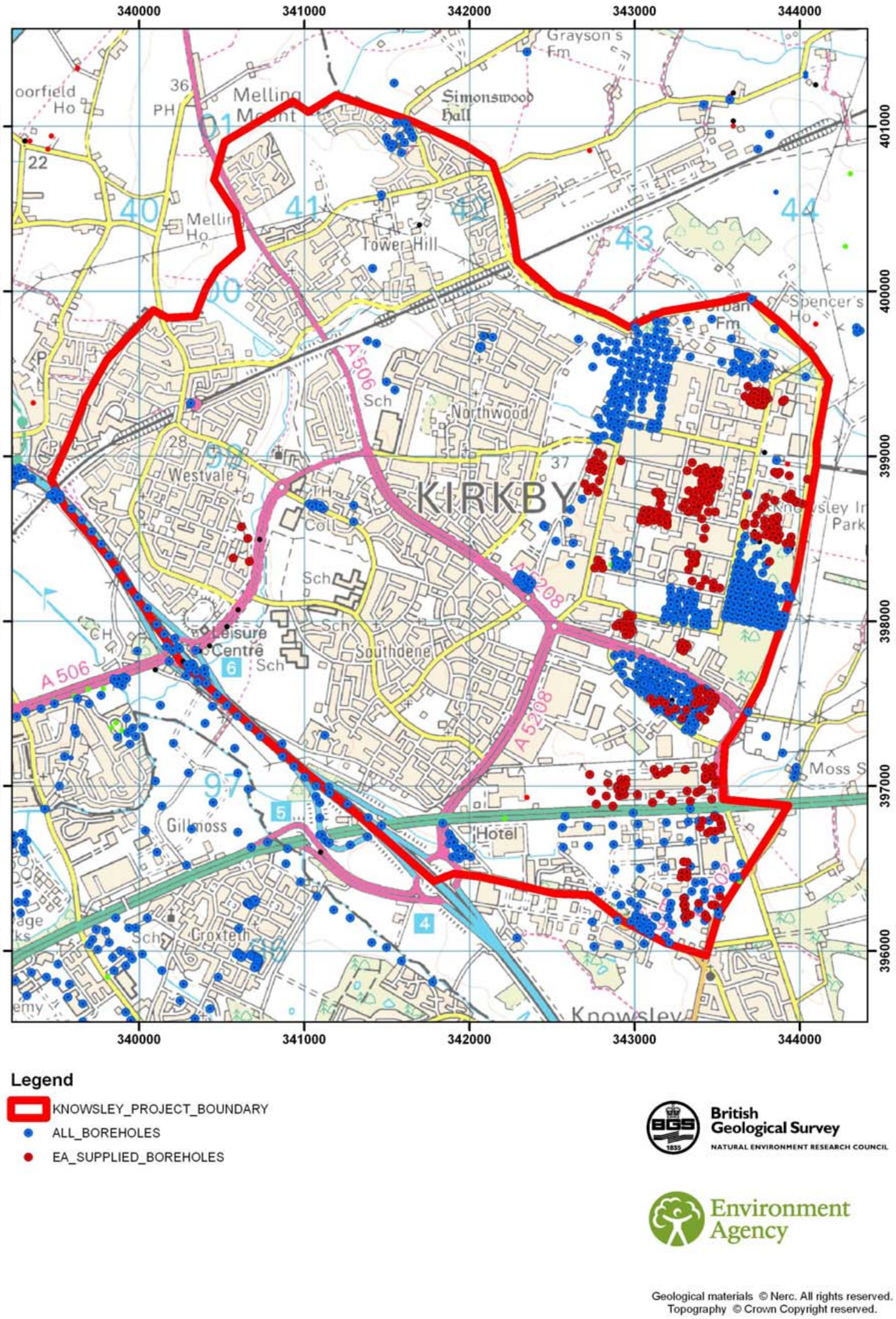


Figure 4 Coded boreholes used in study

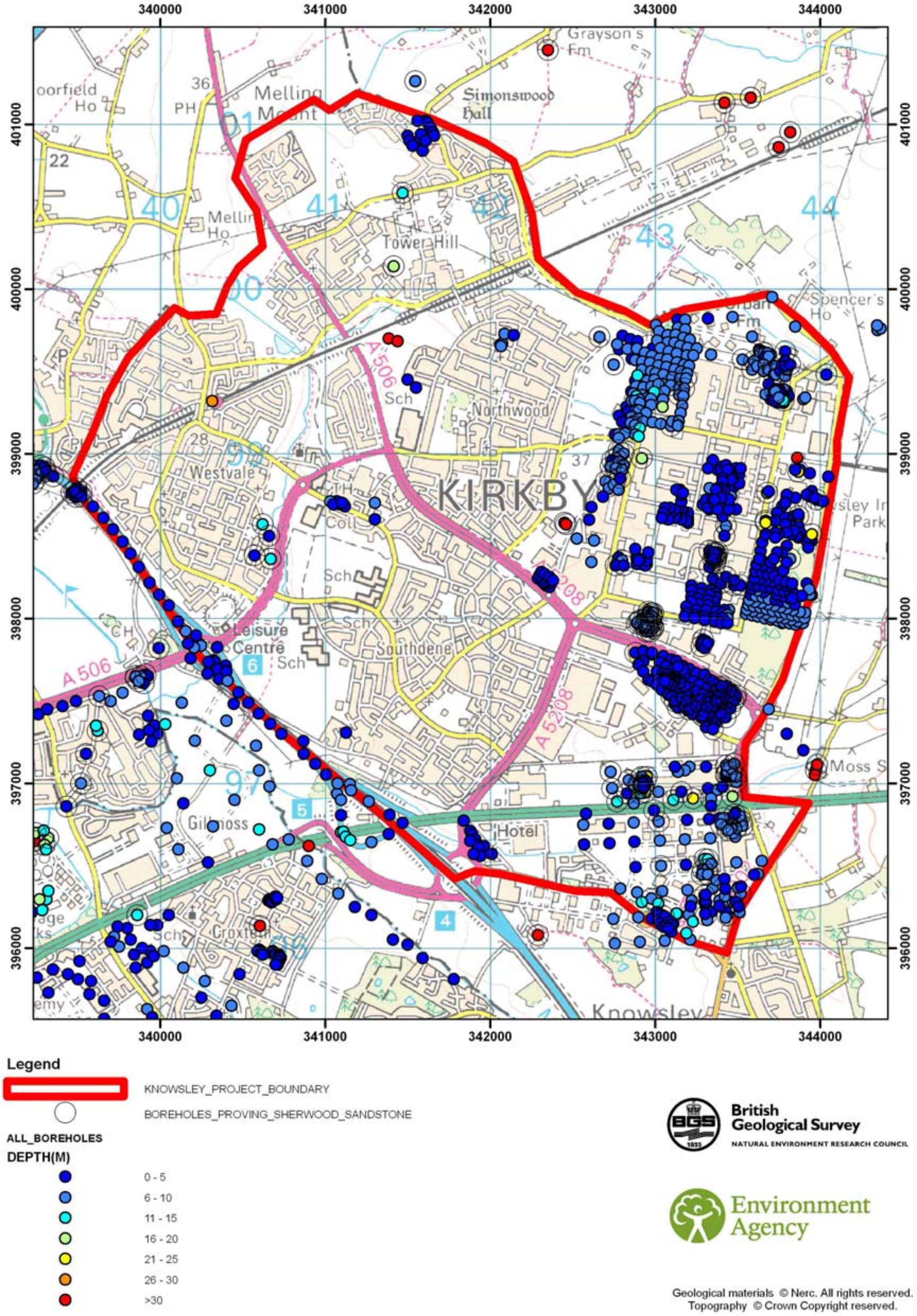


Figure 5 Coded boreholes used in study classified by depth. Those represented with an outer circle also penetrate weathered or un-weathered Sherwood Sandstone

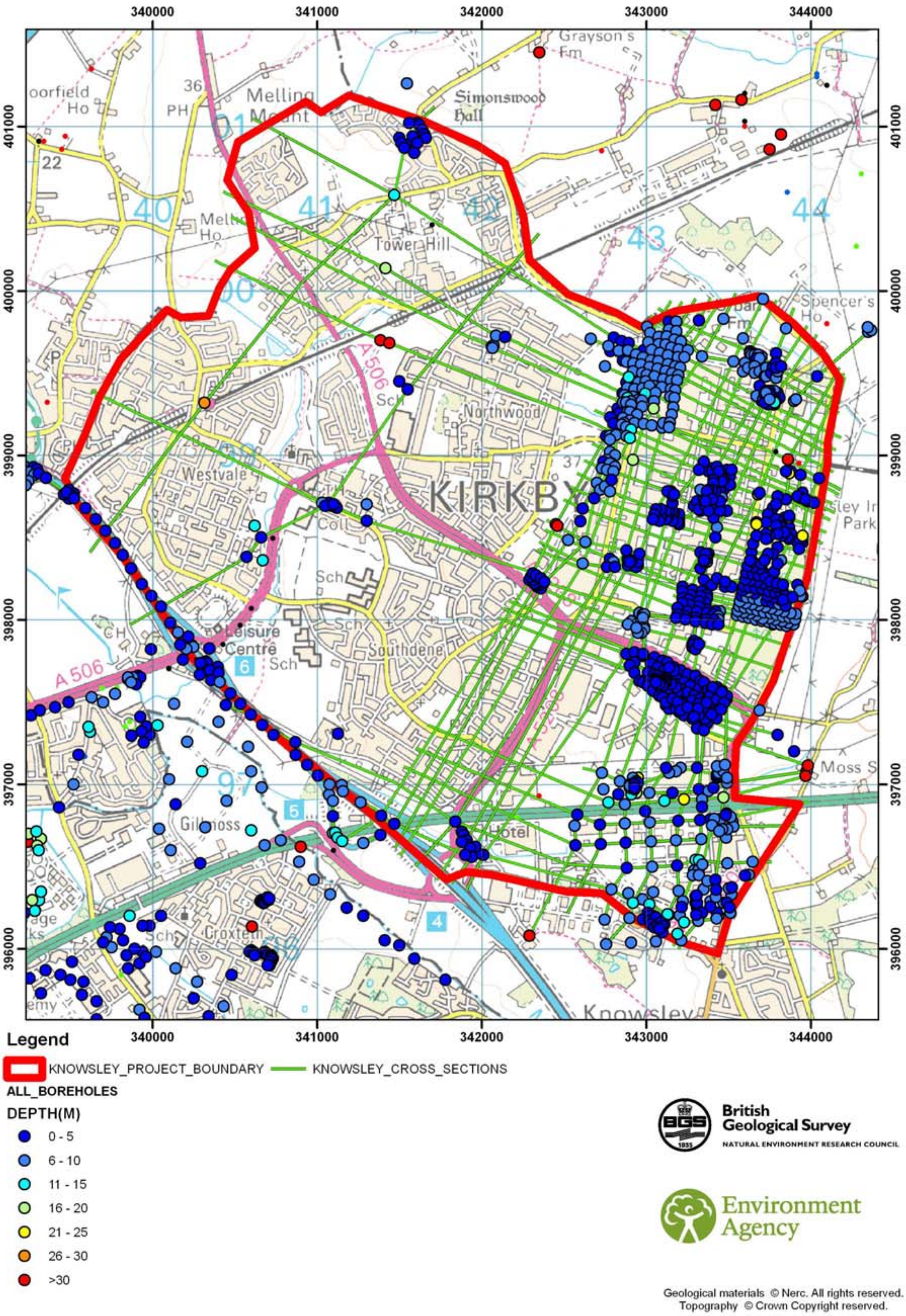


Figure 6 Location of cross-sections

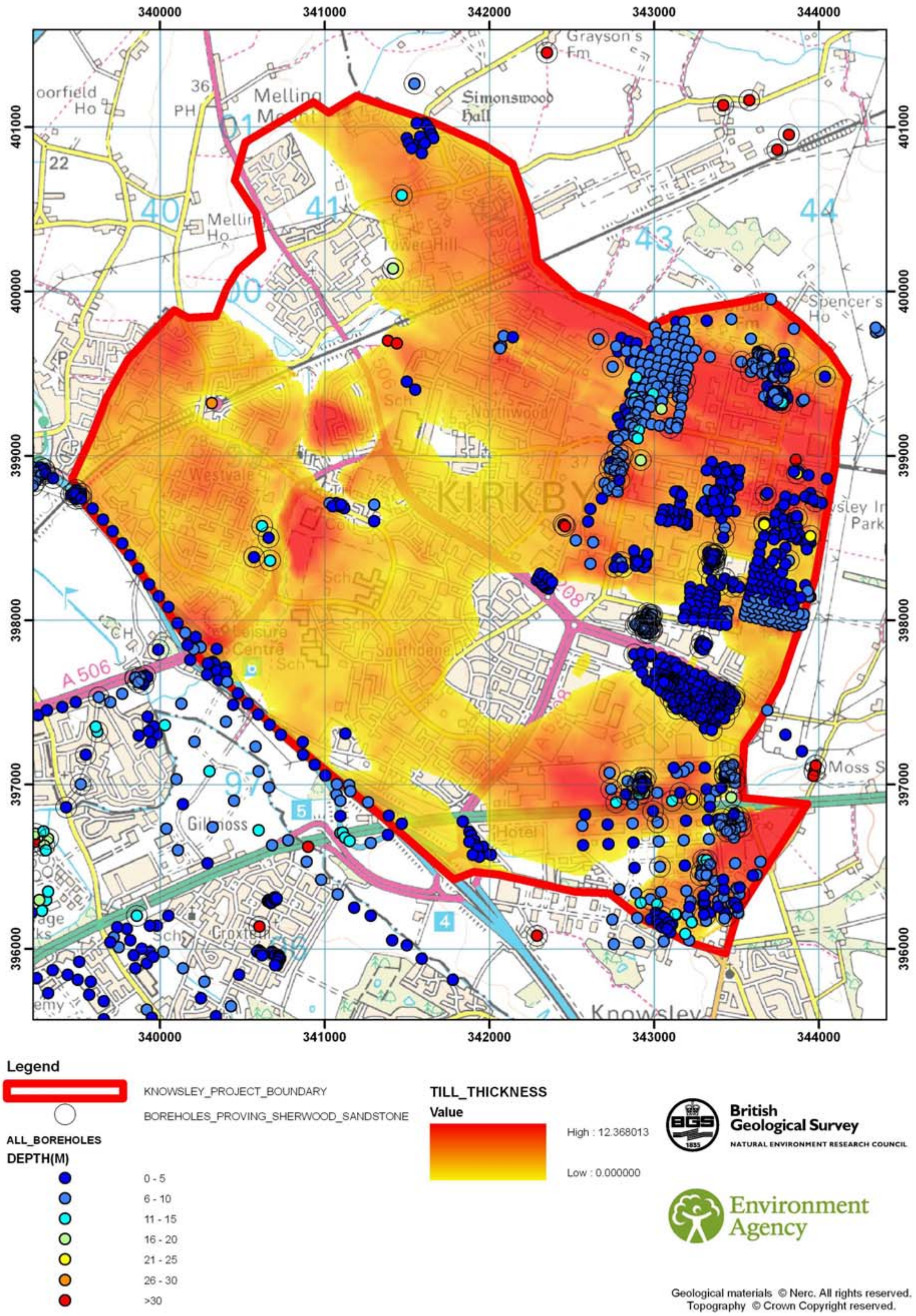


Figure 7 Calculated till thickness (metres) derived from 3D model of superficial deposits

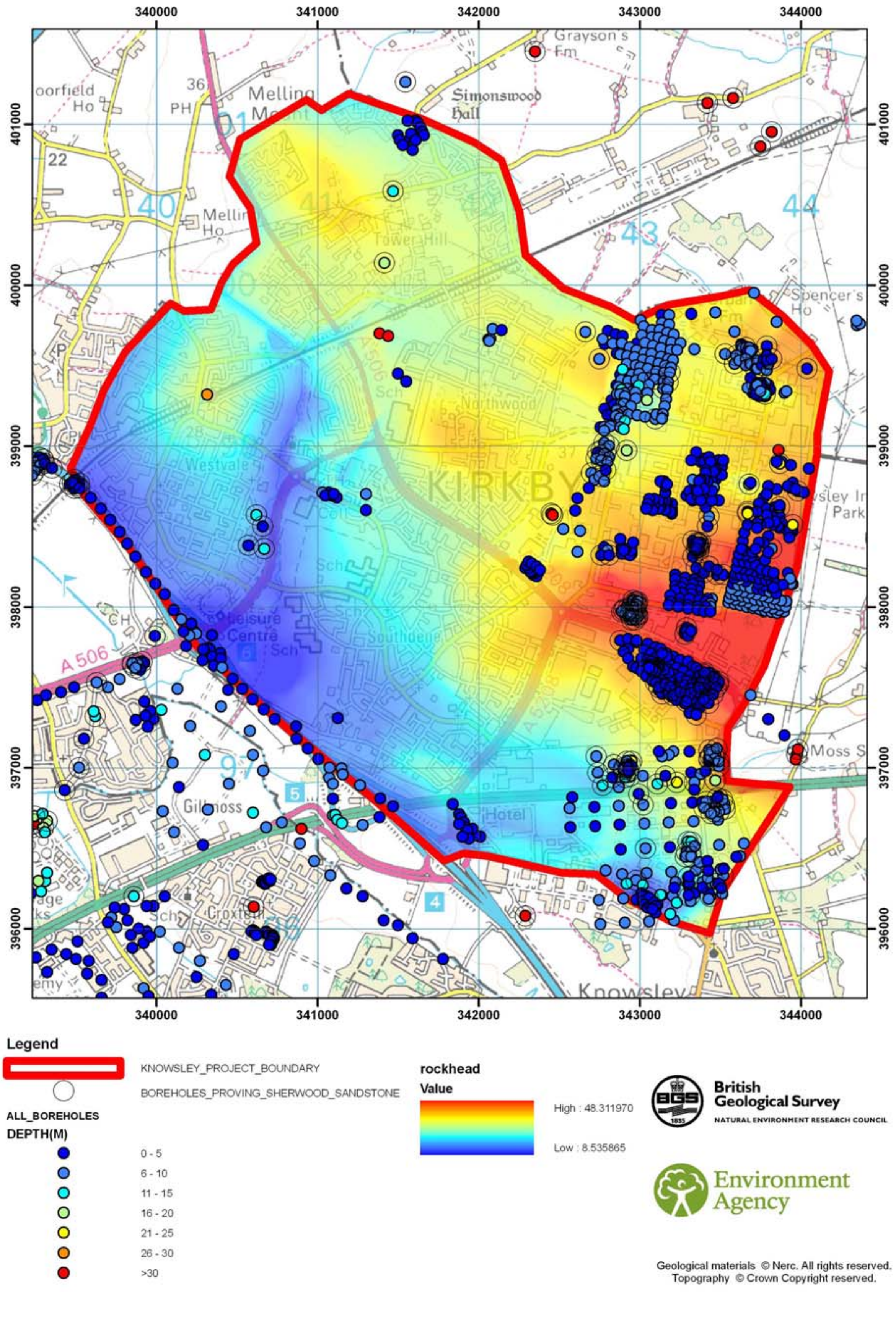


Figure 8 Rockhead elevation (metres) derived from 3D geological model

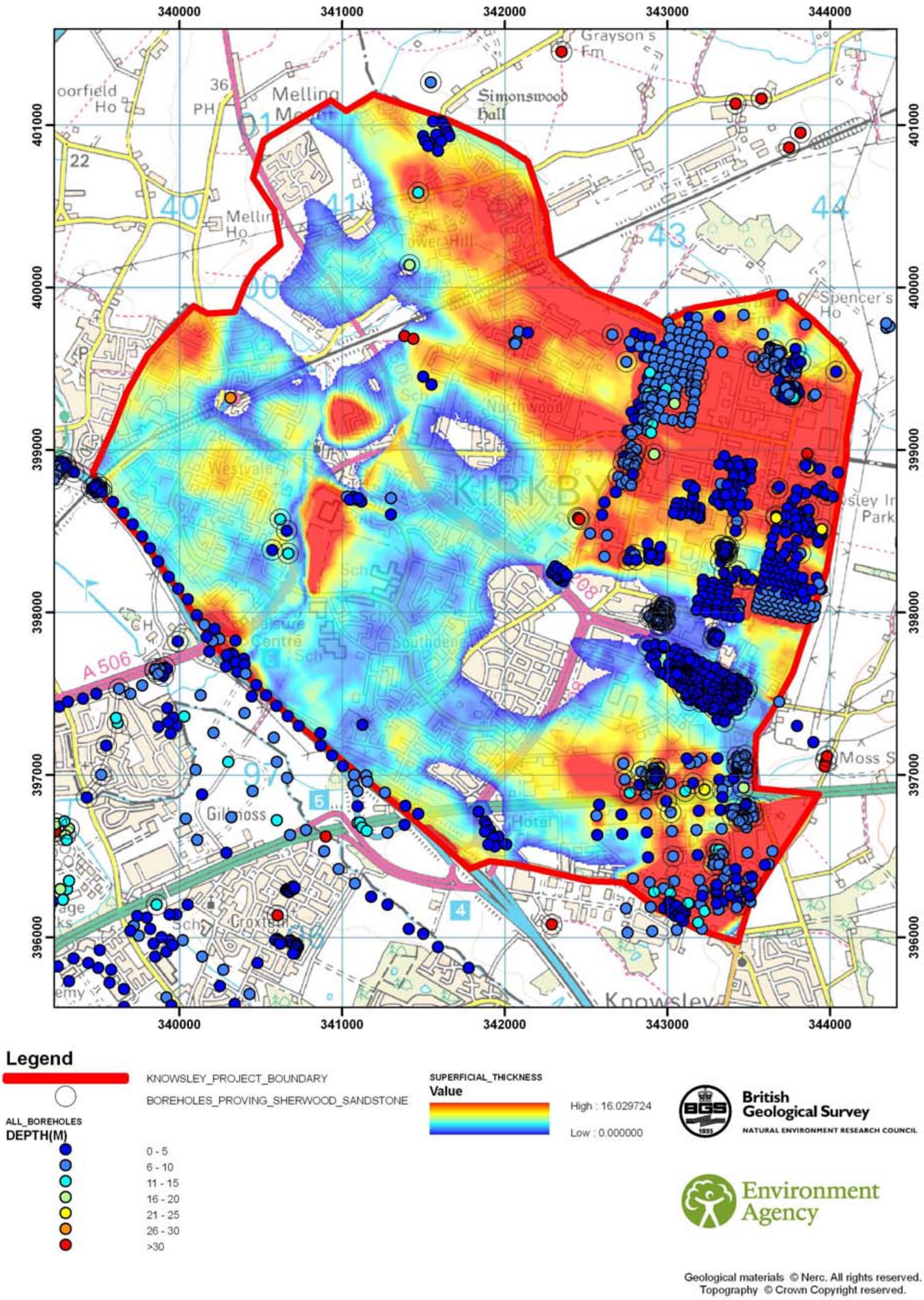


Figure 9 Thickness of Superficial Deposits (metres) derived from 3D geological model

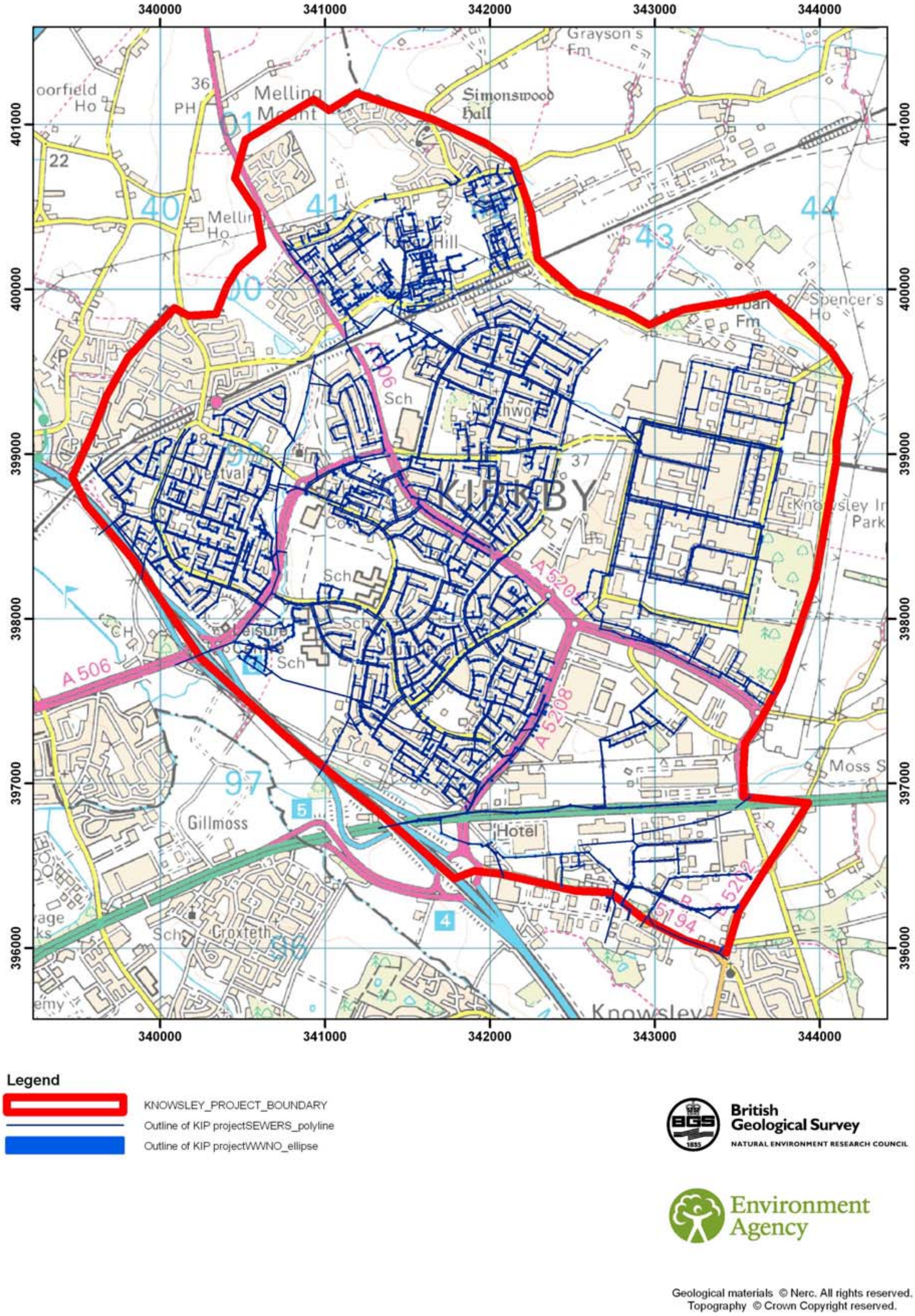


Figure 10 Distribution of foul sewers and surface water drains provided by the Agency from United Utilities data. Pipeline diameter schematic only

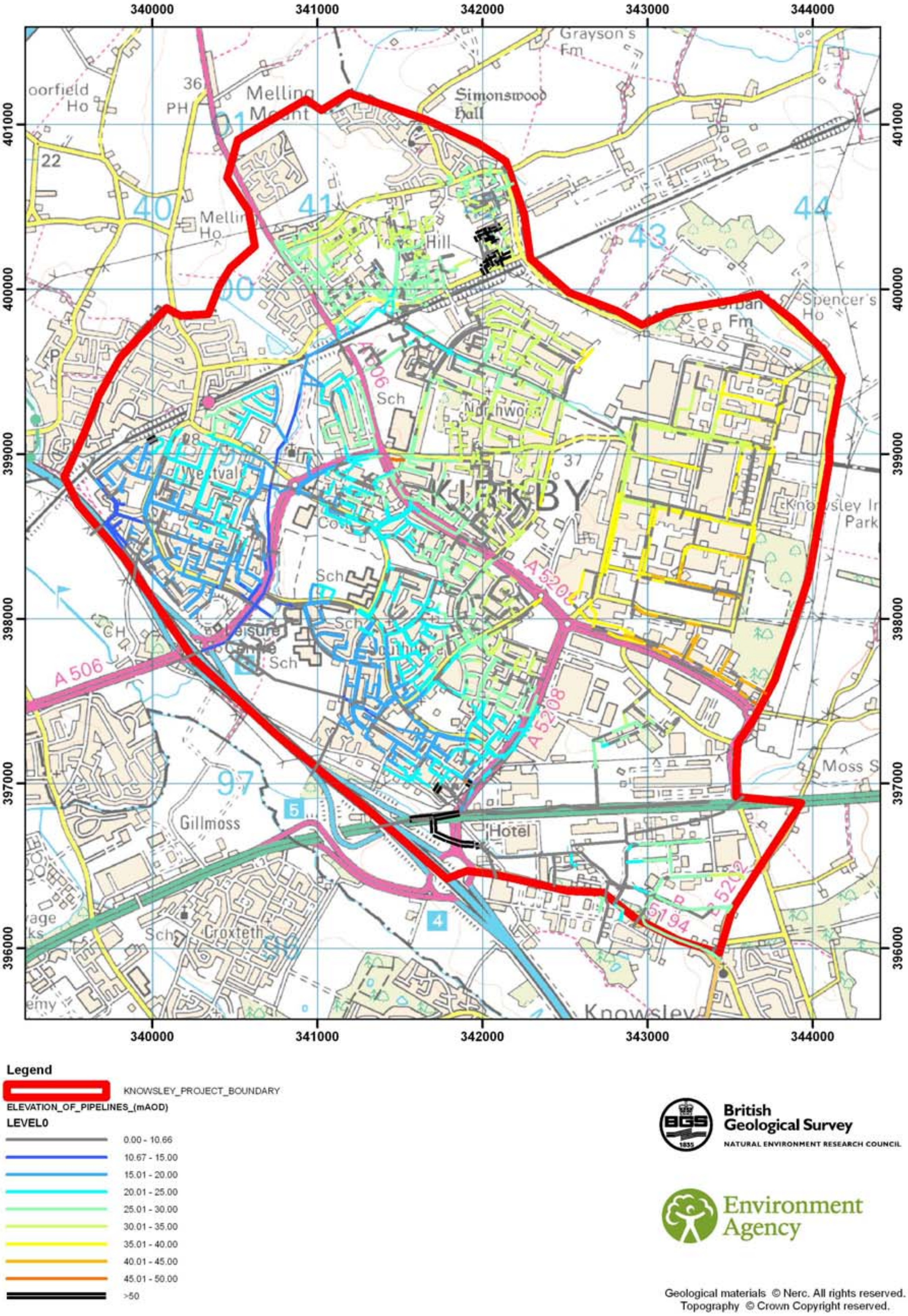


Figure 11 Classified pipeline invert levels relative to OD. Pipeline diameter schematic only

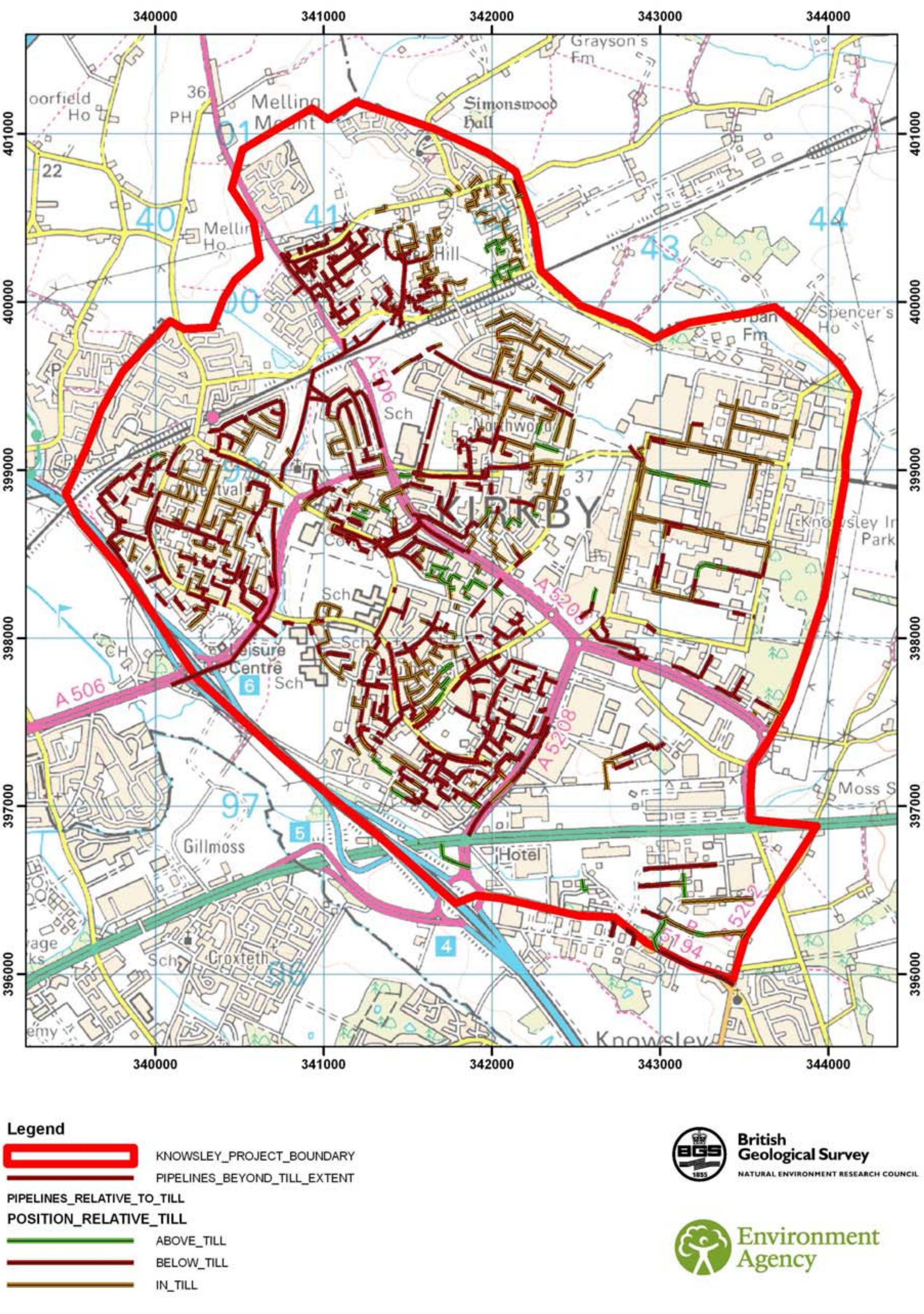


Figure 12 Pipeline comparison relative to elevation (metres OD) of top and base surface of Till. Pipeline diameter schematic only

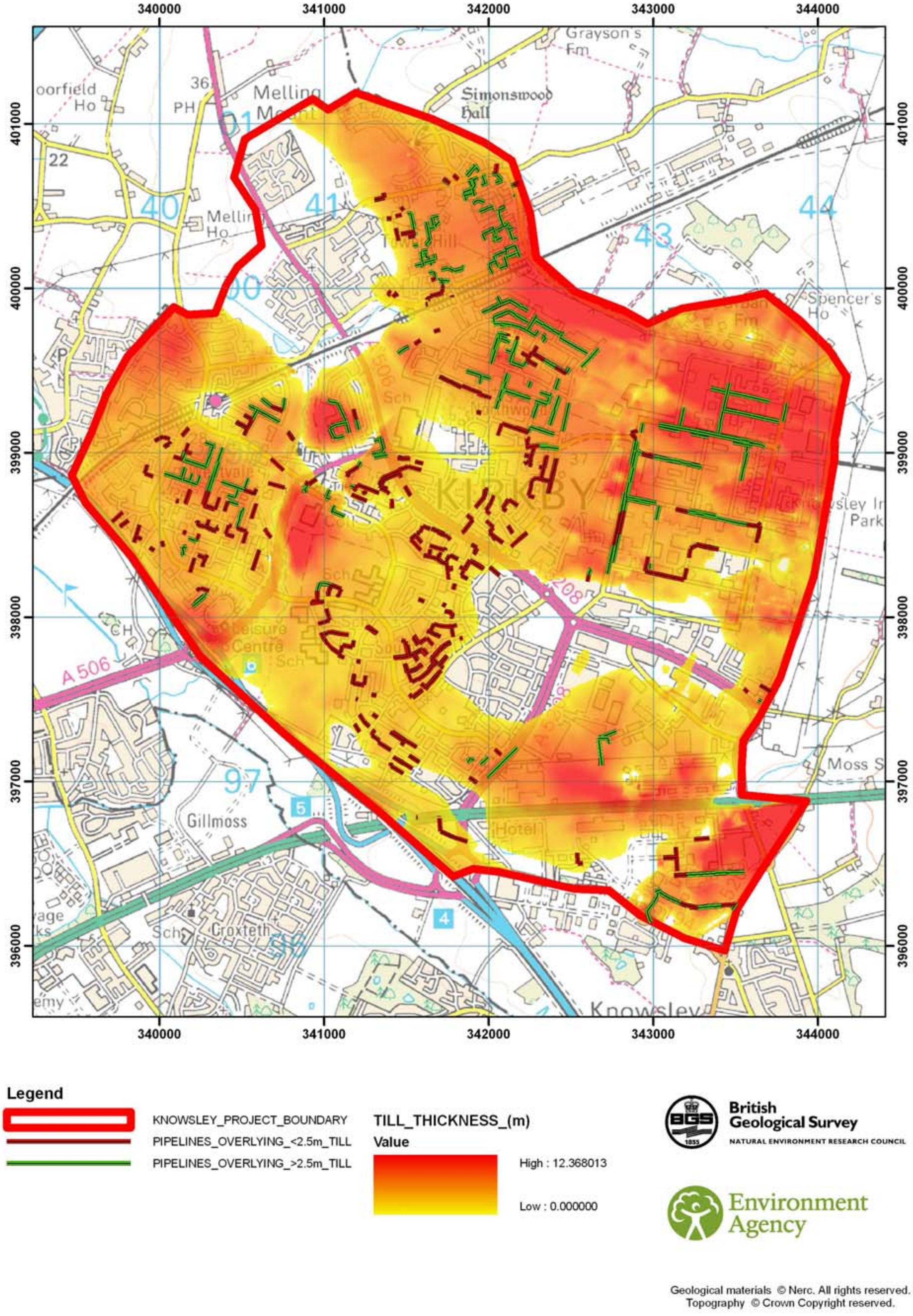
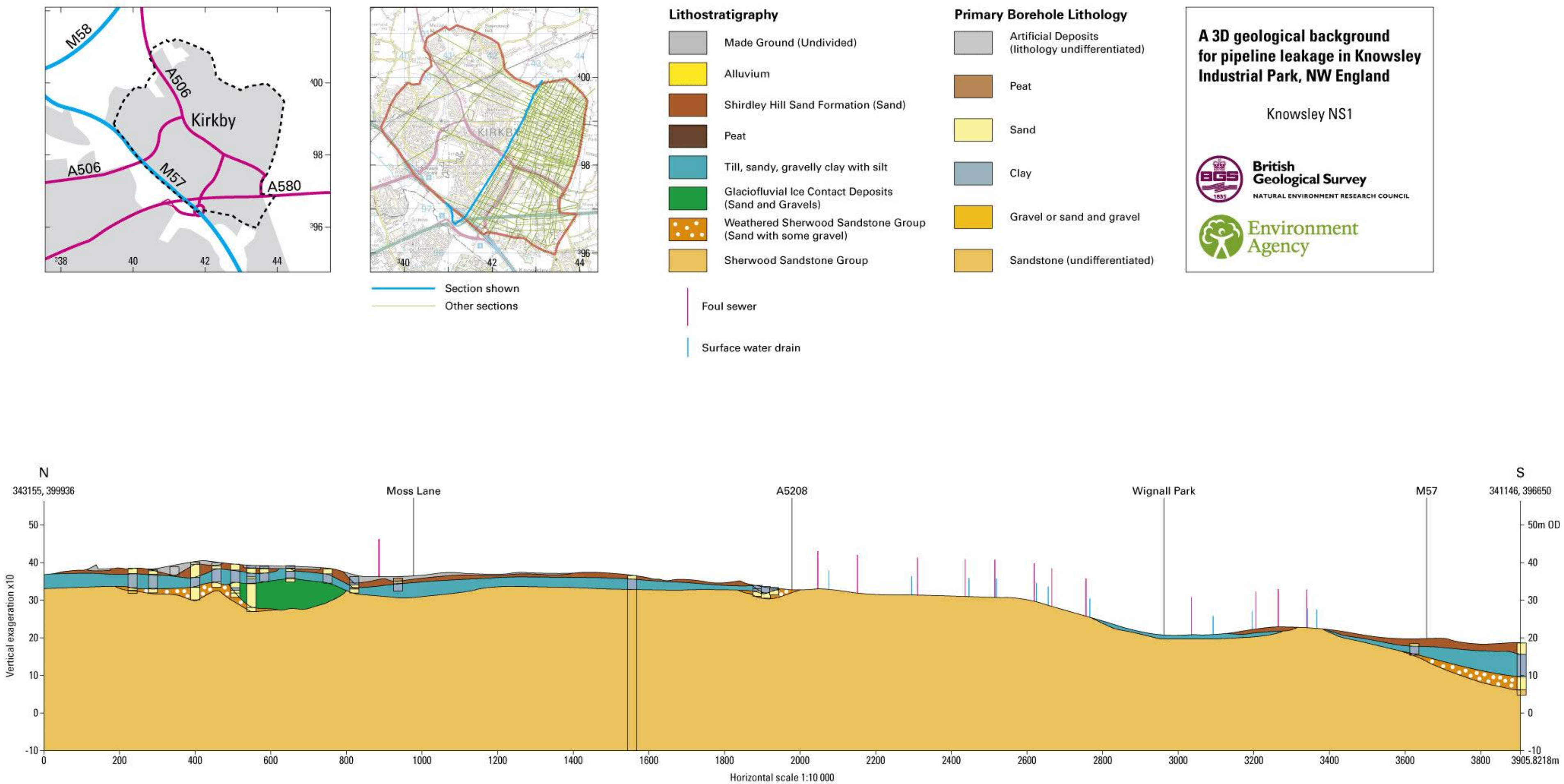
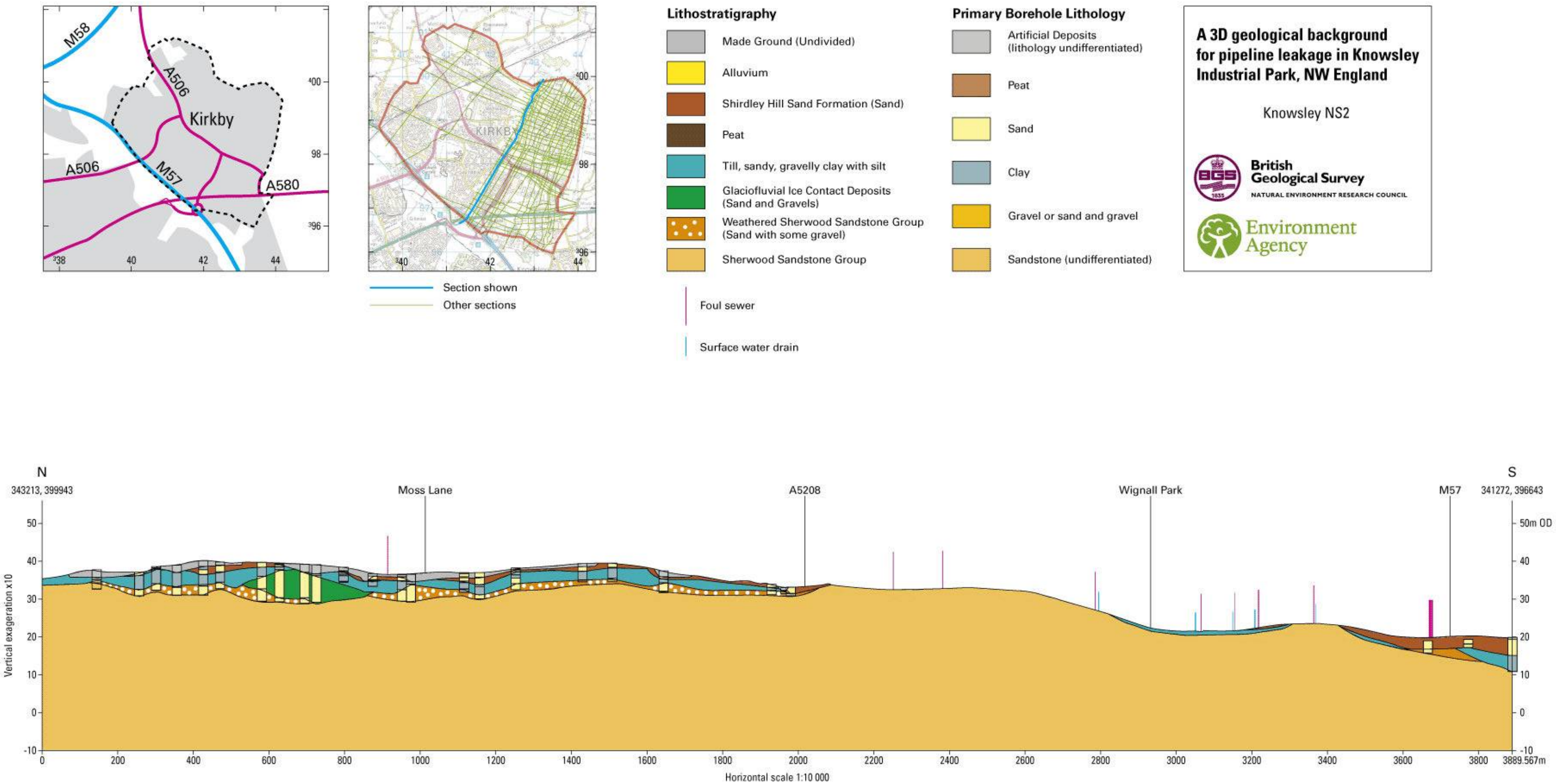
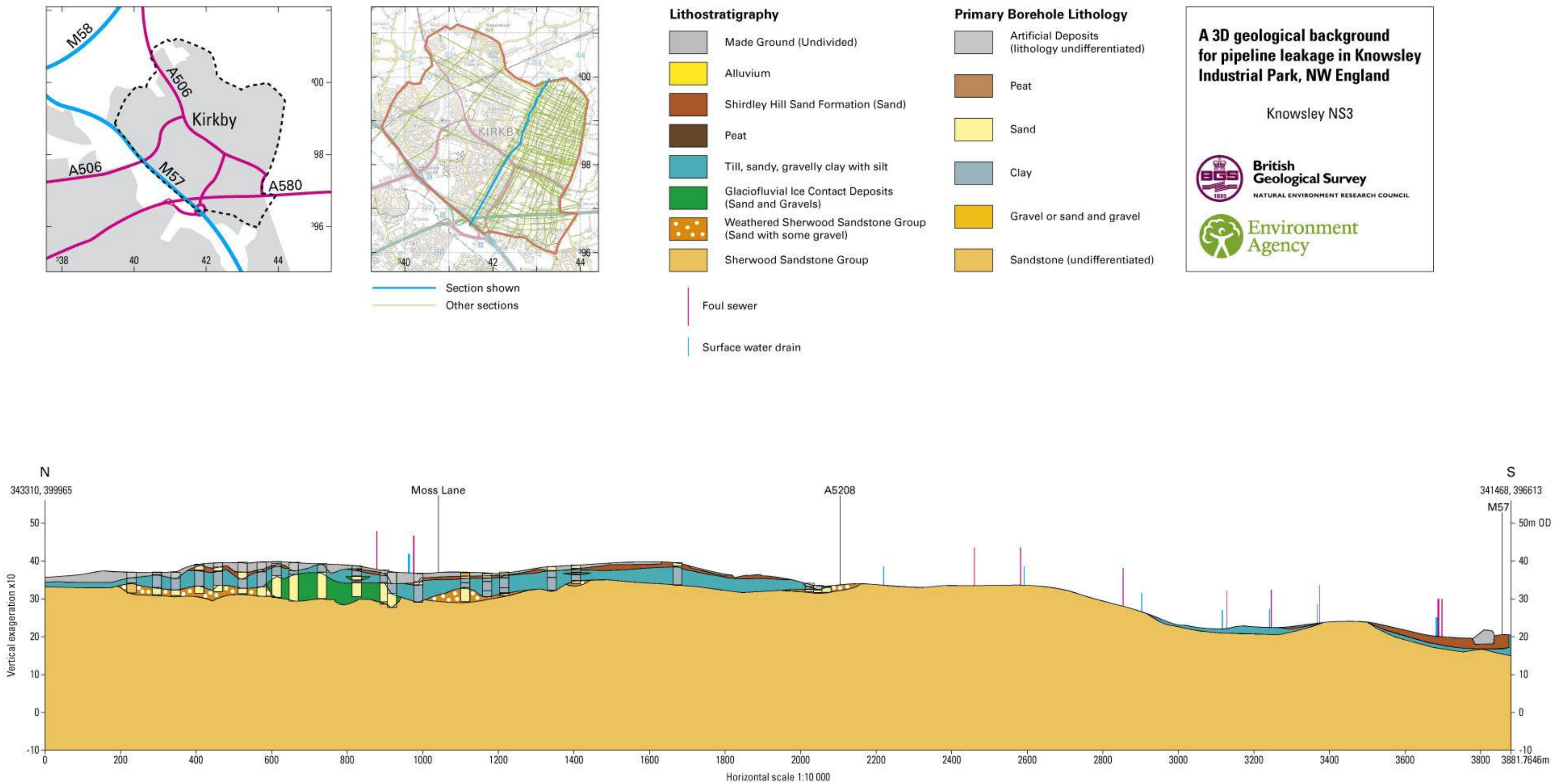


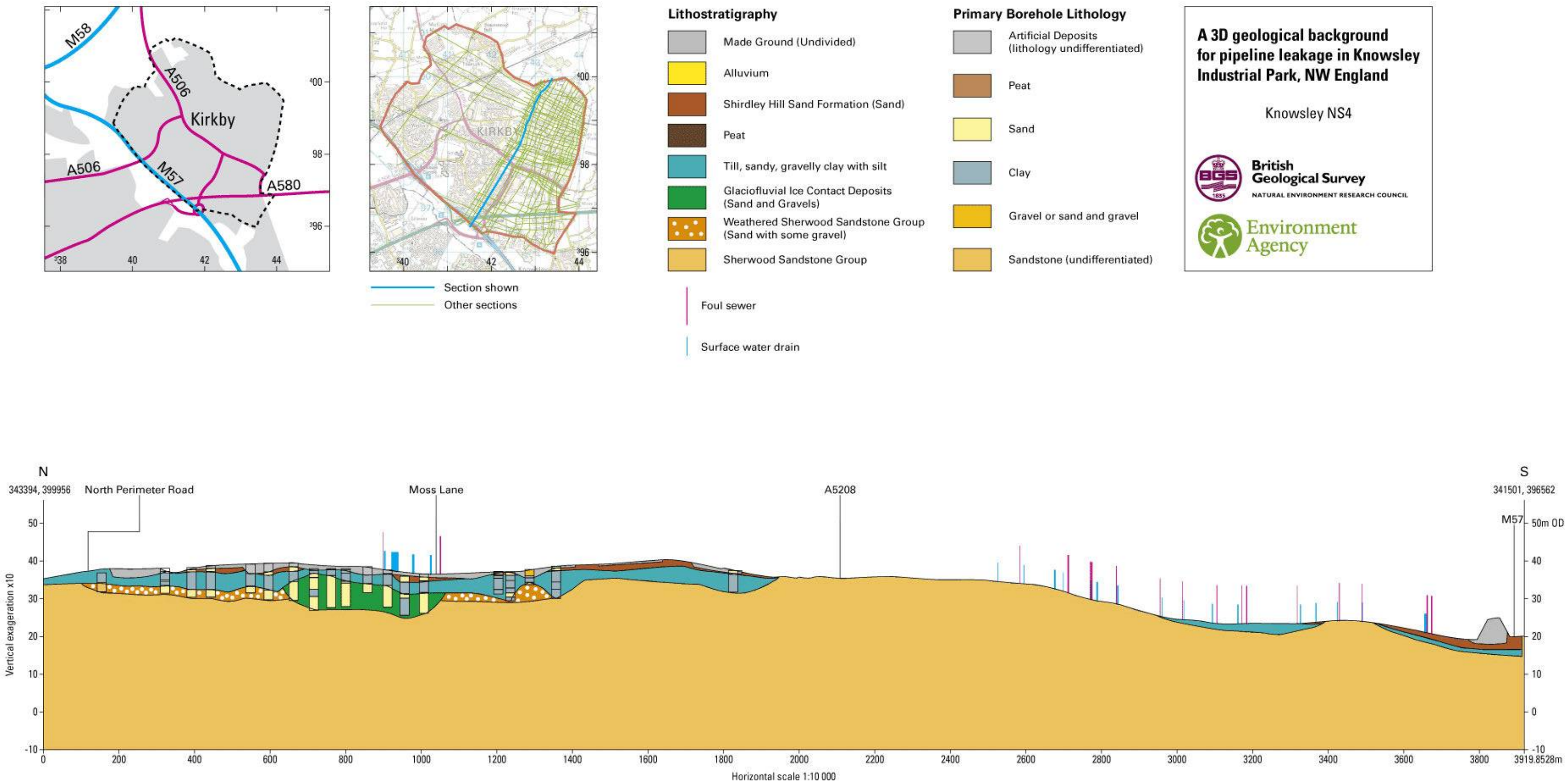
Figure 13 Pipeline segments that lie above or within Till compared to Till thickness. Pipeline thickness schematic only

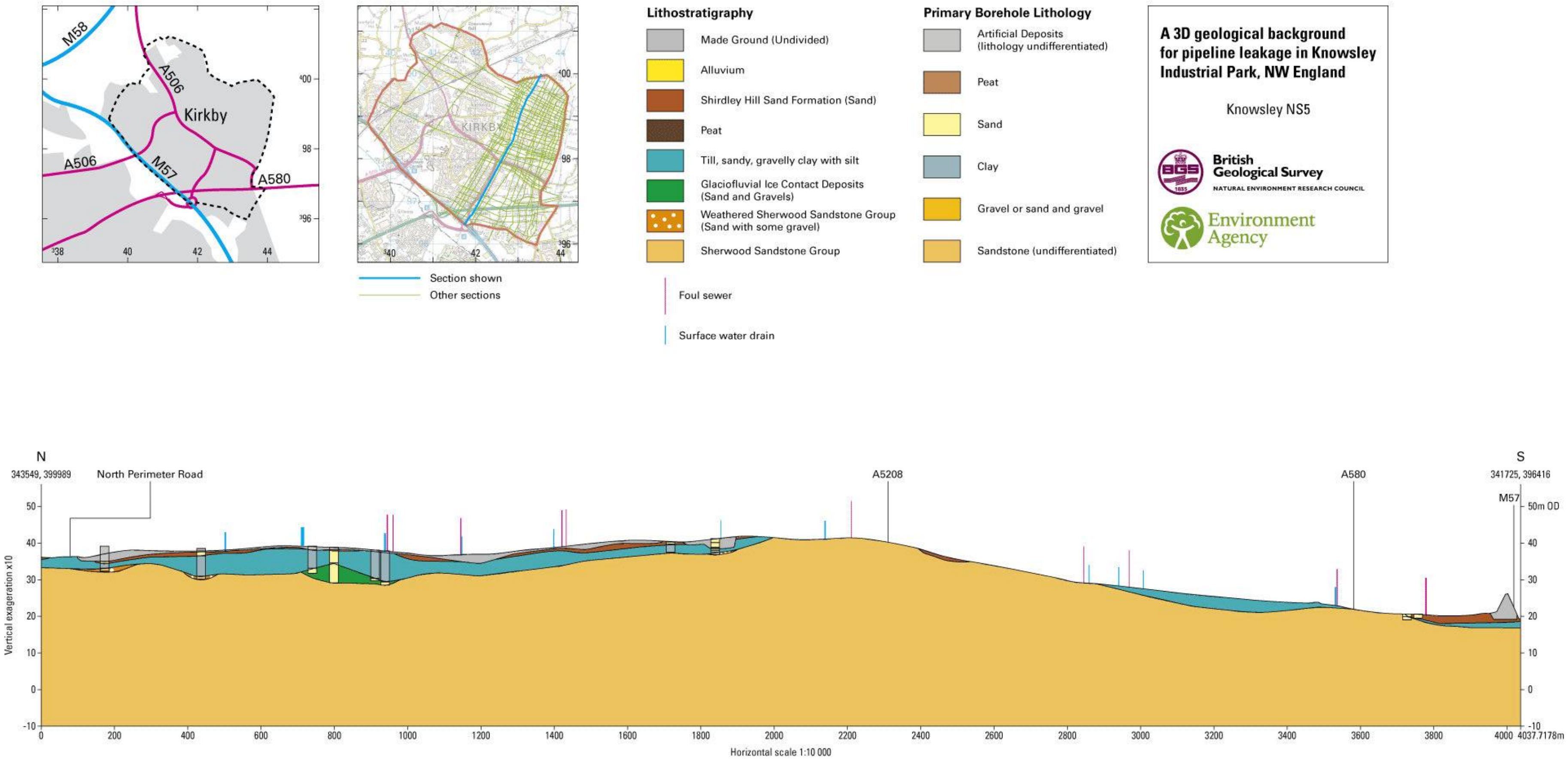
Appendix 3 Cross-sections (not to scale)

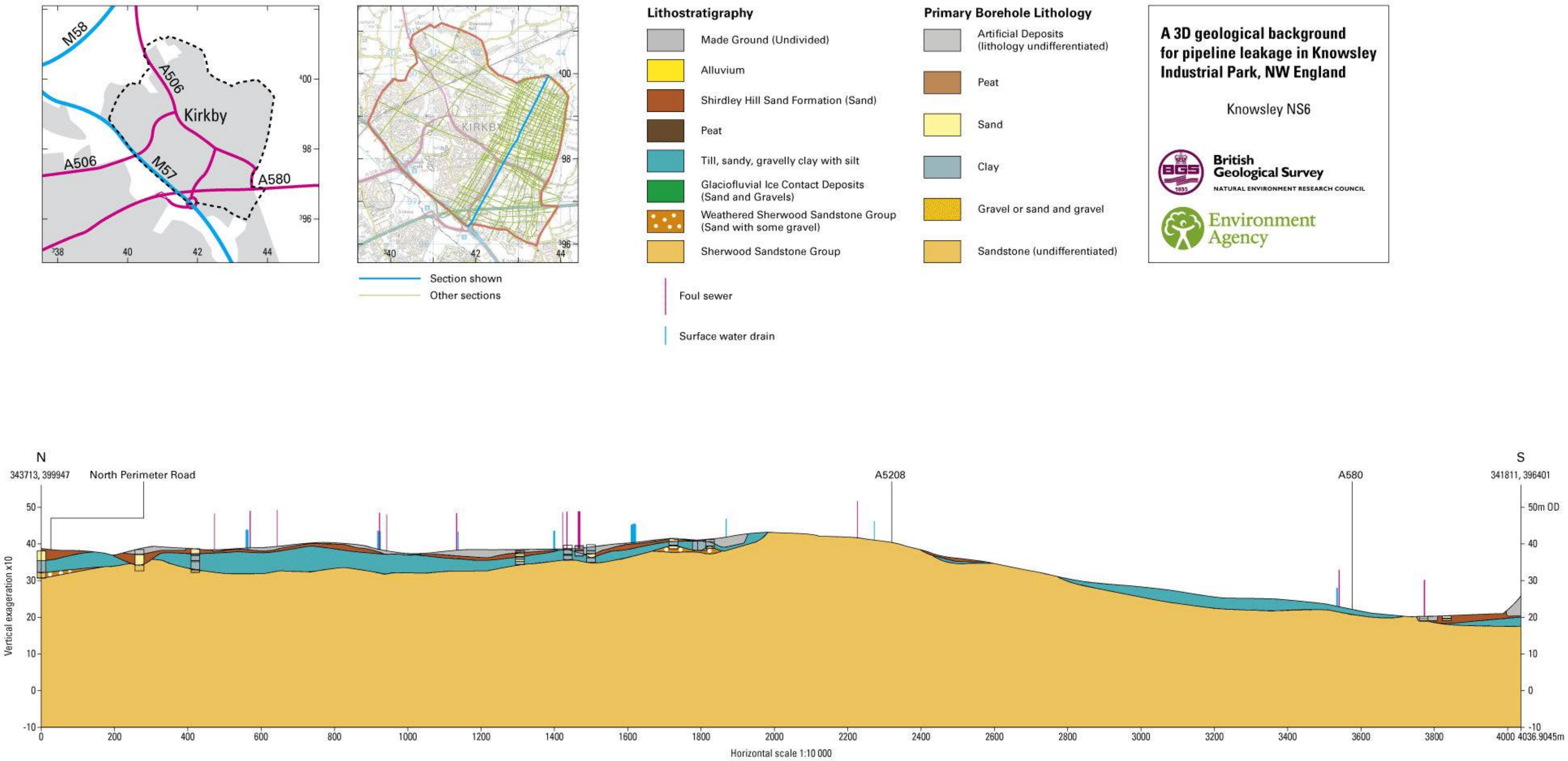

M58
A506
Kirkby
M57
A580
A506
400
98
396
338
40
42
44
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS1
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
343155, 399936
Moss Lane
A5208
Wignall Park
M57
S
341146, 396650
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
3905.8218m

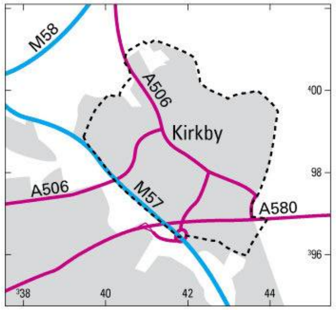

M58
A506
Kirkby
A506
M57
A580
400
98
396
338
40
42
44
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS2
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
343213, 399943
Moss Lane
A5208
Wignall Park
M57
S
341272, 396643
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
3889.567m

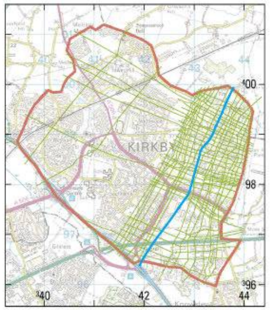

M58
A506
Kirkby
A506
M57
A580
400
98
396
38
40
42
44
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS3
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
343310, 399965
Moss Lane
A5208
S
341468, 396613
M57
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
3881.7646m


M58
A506
Kirkby
M57
A580
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS4
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
343394, 399956
North Perimeter Road
Moss Lane
A5208
S
341501, 396562
M57
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
3919.8528m


M58
A506
Kirkby
A506
M57
A580
38
40
42
44
100
98
96
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS5
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
343549, 399989
North Perimeter Road
A5208
A580
S
341725, 396416
M57
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
4037.7178m


M58
A506
Kirkby
A506
M57
A580
38
40
42
44
400
398
396
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS6
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
343713, 399947
North Perimeter Road
A5208
A580
S
341811, 396401
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
4036.9045m





Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group

- Foul sewer
- Surface water drain

Primary Borehole Lithology

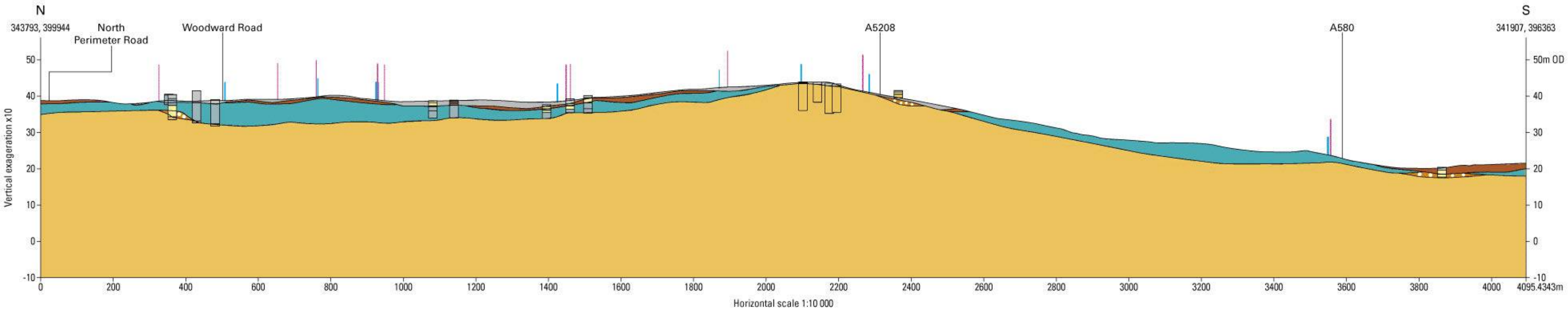
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

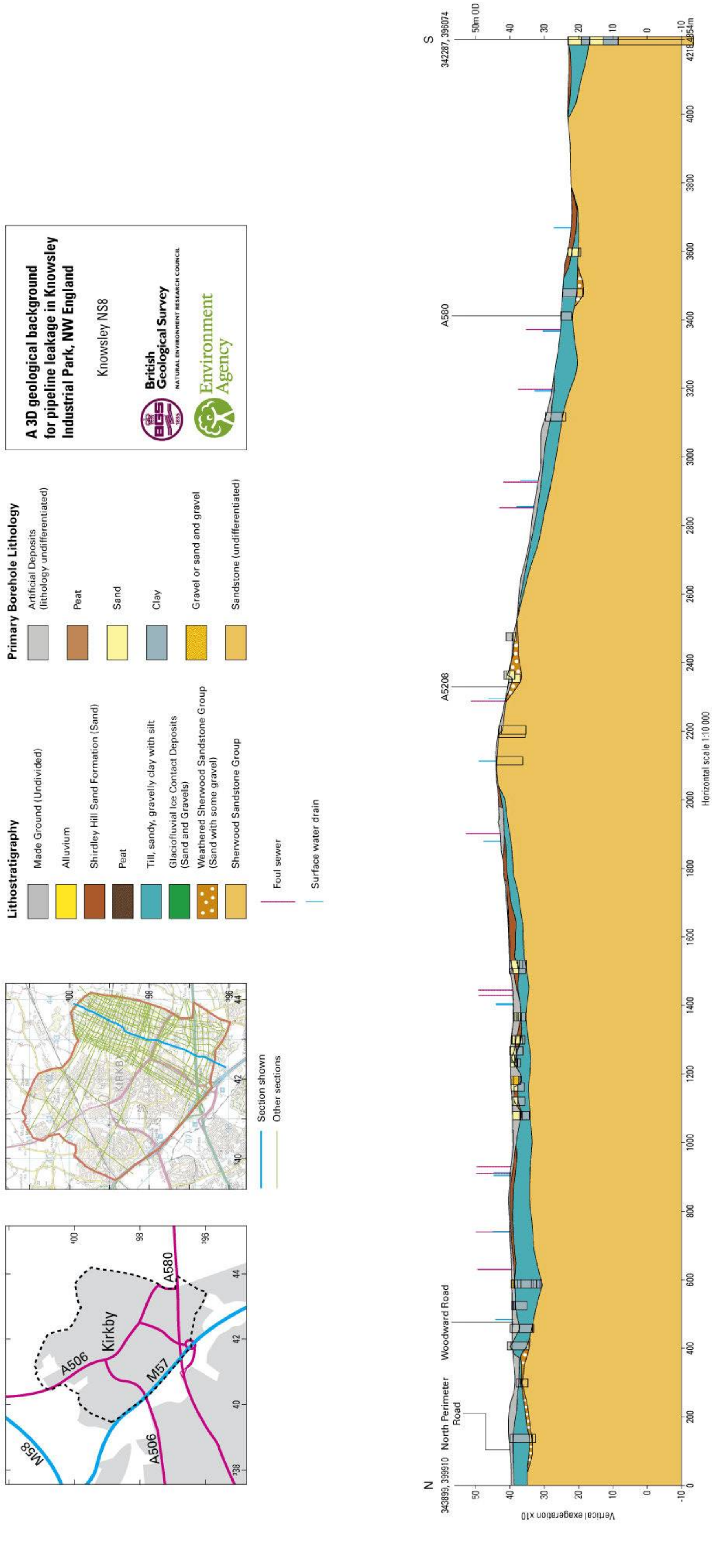
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

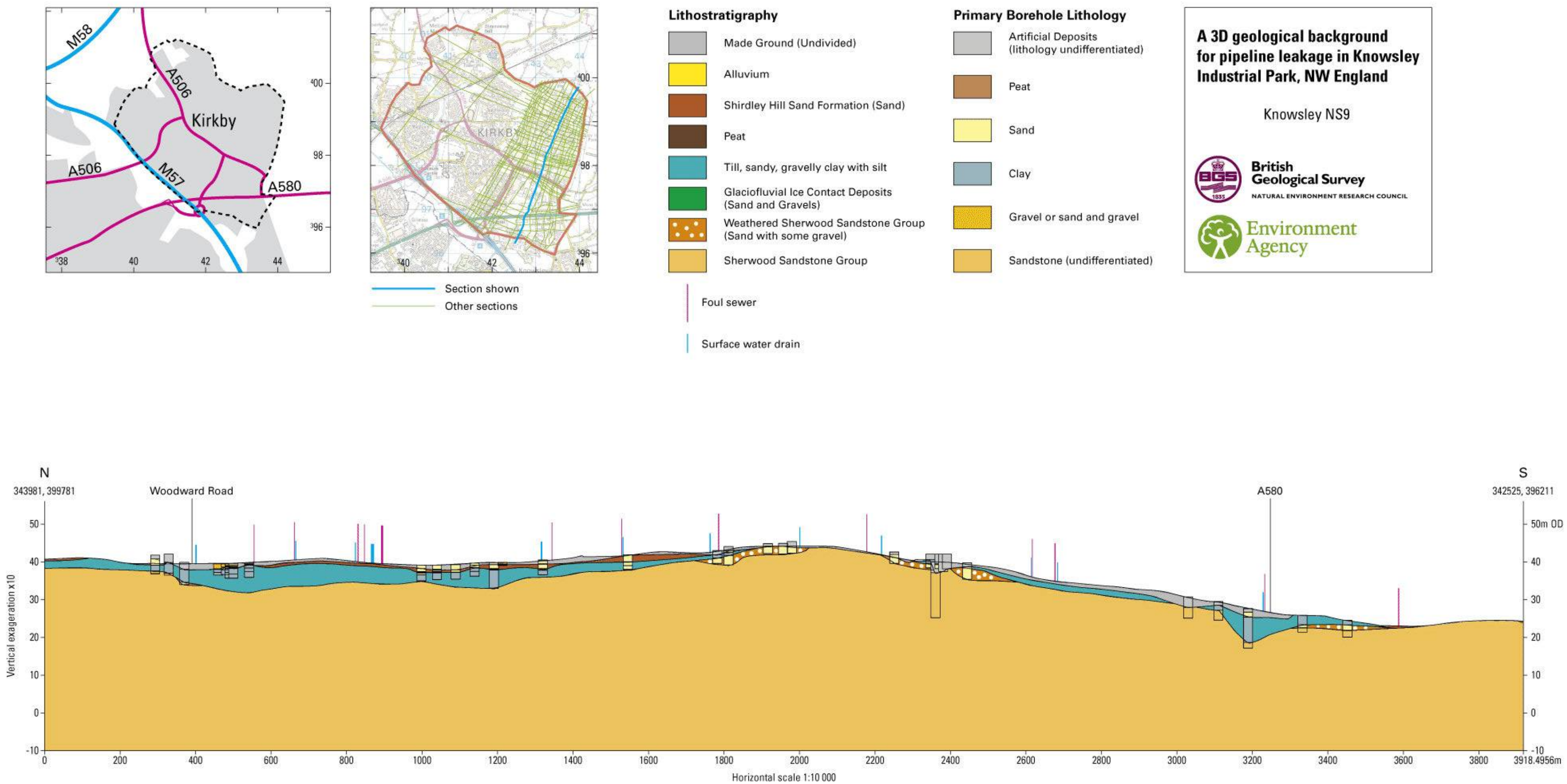
Knowsley NS7

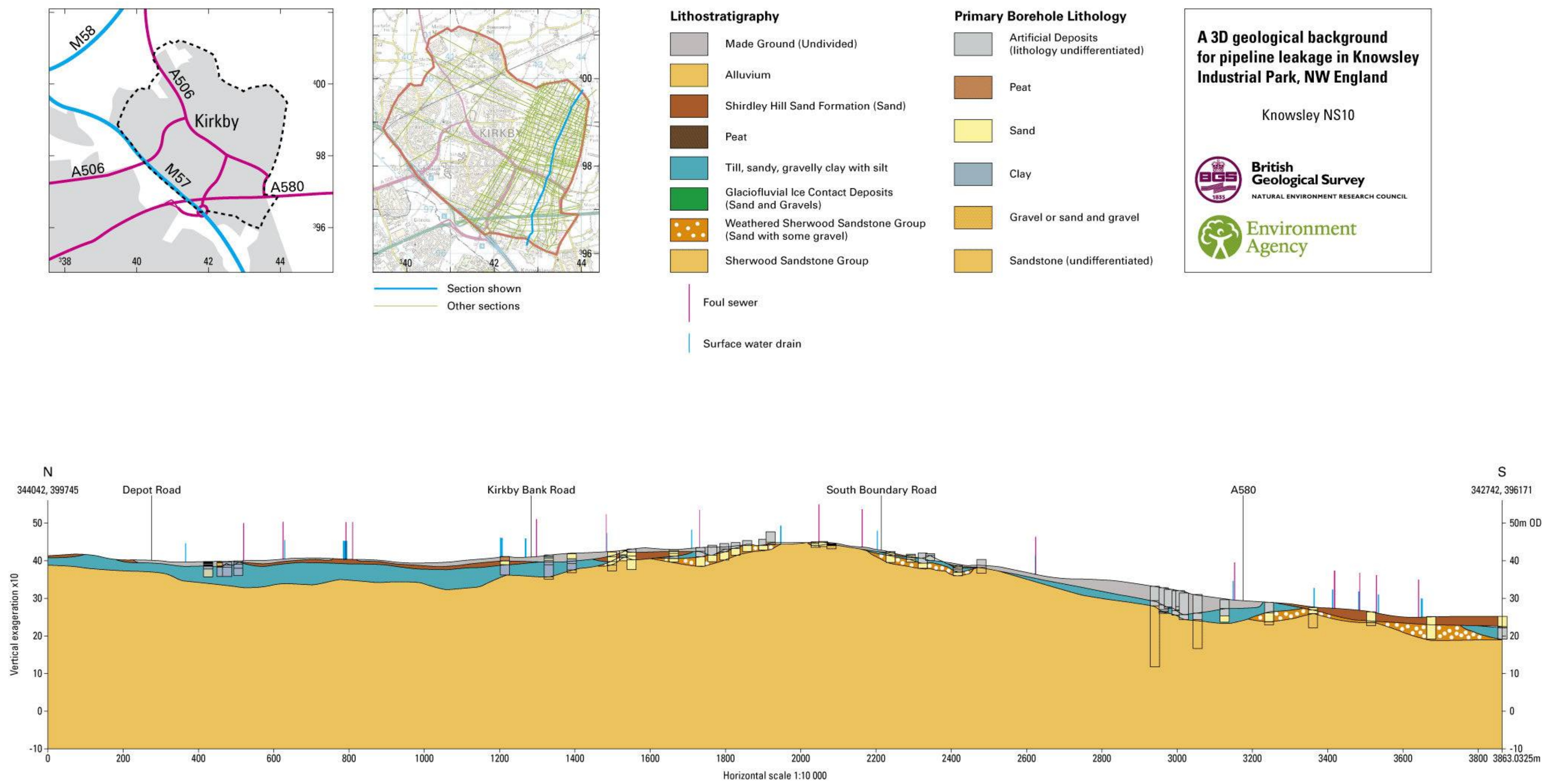
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

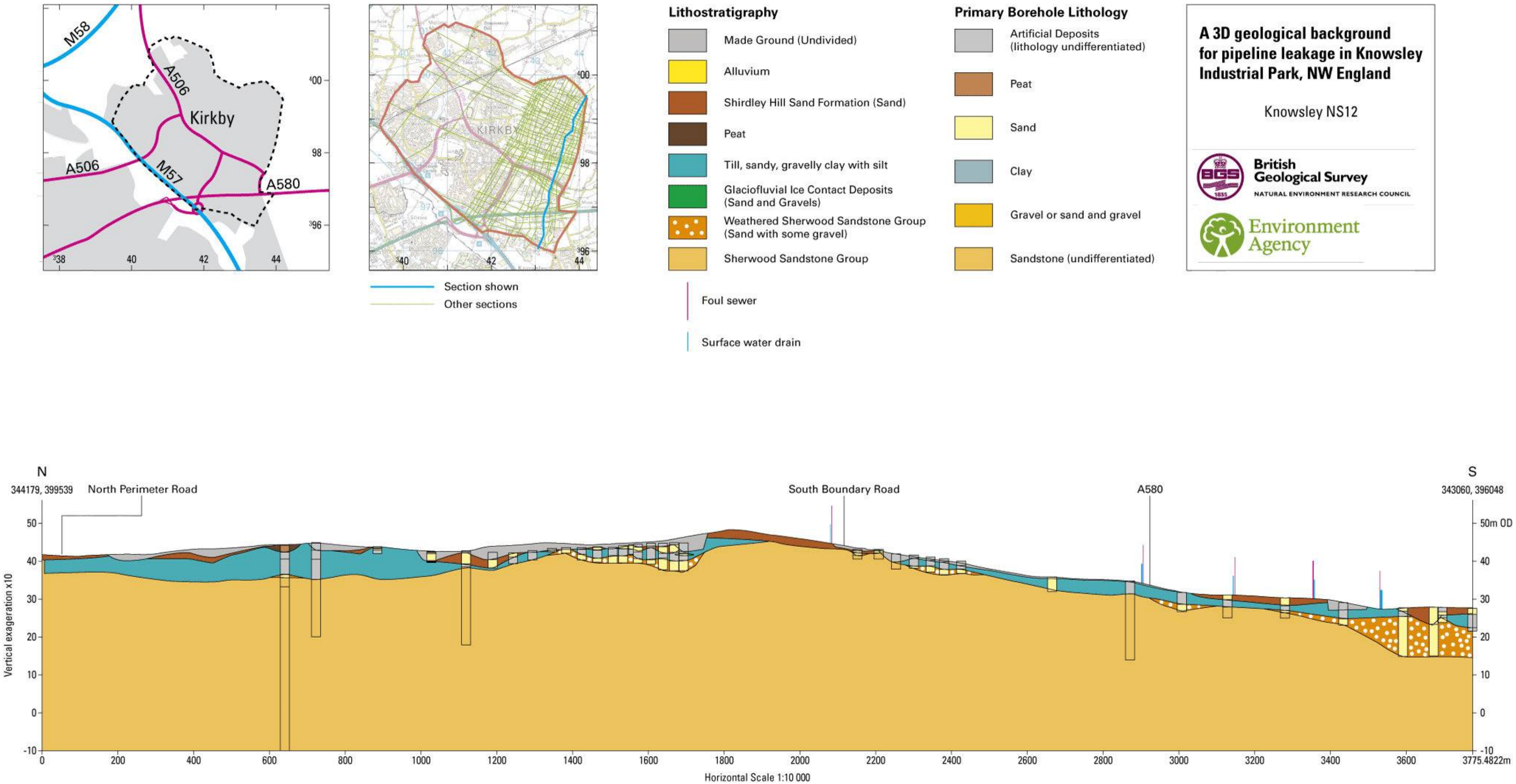
Environment Agency

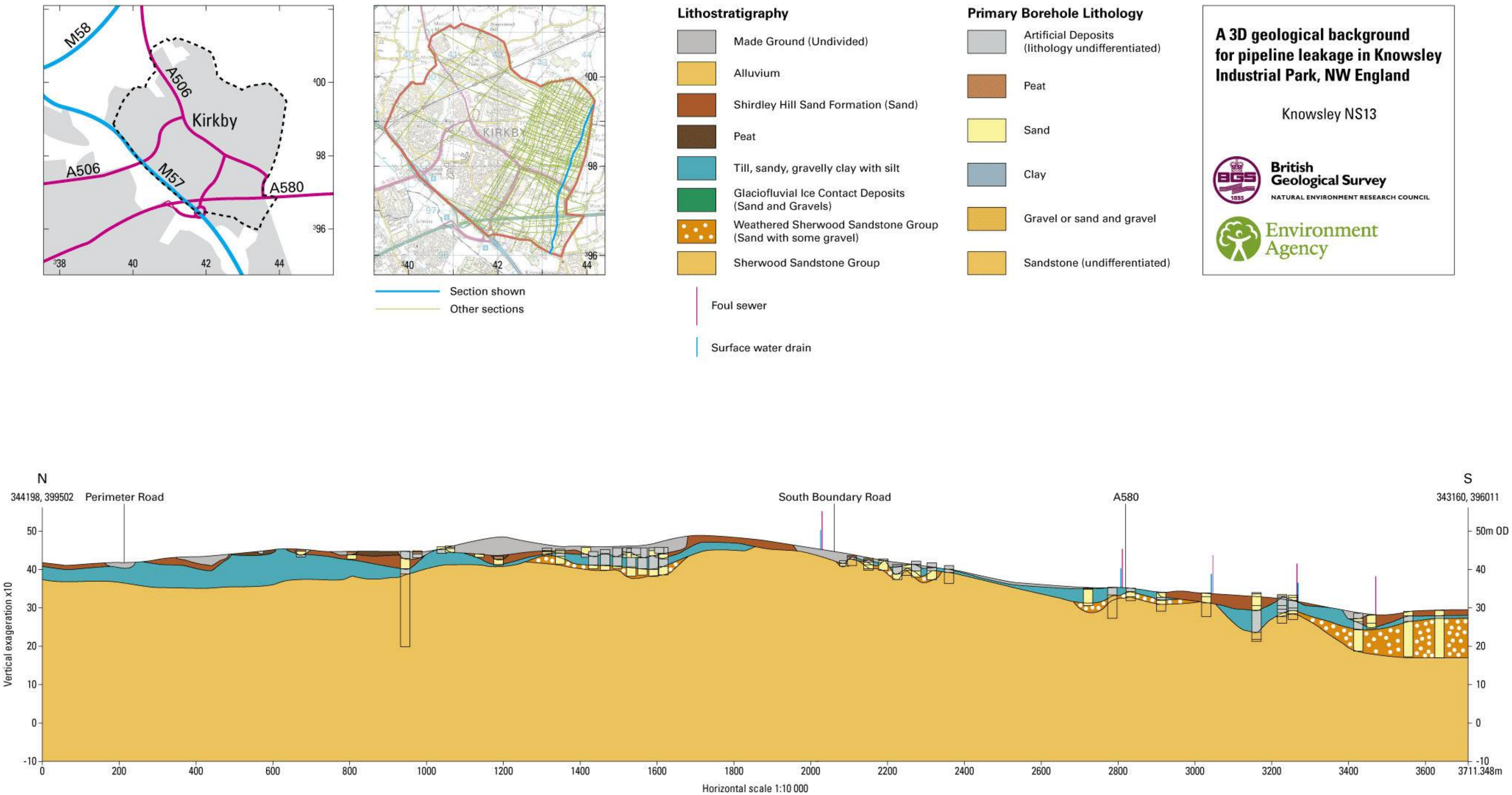


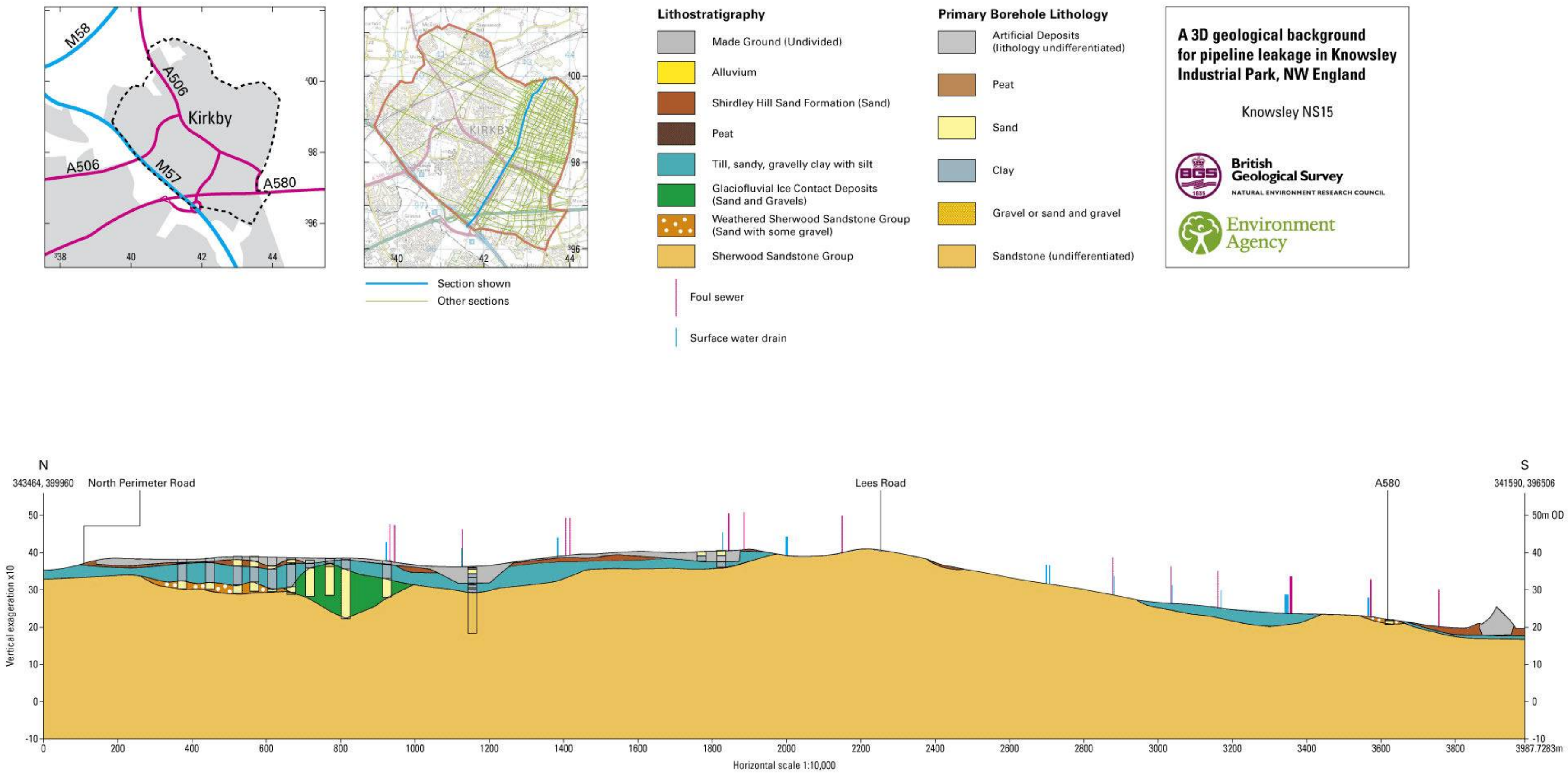

A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS8
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
Section shown
Other sections
Kirkby
A506
A580
M57
M58
N
343899, 399910
S
342287, 396074
North Perimeter Road
Woodward Road
A5208
A580
Vertical exaggeration x10
Horizontal scale 1:10 000
50m OD

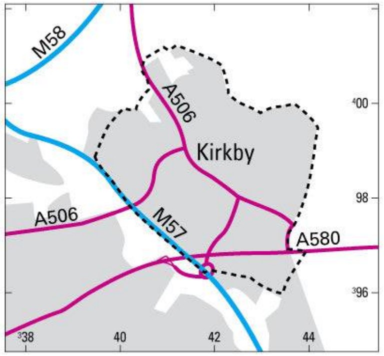

A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS9
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
M58
A506
Kirkby
M57
A580
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
N
343981, 399781
Woodward Road
A580
S
342525, 396211
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
3918.4956m

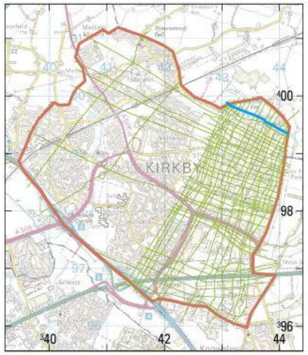

M58
A506
Kirkby
M57
A580
A506
400
98
396
338
40
42
44
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS10
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
344042, 399745
Depot Road
Kirkby Bank Road
South Boundary Road
A580
S
342742, 396171
Vertical exageration x10
50m OD
Horizontal scale 1:10 000
3863.0325m


M58
A506
Kirkby
M57
A580
A506
400
98
396
338
40
42
44
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS12
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
S
344179, 399539
North Perimeter Road
South Boundary Road
A580
343060, 396048
50m OD
Vertical exageration x10
Horizontal Scale 1:10 000
3775.4822m


A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS13
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
M58
A506
Kirkby
M57
A580
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
N
344198, 399502
Perimeter Road
South Boundary Road
A580
S
343160, 396011
50m OD
Vertical exageration x10
3711.348m
Horizontal scale 1:10 000


M58
A506
Kirkby
M57
A580
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley NS15
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
N
343464, 399960
North Perimeter Road
Lees Road
A580
S
341590, 396506
50m OD
Vertical exageration x10
Horizontal scale 1:10,000
3987.7283m





Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group

Foul sewer

Surface water drain

Primary Borehole Lithology

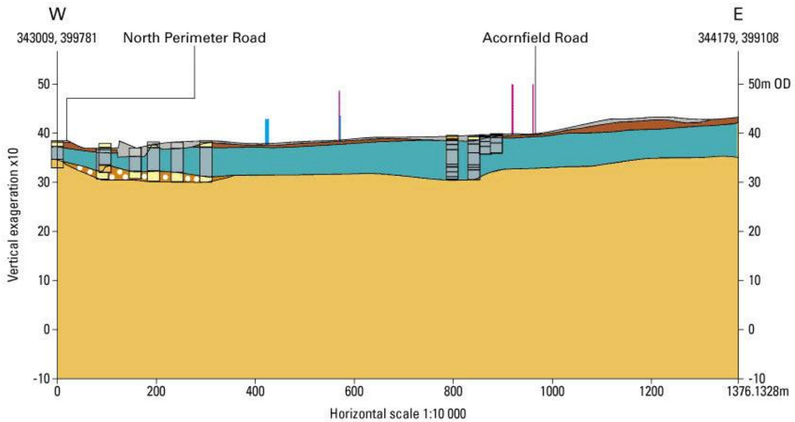
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

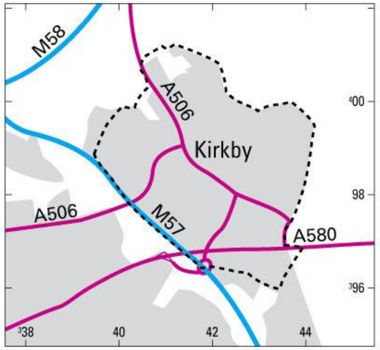
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

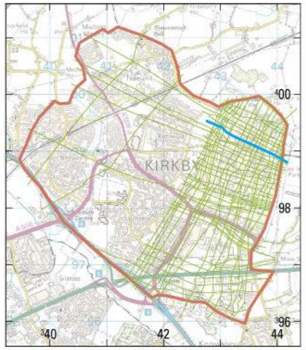
Knowsley WE1

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency







Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group
- Foul sewer
- Surface water drain

Primary Borehole Lithology

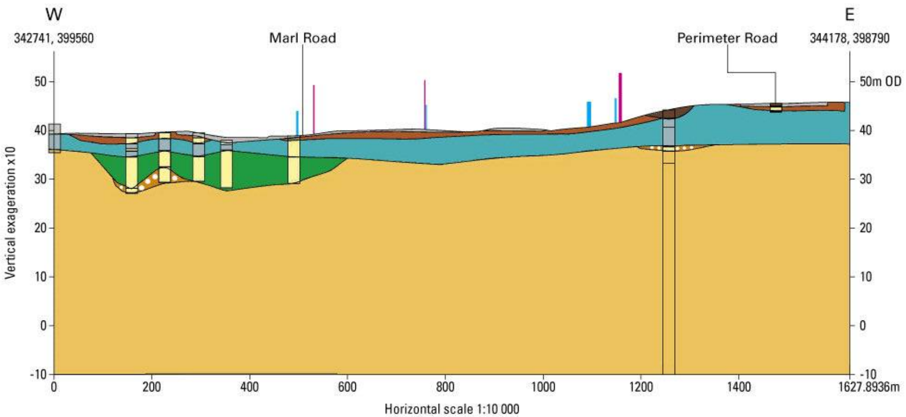
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

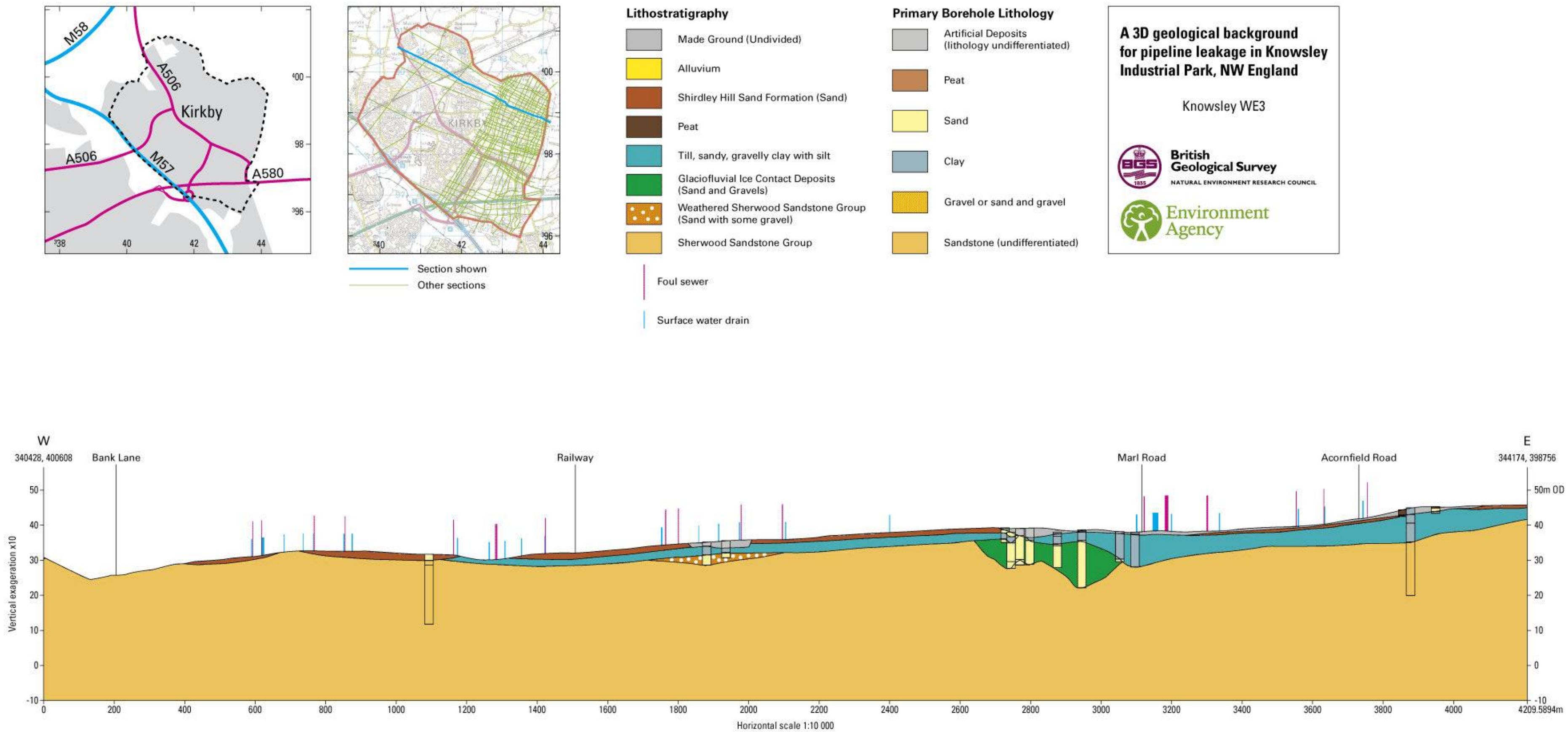
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

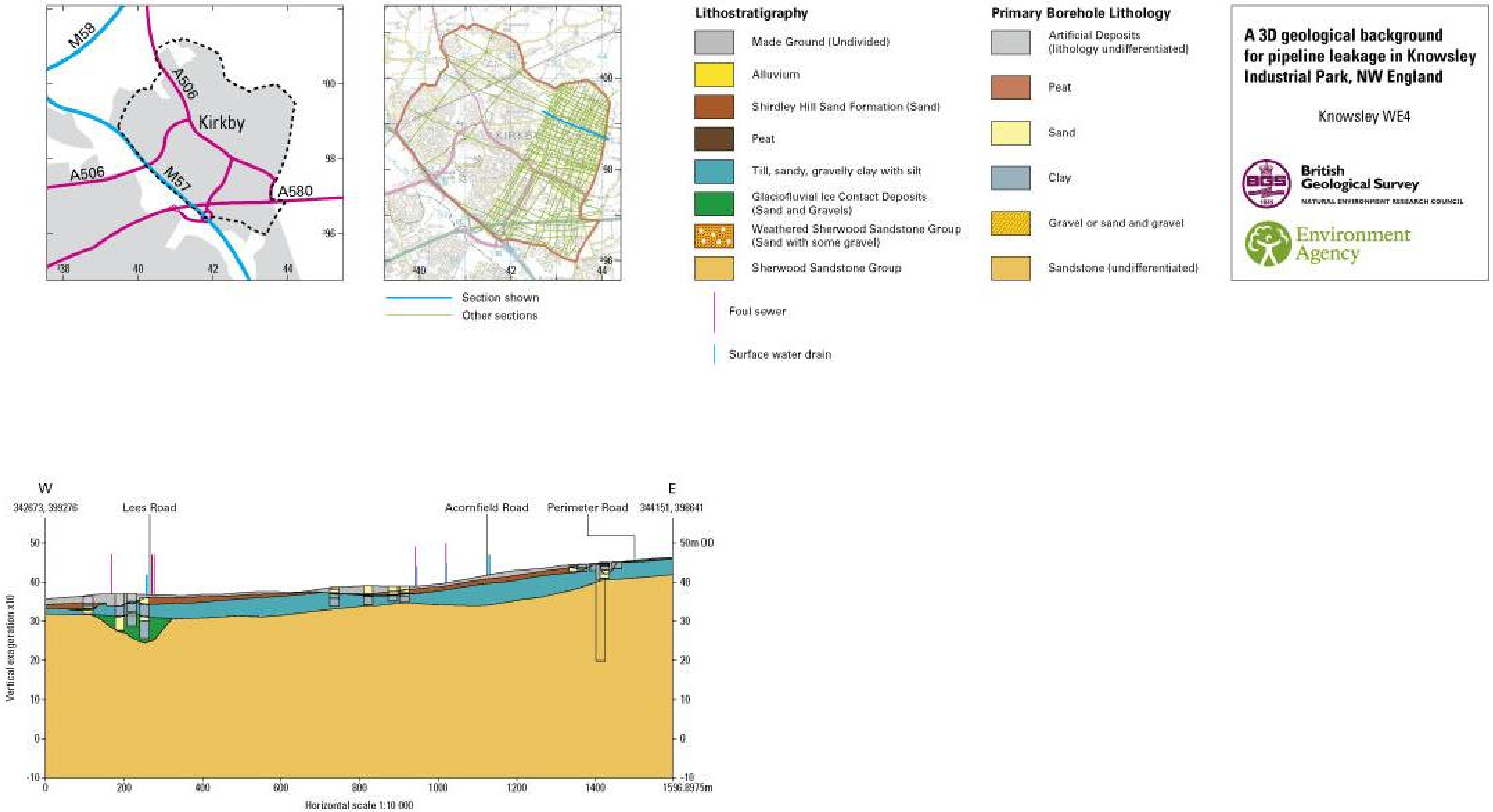
Knowsley WE2

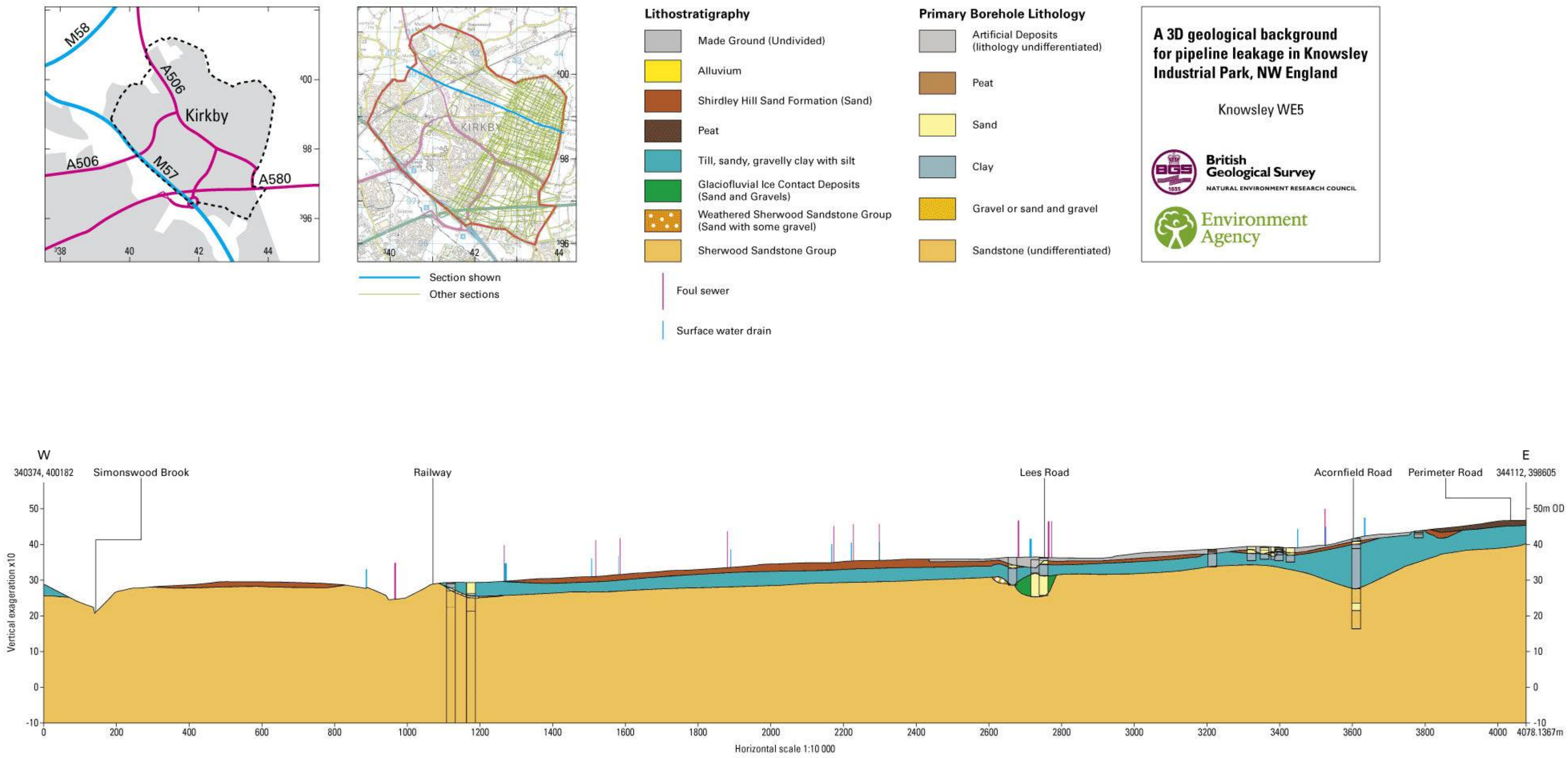
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

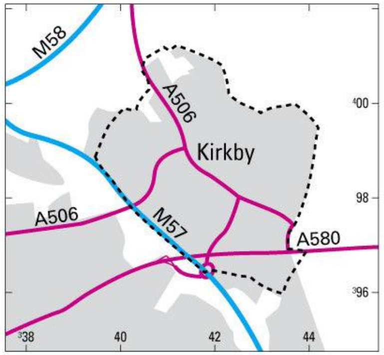
Environment Agency

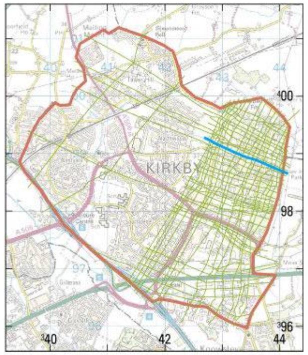



M58
A506
Kirkby
M57
A580
A506
38
40
42
44
400
98
396
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE3
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
340428, 400608
Bank Lane
Railway
Marl Road
Acornfield Road
E
344174, 398756
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
4209.5894m


M58
A506
Kirkby
A506
M57
A580
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE4
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
342673, 399276
Lees Road
Acornfield Road
Perimeter Road
E
344151, 398641
50m OD
Vertical exaggeration x10
Horizontal scale 1:10 000
1596.8975m


M58
A506
Kirkby
M57
A580
Section shown
Other sections
KIRKBY
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE5
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
340374, 400182
Simonswood Brook
Railway
Lees Road
Acornfield Road
Perimeter Road
E
344112, 398605
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
4078.1367m





Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group

- Foul sewer
- Surface water drain

Primary Borehole Lithology

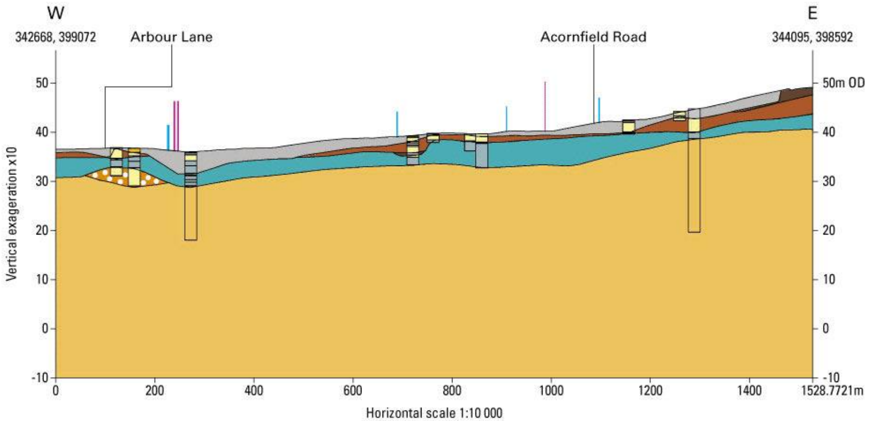
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

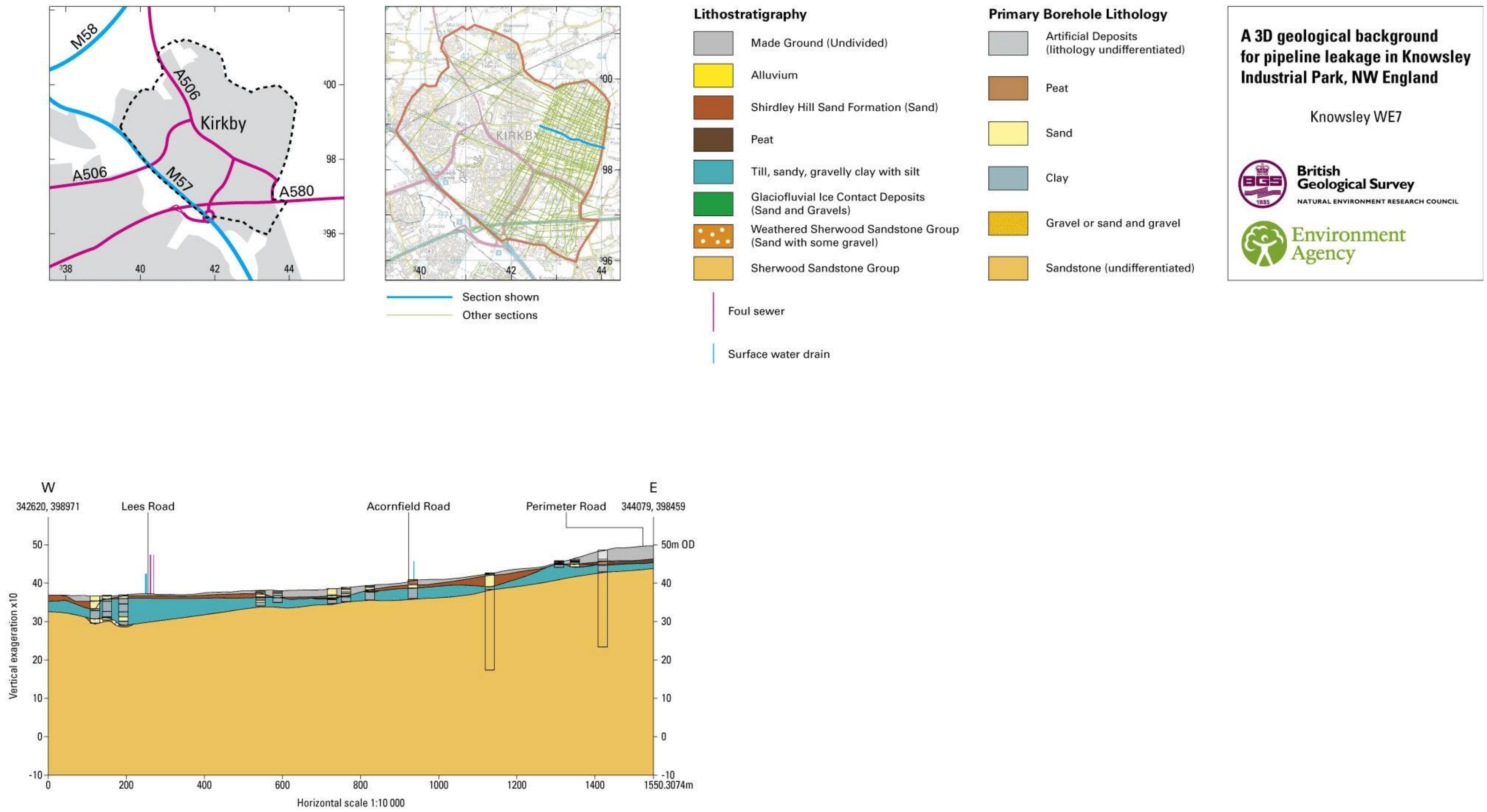
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

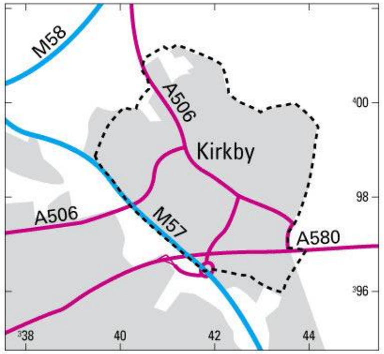
Knowsley WE6

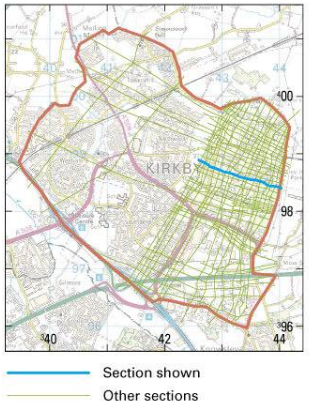
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency




M58
A506
Kirkby
M57
A580
38
40
42
44
400
98
396
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE7
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
E
342620, 398971
Lees Road
Acornfield Road
Perimeter Road
344079, 398459
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
1550.3074m





Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group
- Foul sewer
- Surface water drain

Primary Borehole Lithology

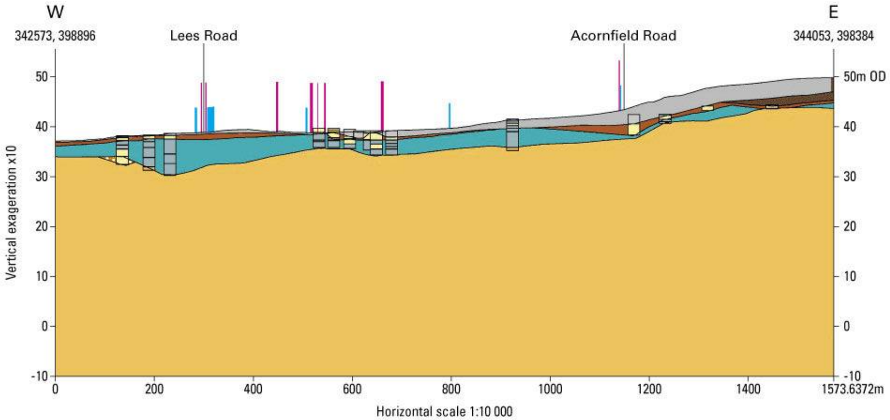
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

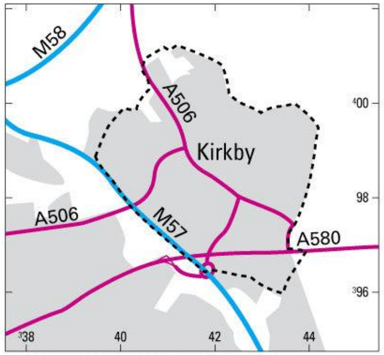
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

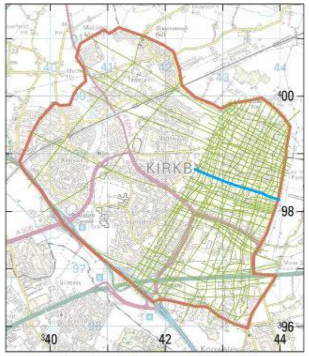
Knowsley WE8

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency







Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group
- Foul sewer
- Surface water drain

Primary Borehole Lithology

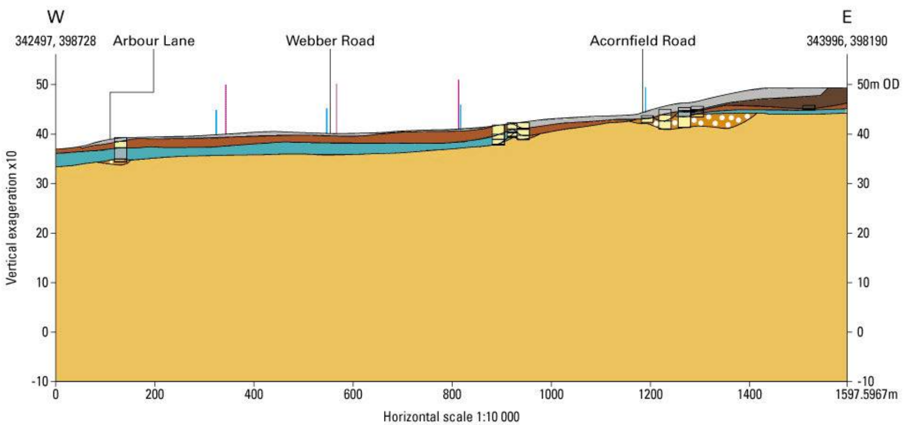
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

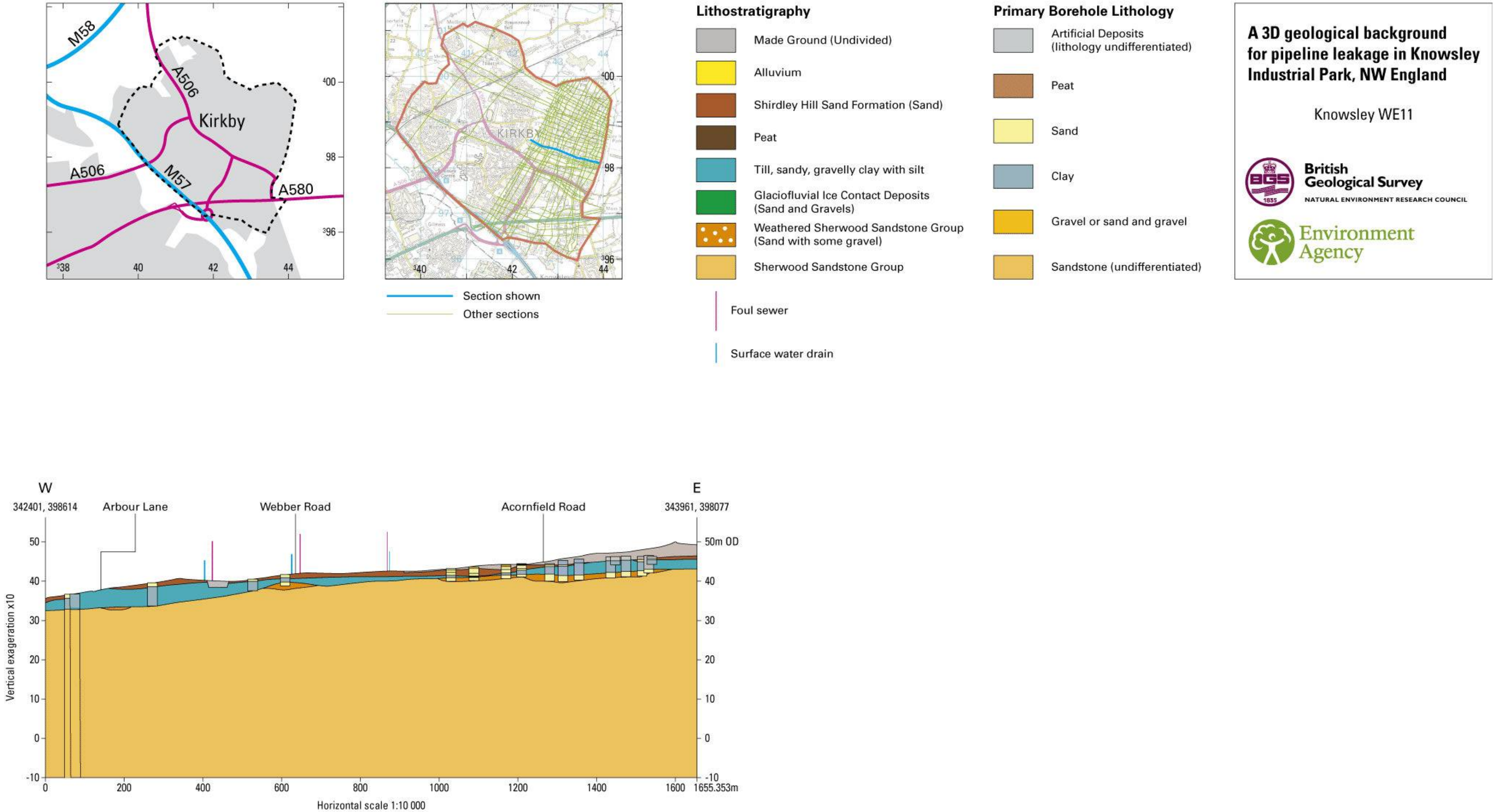
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

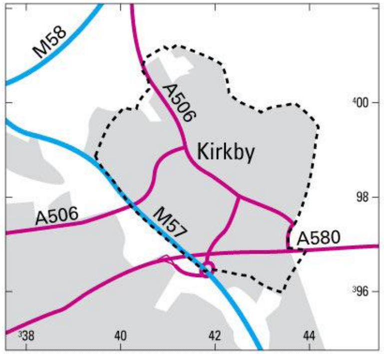
Knowsley WE10

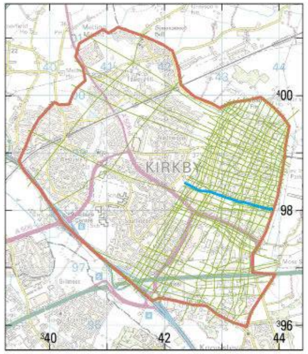
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency




A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE11
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
M58
A506
Kirkby
M57
A580
Section shown
Other sections
W
E
342401, 398614
Arbour Lane
Webber Road
Acornfield Road
343961, 398077
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
1655.353m





Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group

- Foul sewer
- Surface water drain

Primary Borehole Lithology

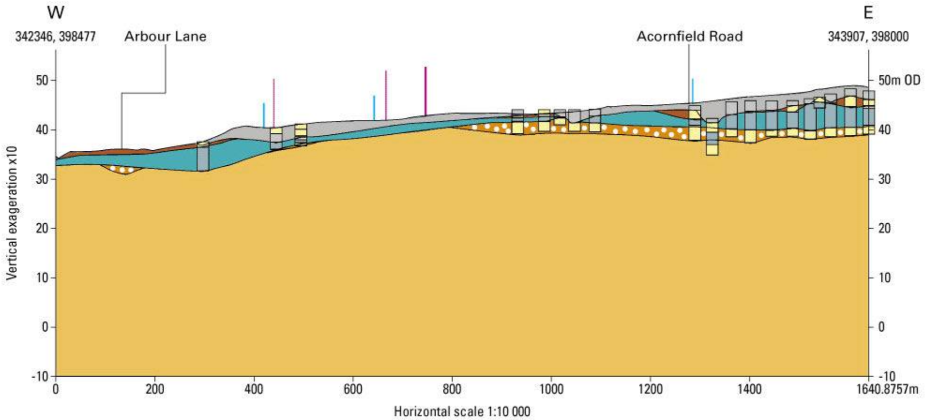
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

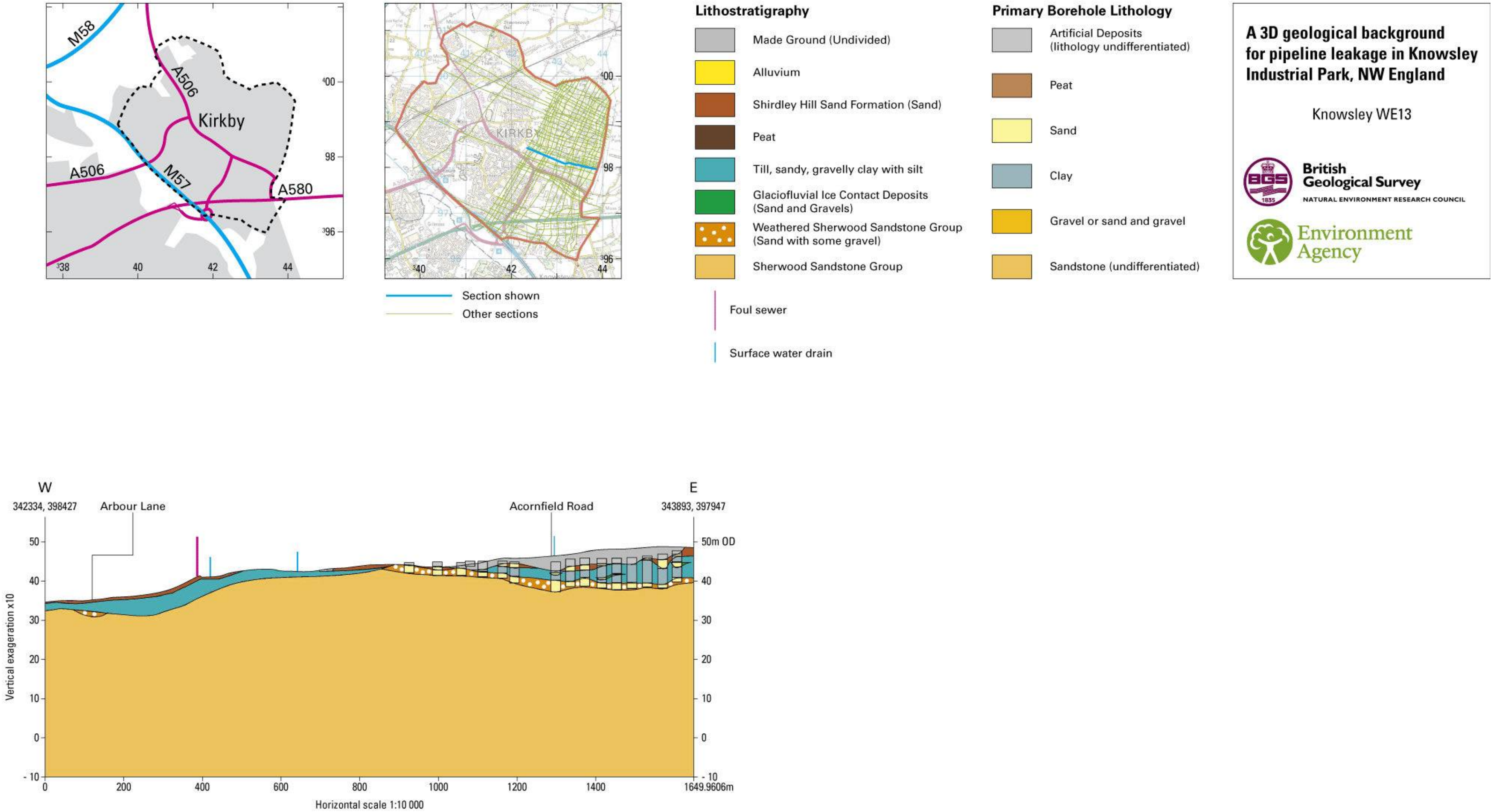
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

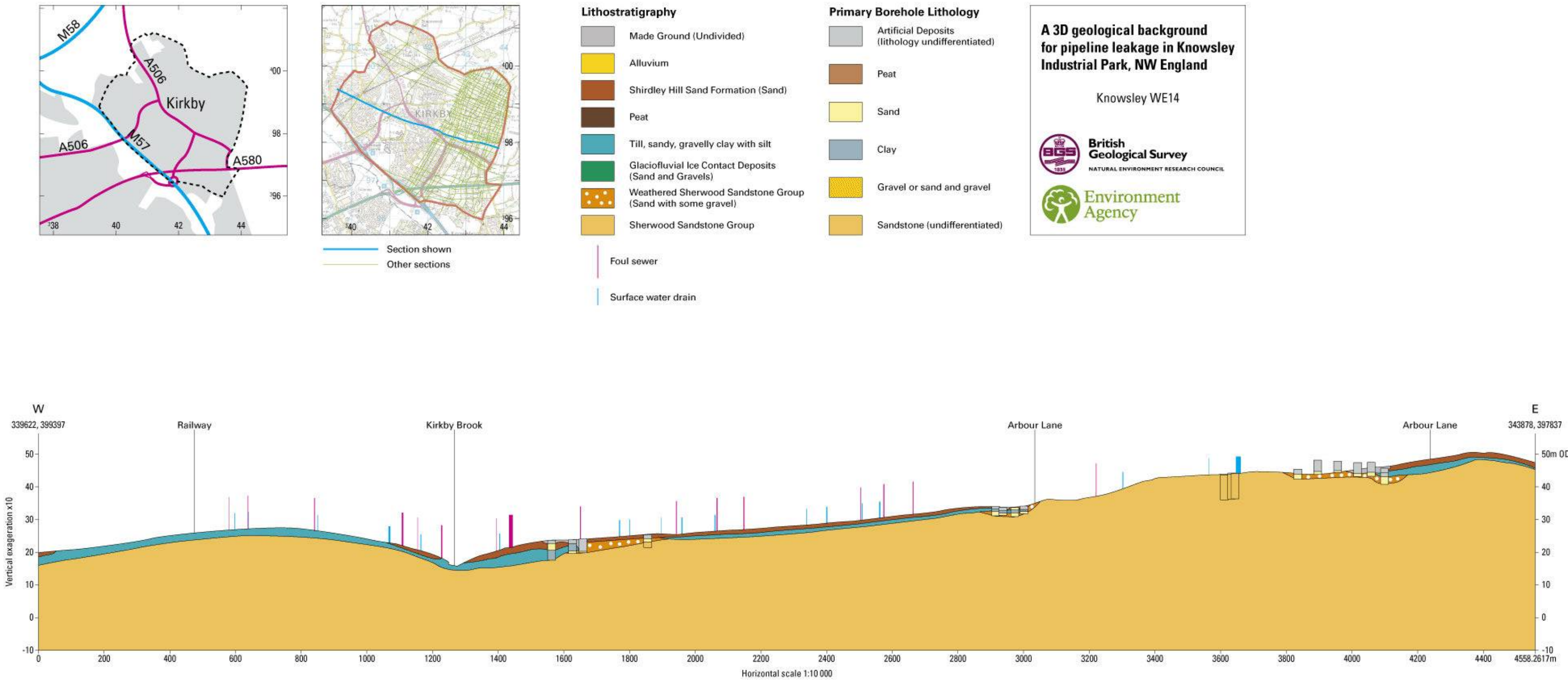
Knowsley WE12

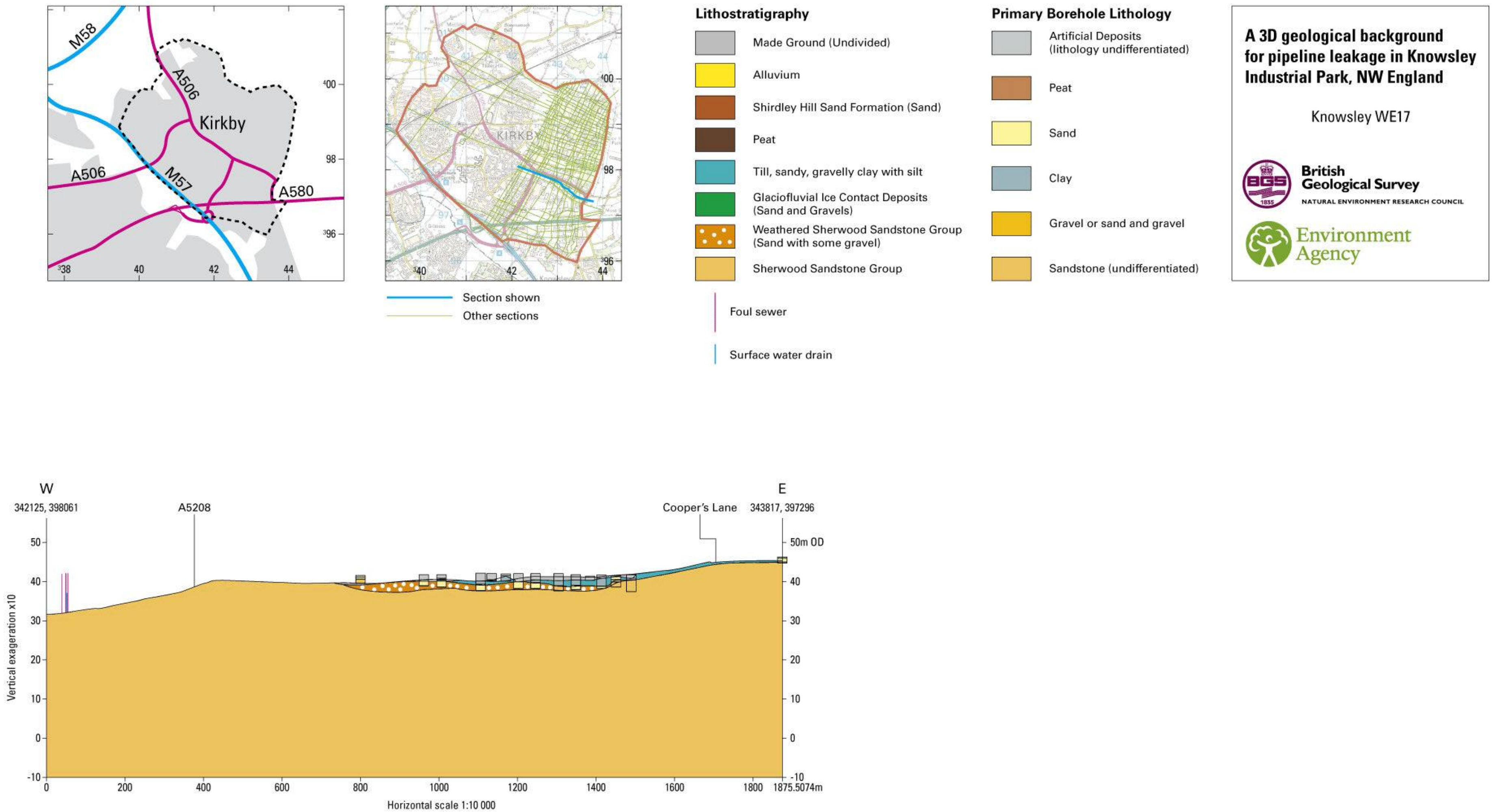
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

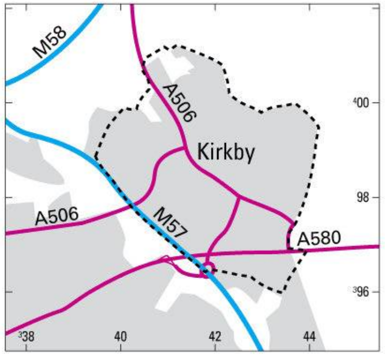
Environment Agency

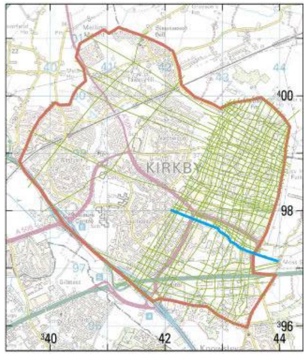



M58
A506
Kirkby
M57
A580
A506
400
98
396
338
40
42
44
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE13
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
342334, 398427
Arbour Lane
Acornfield Road
E
343893, 397947
50m OD
Vertical exageration x10
50
40
30
20
10
0
- 10
0
200
400
600
800
1000
1200
1400
1649.9606m
Horizontal scale 1:10 000


M58
A506
Kirkby
M57
A580
38
40
42
44
96
98
00
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE14
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
339622, 399397
Railway
Kirkby Brook
Arbour Lane
Arbour Lane
E
343878, 397837
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
4558.2617m


M58
A506
Kirkby
M57
A580
A506
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE17
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
342125, 398061
A5208
Cooper's Lane
E
343817, 397296
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
1875.5074m





Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group
- Foul sewer
- Surface water drain

Primary Borehole Lithology

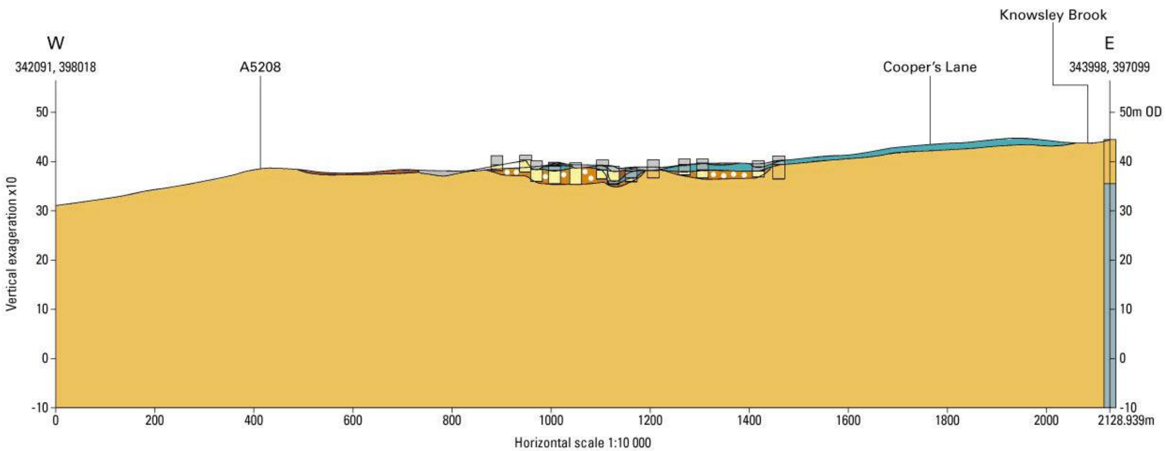
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

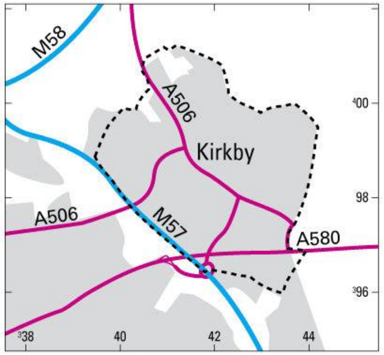
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

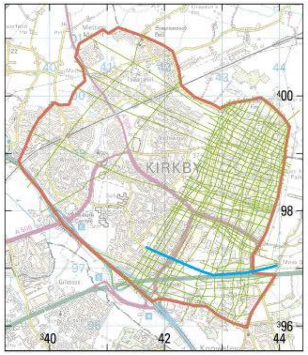
Knowsley WE18

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency







Section shown

Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group

Foul sewer

Surface water drain

Primary Borehole Lithology

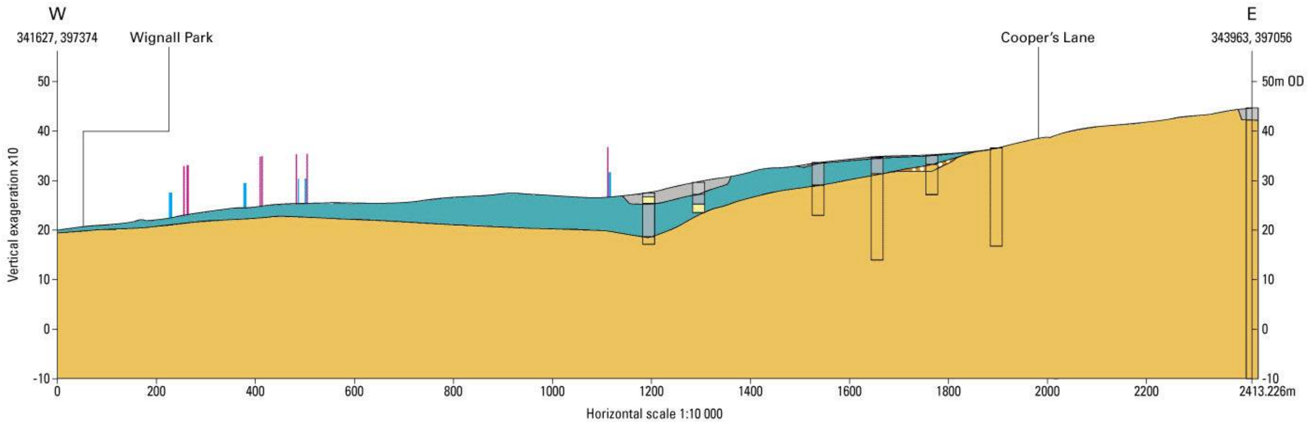
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

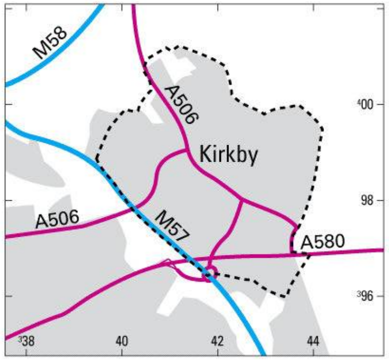
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

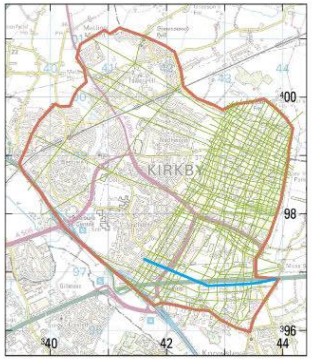
Knowsley WE19

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency







Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group

Foul sewer

Surface water drain

Primary Borehole Lithology

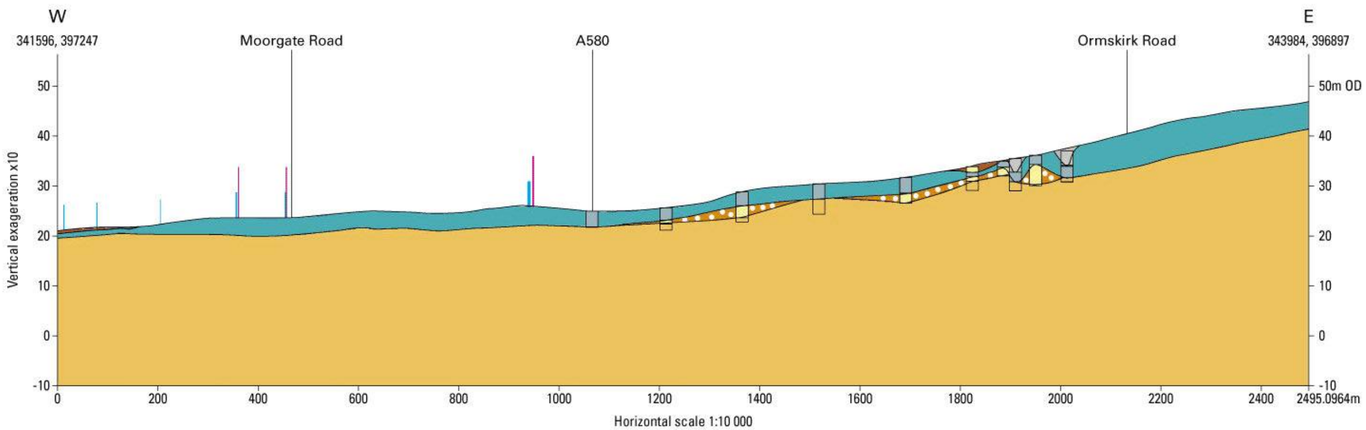
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

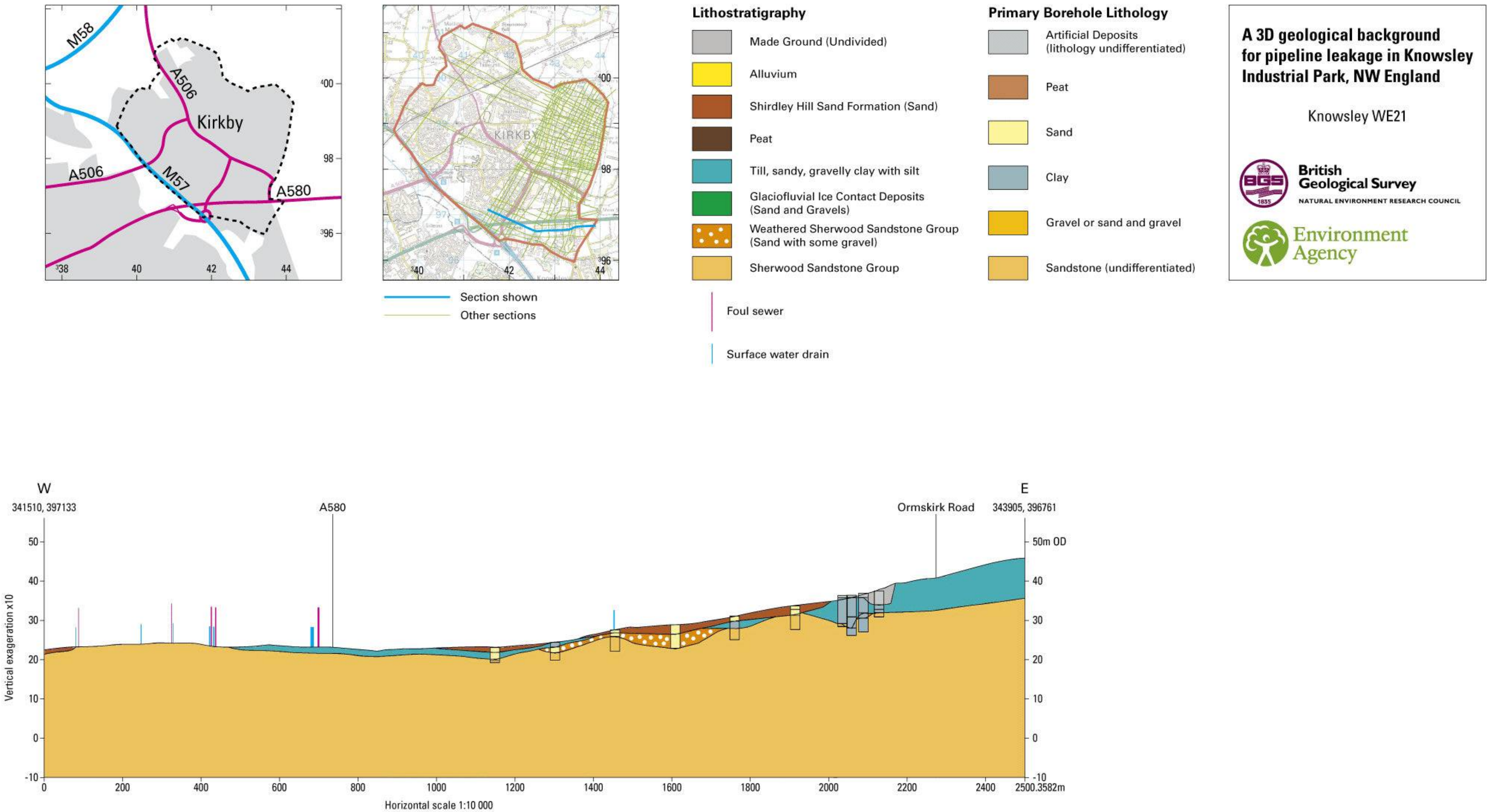
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

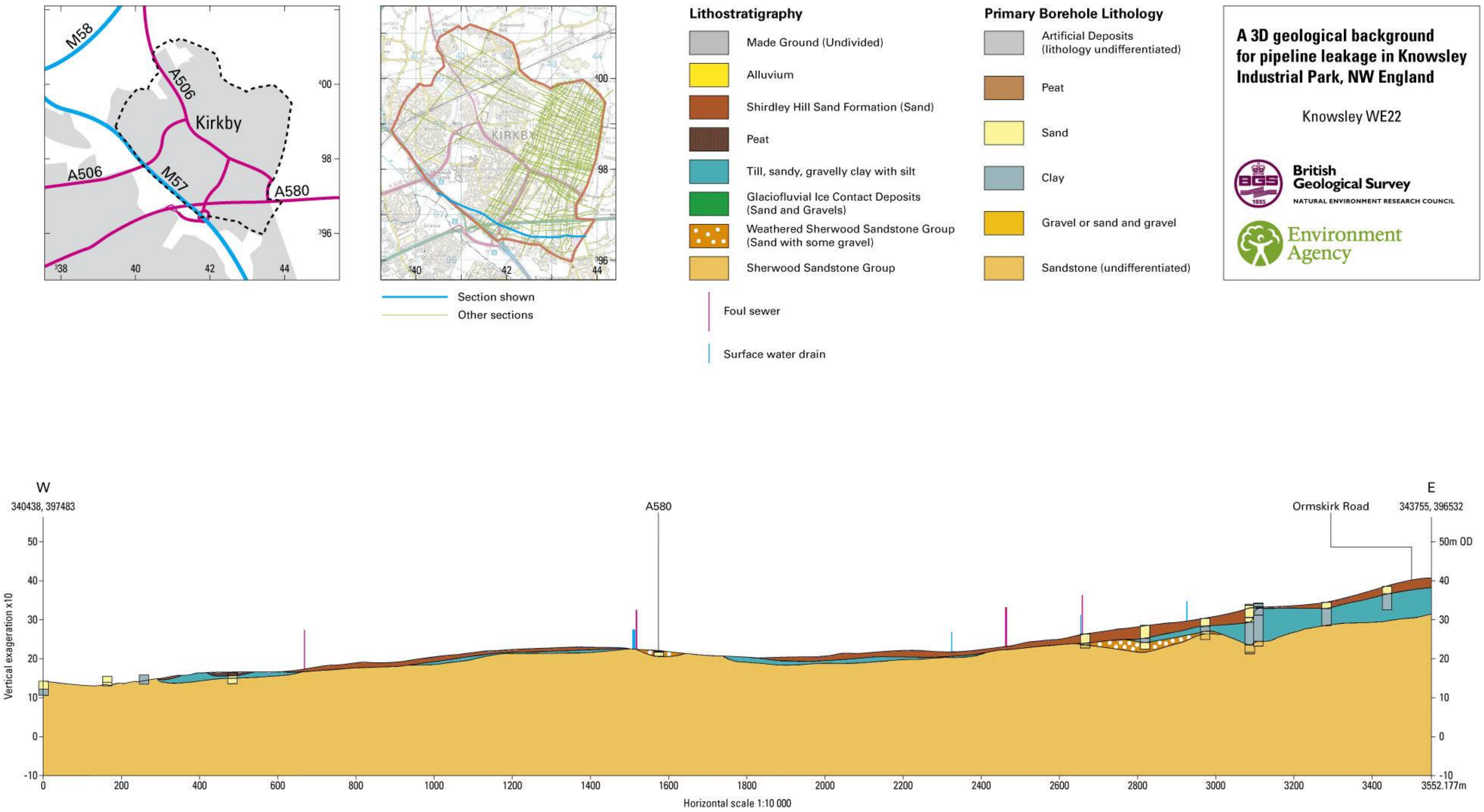
Knowsley WE20

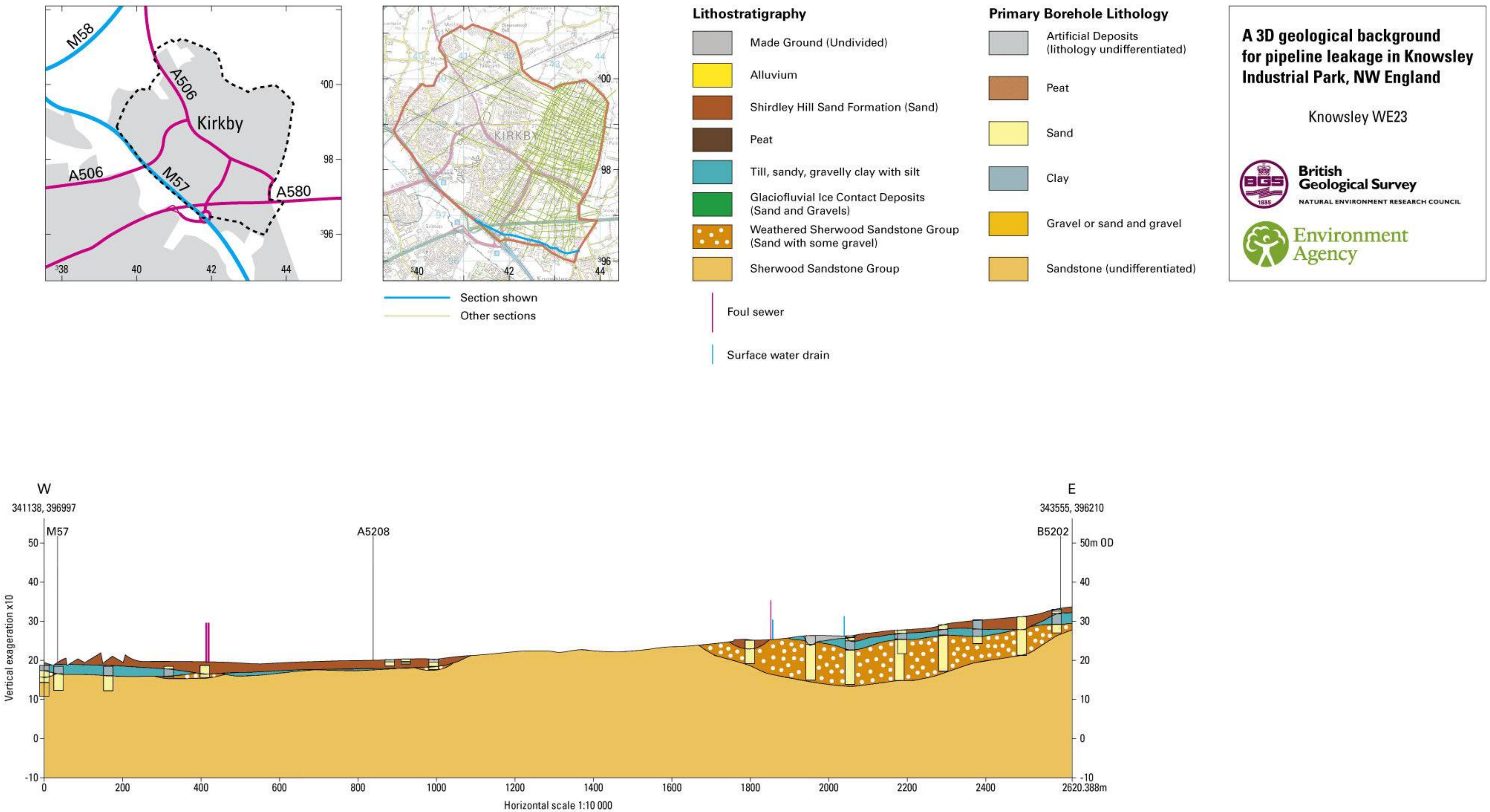
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

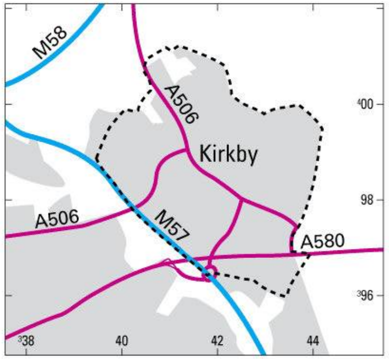
Environment Agency

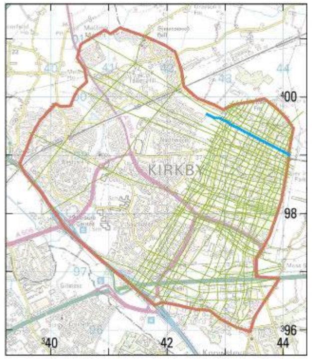



M58
A506
Kirkby
M57
A580
400
98
396
338
40
42
44
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE21
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
341510, 397133
A580
Ormskirk Road
E
343905, 396761
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
2500.3582m


M58
A506
Kirkby
M57
A580
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE22
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
340438, 397483
A580
Ormskirk Road
E
343755, 396532
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
3552.177m


M58
A506
Kirkby
M57
A580
A506
KIRKBY
Section shown
Other sections
Lithostratigraphy
Made Ground (Undivided)
Alluvium
Shirdley Hill Sand Formation (Sand)
Peat
Till, sandy, gravelly clay with silt
Glaciofluvial Ice Contact Deposits (Sand and Gravels)
Weathered Sherwood Sandstone Group (Sand with some gravel)
Sherwood Sandstone Group
Foul sewer
Surface water drain
Primary Borehole Lithology
Artificial Deposits (lithology undifferentiated)
Peat
Sand
Clay
Gravel or sand and gravel
Sandstone (undifferentiated)
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England
Knowsley WE23
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Environment Agency
W
341138, 396997
M57
A5208
E
343555, 396210
B5202
50m OD
Vertical exageration x10
Horizontal scale 1:10 000
2620.388m





Section shown

Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group
- Foul sewer
- Surface water drain

Primary Borehole Lithology

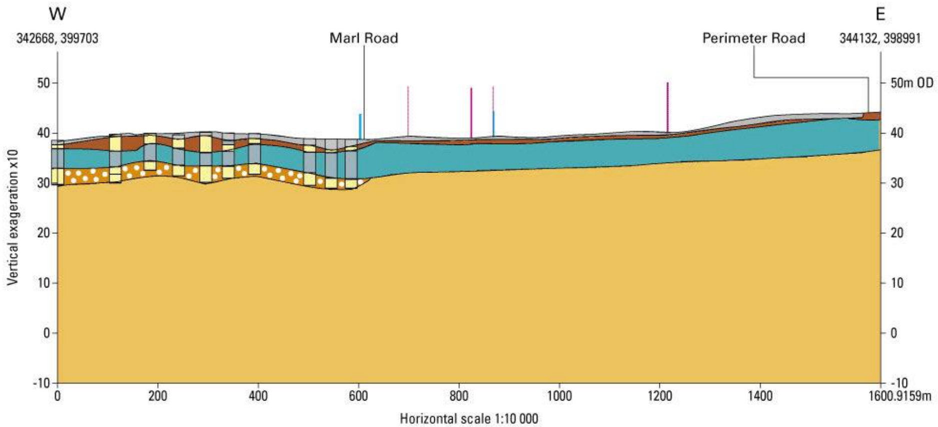
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

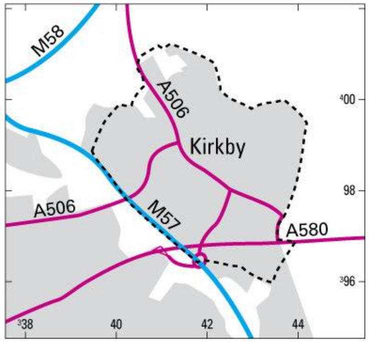
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

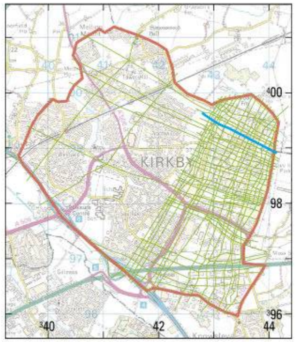
Knowsley WE25

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency







Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group
- Foul sewer
- Surface water drain

Primary Borehole Lithology

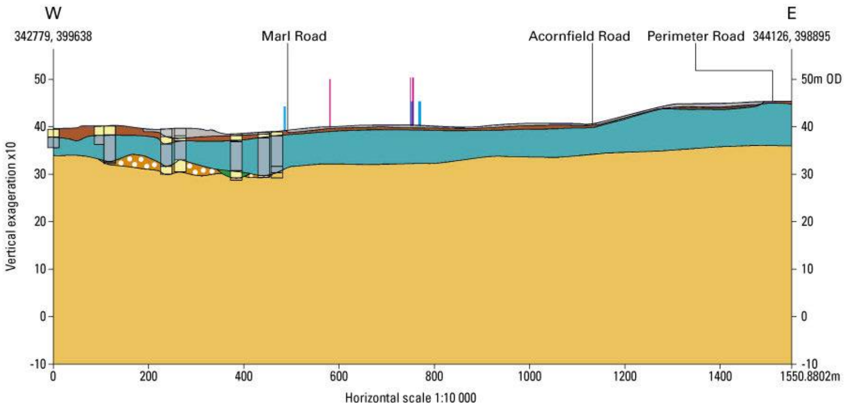
- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

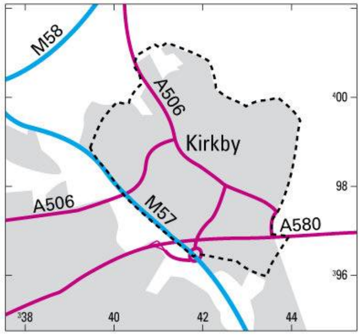
A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

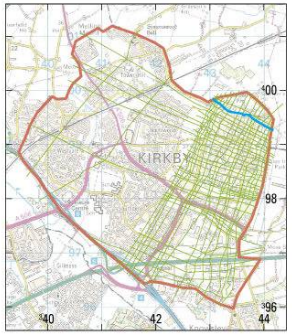
Knowsley WE26

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Environment Agency







Section shown
Other sections

Lithostratigraphy

- Made Ground (Undivided)
- Alluvium
- Shirdley Hill Sand Formation (Sand)
- Peat
- Till, sandy, gravelly clay with silt
- Glaciofluvial Ice Contact Deposits (Sand and Gravels)
- Weathered Sherwood Sandstone Group (Sand with some gravel)
- Sherwood Sandstone Group
- Foul sewer
- Surface water drain

Primary Borehole Lithology

- Artificial Deposits (lithology undifferentiated)
- Peat
- Sand
- Clay
- Gravel or sand and gravel
- Sandstone (undifferentiated)

A 3D geological background for pipeline leakage in Knowsley Industrial Park, NW England

Knowsley WE28

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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