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The Development of an Underground Asset Management Tool in BGS.

Information Products Theme

Internal Report OR/09/023

BRITISH GEOLOGICAL SURVEY

INFORMATION PRODUCTS THEME

INTERNAL REPORT OR/09/023

The Development of an Underground Asset Management Tool in BGS.

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Tunnelling in progress.

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Summary

This report describes the work carried out to scope the potential for BGS to develop an Underground Asset Management tool. This work was funded through both a NERC innovation grant and Science budget funding from the Information Products Theme.

The objective of asset management is 'to ensure that assets deliver the required function and level of performance in terms of service, in a sustainable manner, at optimum whole life cost without compromising health, safety, environmental performance or the organisation's reputation'. It is in this context that this report discusses the data available within BGS that could be provided to external organisations and how to communicate this information to potential clients.

STRUCTURE OF REPORT

The introduction explains the background to the project and looks into why an asset management tool may be required. The second chapter discusses customer need and likely uptake if such a tool were developed. This leads into the third chapter where current tools already on the market in the UK and their limitations are discussed. In the forth and fifth chapters an outline is given of the availability of data critical to the creation of an asset management system and how this could be developed into a tool. Finally we describe a pilot system developed for the Humber–Trent region. The final chapter attempts to summarise the key findings.

1 Introduction

Thirty seven years ago the 'Hoar Report' was commissioned to evaluate the cost of corrosion to the national economy of the UK. The report estimated the cost to be approximately 3-4% gross domestic product (GDP). Since then the development of new construction materials and methods has reduced this cost to an estimated 2.5% - 3.5% GDP (DTI, 2000). Whilst corrosion is being managed more effectively, it is still a significant concern and cost burden to the nation. In recent years, public and media interest has focussed on the cost of leakage from water supply pipelines, but buried assets, whether pipe-work, cabling, sewers or building foundations, present their own challenges as problems are largely hidden from view and are difficult to assess and manage.

THAMES WATER LEAKAGE MEGALITRES per DAY
2000-01: 688
2001-02: 865
2002-03: 943
2003-04: 946
2004-05: 915
2005-06: 894
Source: Ofwat

Table 1: Daily leakage figures.

The susceptibility of pipelines to corrosion and degradation can be determined through the analysis of a number of environmental factors, combined with knowledge of the age and composition of the pipeline in question. It is clear that in order to improve underground asset management in the UK there is a requirement for spatial knowledge of the corrosive properties of the soil in which pipe-work and other underground infrastructure sit. The production of GIS data layers showing the spatial distribution of corrosive properties, either as individual properties or on a cumulative points system would aid users such as utility companies and local authorities to make improved decisions regarding the routeing of pipe-work, selecting anti-corrosion measures or materials and to manage maintenance and renewal schedules. The challenge for BGS is to combine national-scope, local-scale geological information into a GIS and then create a simple, easy to understand Asset Management tool for the UK market.

This report provides summary of the requirements for underground asset management in the UK today and looks at how BGS could provide and develop relevant spatial geo-environmental datasets to aid and improve buried asset management within the UK.

2 Customer Need

Civil engineers and surveyors will always need to build structures and lay pipelines in corrosive environments and it is therefore essential to address the problems that result (Broomfield, 2006). Corrosion prevention is often the most economical solution when compared with conventional removal and repair methods.

Interest in an underground asset management system has been shown by Thames Water in relation to their current issues with pipeline leakage. Thames Water is currently responsible for around 16,000 kilometres of water pipes under London of which 30% have been there for more than 150 years, and 50% for more than a century. These ancient pipes are made of cast iron and are now brittle and corroded from sitting in highly plastic clay soil. Extra stresses have come from traffic and inflexible lead joints, which lock and fracture producing leakage of water (Thames Water official website, 2008).

Leakage issues are increasingly important as water resources within Thames Water are under increasing pressure from the climate change and population growth. Thames Water currently identify areas in which burst pipes are likely by using historical and current weather data. Leakage is often found to occur under cold conditions and when clay soils expand and contract. This data could be refined if they knew where the most corrosive soils and highly plastic clays are located.

In addition the network was developed by a whole host of small water companies and repairs over the years have not been carried out systematically and have in certain circumstances added to the profusion of pipes, many of which are not in use.

Recently, there has been an increasing awareness of the need to manage physical assets more systematically. In May 2004, the Institute of Asset Management produced a specification for Asset Management. This was updated in December 2008 along with development of a toolkit for evaluating compliance to the specification. PAS (Publicly Available Specification) 55 is specifically intended to cover the management of physical infrastructure assets and in particular the assets that form the main element of those in the built environment such as utility networks. PAS 55 gives guidance and best practice in asset management, typically this is relevant to infrastructure, gas, electric and water utilities. The standard is split into two parts: part 1 – specification for the optimised management of physical infrastructure assets and part 2 guidelines for the application of PAS 55 part 1. While PAS 55 is not required for non regulated industries it has been generating more interest. In April 2008 OFGEM (the Office of the Gas and Electricity Markets) reported that all gas and electrical suppliers had achieved PAS 55 certification. This provides BGS with a ready market that requires detailed underground asset management information in order to comply with the recommendations in PAS 55.

3 Current Asset Management tools and their limitations.

3.1 CURRENT ASSET MANAGEMENT TOOLS

3.1.1 Soil Corrosivity Map.

Within the U.K., the main source of information regarding soil corrosivity is the National Soil Research Institute (NSRI) at Cranfield University (Figure 3). Their corrosion map is based on the methodologies developed by Corcoran et al. (1977), Argent & Furness, (1979) and Jarvis & Hedges (1994). Their approach was to use a combination of archive and new data with respect to their soil series (domain) maps to produce a corrosivity factor. This method was based on the scheme originally devised by the Cast Iron Pipe Research Association (CIPRA) (1964), using a mixture of field measurements and measured archive values to produce an accumulative score for potential corrosivity of ferrous pipes for each soil series (map domain).

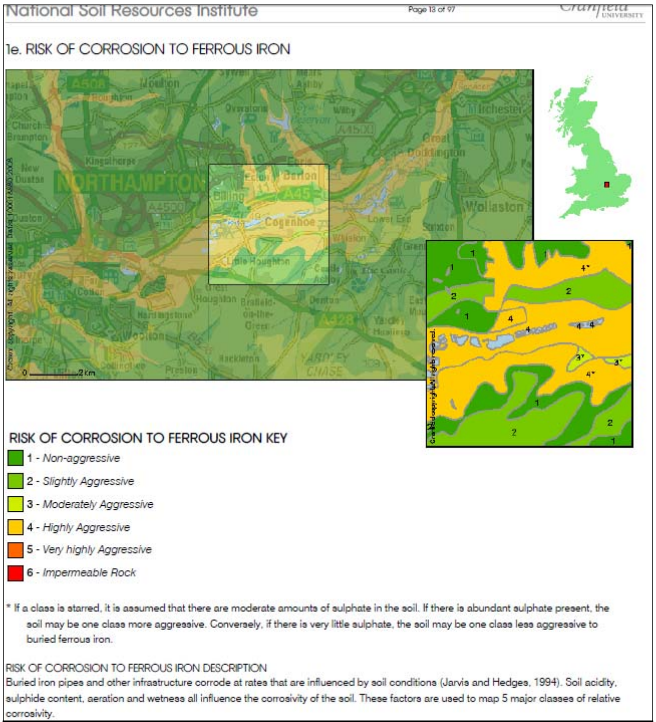


Figure 1: NSRI Corrosion Risk Map.

The NSRI map was created by:

1. Field measurements of resistivity and redox potential at depths of 0.79 and 1.59 meters for each soil series
2. Simultaneous collection of samples for laboratory measurement of minimum resistivity, pH and soluble sulphate content.

This work has been included the CatchIS software as an 'environmental risk modelling tool'. CatchIS contains a suite of additional modules which supports the operational management of underground assets for example water pipes called 'LEACS'. This tool predicts the risk of corrosion to piping by looking at the following factors:

1. Soil moisture: soil moisture levels exceeding 20 % are particularly susceptible.
2. Soil acidity: values less than pH 4 are likely to result in greater corrosion.
3. Soil aeration: poorly aerated soils. Soil aeration is generally measured by its redox potential with values less the 400-430mV indicating a suitable environment for sulphate reducing bacteria.
4. Electrical resistivity: soils with low resistivity will encourage corrosion. Values less than 2000 ohm cm are likely to be aggressive

Once measured values are determined for these parameters a score can be calculated based on the CIPRA rating system (Table 2).

Table 2: Cast Iron Pipe Research Association corrosion rating

Soil Property	Range	Points[1]
Resistivity (ohm cm)	<700	10
	700 – 1000	8
	1000 – 1200	5
	1200 – 1500	2
	1500 – 2000	1
	>2000	0
pH	0-2	5
	2-4	3
	4-6.5	0
	6.5-7.5	0[2]
	7.5-8.5	0
	>8.5	3
Redox potential	>100 mV	0
	50-100 mV	3.5
	0-50 mV	4
	Negative(-)	5
Sulphides / sulphates	+	3.5
	Trace	2
	Negative	0
Moisture	Poor drainage, continuously wet	2
	Fair drainage, generally moist	1
	Good drainage, generally dry	0

[1] A total of 10 points indicates that the soil is certain to be corrosive to ferrous pipe

[2] If sulphides or sulphates present and low or negative redox results are obtained, 3 points should be given for this range.

3.1.2 American Association of State Highways and Transport Soil reinforcement limits

Similarly, work has been carried out to devise safe limits (below which corrosion is less likely to occur) such as those carried out by the American Association of State Highway and Transportation Officials (AASHTO) which recommends the limits outlined in Table 3. These results are based on laboratory tests for corrosion/degradation of soil reinforcements for mechanically stabilized earth walls and reinforced soil slopes.

Table 3: Limits in characteristics for soil reinforcements.

Property	Standard	Test Procedures
Resistivity	ohm-cm >3000	AASHTO T-288-91
pH	>5 < 10	AASHTO T-289-91
Organic content	1% max	AASHTO T-267-86
Chlorides	< 100 ppm	AASHTO T-291-91
Sulphates	< 200 ppm	AASHTO T-290-91

3.1.3 Department of Transportation, California formula.

A further study by the Department of Transportation in California used pH and laboratory measurements of minimum resistivity (R) to estimate the service life of steel culverts as in the equation below for soils with pH < 7.3.

$$\text{Years} = 13.79[\text{Log}_{10}\text{R}-\text{Log}_{10}\ (2160-2490\ \text{Log}_{10}\ \text{pH}] \qquad \text{(eq.1)}$$

3.2 LIMITATIONS WITH CURRENT ASSET MANAGEMENT TOOLS

The most significant limitation with current Underground Asset Management tools is the limited number of factors used to determine an assets susceptibility to corrosion. In reality a whole host of physical and chemical factors contribute to underground corrosion e,g, the shrink-swell potential of the soil, fracture potential of the ground, meteorological information and groundwater level as well as those factors already mentioned above.

Another significant issue is the complexity of the processes involved in creating corrosive environments. These are described in detail in Appendix 1. Problems with estimating soil corrosivity are a result of its potential to occur in very localised areas. For example, where an obvious factor such as high sulphide content is not present in a soil, corrosion may still occur, linked to other variables that are difficult to map. These may include local water-logging or a difference in substrate composition created as the structure was placed in the ground which then contributes to the formation of a corrosion cell. To improve on existing tools, BGS would need to provide a tool which takes into account as many, if not all the contributory factors and provide superior quality data.

It would be difficult to produce maps that show specific areas of likely corrosion with geologies or along pipes as will occur and are described in Appendix 1. It is felt that the domain approach used by NSRI to produce their corrosivity map is a reasonable and logical approach. However it is a very broad brush approach to a very complicated and variable problem and consequently doesn't represent the true ground conditions adequately. It is felt that with the development of GIS, Prop-Base and the Geotechnical Database BGS would be able to produce a more statistically integrated approach than NSRI which would result in a superior quality dataset. For example, the BGS Geotechnical GIS demonstrates an approach whereby all available data for a domain is presented using graphs linked to the spatial reference data and held in a GIS. Additionally, statistical packages such as 'R' could be used to interrogate the Geotechnical Database and provide up to date statistics for domains or areas within domains as new information is added. This would improve the quality of information provided in the underground asset management system as time goes on.

4 Data required and availability

Data required for an asset management system can be split into three headings: Natural physical, Chemical and Contaminants effecting pipeline composition. A table listing and describing all the assets used in the Humber-Trent pilot study area are given in Appendix 2.

4.1 PHYSICAL DATA

Physical properties such as fracturing and shrink swell contribute to corrosion potential by significantly weakening the pipeline material by causing them to bend and crack. The physical data used for the pilot study was taken directly from the Geosure-50 data, (slope instability, collapsible, compressible, dissolution, running sand, shrink swell) with the addition of a fracture layer i.e. those deposits that are likely to contain a high proportion of discontinuities. The fracture layer was derived for the project from the soil parent material map and proximity to known faults. All these data sets are currently available and were included in the demonstration version of the underground asset management tool.

4.2 CHEMICAL DATA

Several datasets already exist within BGS, that could contribute to assessing chemical elements of soil corrosivity. These include datasets of coal mining areas, superficial thickness, water saturated deposits, and permeability including that of artificial ground. This information could be easily integrated into the Underground Asset Management system. A number of useful but unavailable data sets were identified that require work to generate applicable and valuable data relating to resistivity. In addition, the feasibility of developing new datasets from existing data sources (Prop-Base and the Geochemistry database) are considered.

4.2.1 Chloride (Cl^-)

The stream data collected by the G-BASE project and collated in the Geochemistry database could be used as a basis for development of the chemical data layers. For example G-BASE stream water data could be assessed for its usefulness for the following reasons

1. G-BASE stream water data has been taken from 1st or 2nd order streams. These streams normally have small catchments with limited parent material complexity.
2. A considerable proportion of the base flow will be influent flow
3. Chloride is a conservative ion in soil and will not sorb to soil surfaces.

An initial requirement would be to use ArcGIS to delineate 1st and 2nd order stream catchments on single parent materials and collate stream water data for these parent materials. Once collated, the data could be statistically analysed (mean, median, and, box & whisker plots). A further approach could be to analyse the major cation and anion concentrations using Piper Diagrams to try and determine which waters have a high Cl^- ratio in their anion component. Both approaches may indicate those domains where Cl^-

may be a contributing factor to corrosivity. Once the data has been analysed verification with parent material properties would need to be undertaken.

A similar exercise could be carried out using Prop-Base in the future, when sufficient data has been collected from consultants reports. This would provide a more stochastic and reliable dataset.

In addition, some parent material types, particularly those that make up coastal soils, where atmospheric sea salt deposition is a component would need to be investigated as being possibly high in Cl^-.

4.2.2 Sulphate (SO_4^{2-})

Sulphate could be examined using a similar analysis of G-BASE data to that of Chloride above in the short term. However, sulphate is reactive and may undergo precipitation, sorption and dissolution reactions with the material of the stream bed, particularly with the pH change caused by CO_2 de-gassing as pore waters reach the stream, which will give erroneous results if just using G-BASE data.

However, statistical analyses of Prop-Base soil pore water SO_4^{2-} data would offer an opportunity to develop a more robust sulphate layer in the future. In addition, the Parent Material Map exists as a source of information about the presence of high sulphide mineral concentrations.

4.2.3 Salts

Some parent material domains e.g. Mercia Mudstone are known to have potentially high salt concentrations because of the environment in which they were deposited. Again G-BASE data could be used, specifically conductivity measurements. This would provide a proxy for salt concentrations, which would then be combined with geology. This could be mapped on a domain basis.

4.2.4 Sulphide / Coal mining areas

Soils with high sulphide contents have the potential to create acidity if oxidation of the sulphide takes place. Within the U.K. these soils would generally be associated with black shales, Jurassic mudstones, siderites and the coal measures. In addition, many metals are hosted in sulphide ores e.g. sphalerite, galena and chalcopyrite. These areas should be located through:

1. The mineral assessment within the BGS Parent Material Map
2. Old land use maps of mining areas combined with geological knowledge.

4.2.5 Soil acidity

The G-BASE project has collected some soil pH values, but this dataset is far from complete for the whole country. However, it is now a regular measurement. Where information isn’t available an assessment can be made from parent materials. For example, parent materials with high carbonate concentrations will generally have high (alkaline) pH values. Soils with high sulphide concentrations, high organic matter (e.g. peat) will generally have low (acid) pH values. In terms of land-use, ancient and coniferous forests will tend to be below pH 5, land used for arable agriculture will usually have pH values between 6 and 7. G-BASE data could be used to generate mean / median values for each domain type.

4.2.6 Soil Thermal Conductivity

Soil thermal conductivity (STC) is a contributing factor to corrosion through the transfer of heat from the pipes into the surrounding soil. Increasing the soil thermal conductivity can result in an increase in corrosion in underground assets. The flow of heat is directly proportional to the conductivity of the soil (Webb, 1956). Important soil factors include texture and mineralogy, bulk density, moisture content and salt concentration (Abu-Hamdeh et al. 2000). The effects of increasing heat transfer are that soils can become more 'aggressive' by:

1. changing the moisture dynamics along the pipeline
2. Increasing the movements of salts (especially Cl^-) thus leading to the formation of corrosion cells.

Abu-Hamdeh et al. (2000) suggests that the thermal conductivity of soils can be divided into two broad groups. These are:

1. Properties inherent to the soil itself (texture, mineralogical composition)
2. Externally managed properties (water content & soil management)

Water content is a major factor and is difficult to manage overall, but the way a soil is managed can have effects on thermal conductivity particularly the management of compaction which affects bulk density and decreases porosity. Abu-Hamdeh et al. (2000) carried out a series of experiments to examine the effect of various properties on soil thermal conductivity.

The Results can be summarised as follows:

1. At given bulk densities increasing moisture content increases STC for sand and clay loam soils
2. Increasing bulk density increased STC
3. A decrease in STC was found as salt concentrations increased between 0.01 and 0.1 (kg /kg)
4. STC decreased as a function of organic matter in a clay loam.

Interpretation of the results suggest that increasing bulk density increases STC through improved point to point contact of minerals whereas increasing moisture increases STC because of improved heat transfer through water films surrounding particles.

Sandy soils exhibited higher potential thermal conductivity values compared to clay soils suggesting that the greater number of particles required for the same porosity in a clay soil may increase thermal resistance between particles.

Increasing salt content has been found to decrease soil thermal conductivity (Abu-Hamdeh et al. 2000) or has been found to have no apparent effect (Van Rooyen & Winterkorn, 1959). The movement of moisture away from pipes caused by evaporation, the pipe being the heat source, could potentially increase the salinity of pore waters around the pipe leading to increased conductivity and the creation of corrosion cells (see Appendix 1).

Thermal properties of soil are typically measured using the dual-probe heat pulse technique. It consists of two parallel needles inserted into the soil at a known distance. A heat pulse is applied to one probe and the temperature at the sensor probe is recorded as a function of time. This measurement allows three linked soil properties to be determined i.e. thermal conductivity, heat capacity and thermal diffusivity. Various authors have used models to predict soil thermal conductivity. These models generally use variables including bulk density, texture and a range of moisture contents to develop models for specific soil types. One attempt has been made to predict soil thermal properties using pedo-transfer functions. Hendrickx *et al*. (2003) and Bristow (2002) predicted soil thermal conductivity (λ) from an empirical equation

$$\lambda = A + B\theta_v - (A - D)\exp\left[-(C\theta_v)^E\right]$$

Where θ_v is the volumetric soil water content and A, B, C, D, and E are soil dependent co-efficients related to soil properties as below.

$$A = \frac{0.57 + 1.73\phi q + 0.93\phi m}{1 - 0.74\phi q - 0.49\phi m} - 2.8\phi s(1 - \phi s)$$

$$B = 2.8\phi_s$$

$$C = 1 + \frac{2.6}{m_c^{0.5}}$$

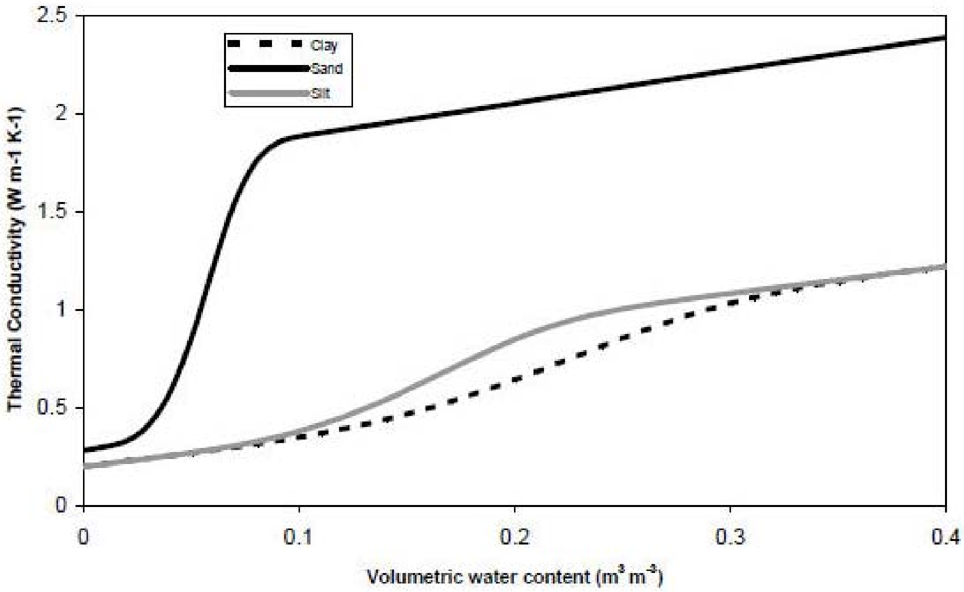
$$D = 0.03 + 0.7\phi_s^2$$

$$E = 4$$

Where Ø is the volume fraction of a particular component, subscripts ‘q’, ‘m’, and ‘s’ indicate quartz, minerals other than quartz and total solids, and mc is the clay mass fraction.

To generate information with respect to soil thermal conductivity, new data of direct measurement or data required for pedo-transfer will need to be generated. For example, pedo-transfer functions could be used on East Midlands G-BASE data because particle size data has been obtained. Plots could be produced of volumetric water content v thermal conductivity by using the pedotransfer factor of Hendrickx et al. (2003). Results would be graphs of soil thermal conductivity v moisture content (Fig. 2). This could be used as a guide to developing an appropriate corrosion coding system for a map.

Figure 2: Example plot of volumetric water content v thermal conductivity (W m^{-1} K^{-1}) taken from Hendrickx et al. (2002).



4.2.7 Resistivity / Conductivity

Probably the most important measurement in soil corrosvity are resistivity measurements. Currently, BGS has no national scale information with respect to resistivity or the conductivity of soil parent material. A laboratory assessment for 'Minimum Resistivity' can be made. Various laboratory protocols are available such as AASHTO T288 (1991). The procedure is relatively simple and involves packing a small box with the relevant soil and inserting probes to measure the resistivity. The resistivity measurement is made as soil moisture is increased until the minimum resistivity is found.

A general guide to linking corrosivity to Resistivity (Cunat, 2001) is given below (Table 4). Cunat (2001) also produced a table indicating the corrosivity of different soil types. In the first instance, this could be used as a guide to allocating Parent Material domains with a range of resistivity measurements (Table 5).

Table 4: General guide to corrosivity (after Cunat 2001).

Corrosivity	Resistivity (ohm.cm)
Very corrosive	< 1000
Aggressive	1000 – 5000
Mildly corrosive	5000 – 10000
Slightly corrosive	10 000 -20000
Progressively less corrosive	> 20000
Not corrosive	30000 – 100000

Table 5: Resistivity of soils based on their physical properties and chemical composition after Cunat (2001).

Type of Soil	Physical Properties	Chemical	Resistivity

		Composition	(ohm*cm)
Sand	Particle sizes: Fine: 0.02 / 0.06mm Medium: 0.06 / 0.2mm Coarse: 0.2 / 0.6mm Good drainage	SiO_2	10 00 – 500 000
Gravel	Particle sizes Fine: 2/6mm Medium: 6/20mm Coarse: 20/60mm Excellent drainage	SiO_2	20 000 – 400 000
Loam	Plastic mixture High Moisture	SiO_2, Al_2O_3 Dissolved species H^+, Cl^-, SO_4^{2-}, HCO_3^-	3 000 – 20 000
Clay	Very plastic mixture High Moisture	SiO_2, Al_2O_3 Dissolved species H^+, Cl^-, SO_4^{2-}, HCO_3^-	500 – 2 000
Silt	Coarse Clay High Moisture	SiO_2, Al_2O_3 Dissolved species H^+, Cl^-, SO_4^{2-}, HCO_3^-	1 000 – 2 000

Resistivity information is also available from the 'National Resistivity Sounding Database'. This was setup by the University of Birmingham for BGS in 1990 and continued until approximately 1996. The working system was installed at the BGS on a VAX 8700 using the oracle relational database management system. It contains more than 8200 soundings drawn from work carried out by a number of universities, BGS and a small number of consultants (Barker, 1996). Figure 3 illustrates the distribution of soundings. From the resistivity sounding data it would be possible to select a representative suite of soundings for each geological code/unit.

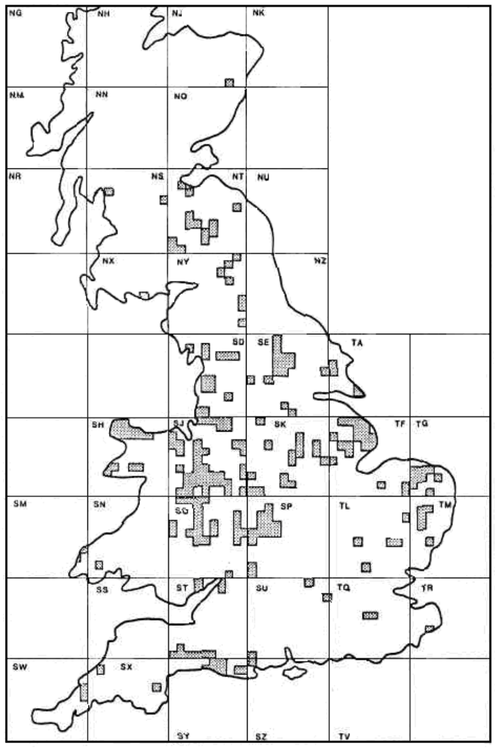


Figure 3: Summary map sounding distributions 10km^2 grid units (Baker et al 1996)

An alternative data source would be the large number of resistivity soundings collected as part of regional geophysical surveys under the Land Survey's mapping programme. The majority of this data is only available as hard copy reports and would require digitising and adding to the database. It would however compliment and supplement the information contained within the 'National Resistivity Database,' providing greater geological code/unit coverage.

A combined approach using soil particle size, the national parent material map, and data from the resistivity sounding database could be used to derive a national resistivity dataset for the UK. This should ideally, over time be augmented with additional measured data as it is collected e.g. data collected by low-level airborne geophysical survey such as in the Tellus project in Northern Ireland.

4.2.8 Drainage

The BGS Parent Material Map will have permeability ratings for each domain. In addition, the potential for identifying wetness caused by slope could be determined using the DEM combined with an algorithm to establish the 'Compound Topographic Index' such as that run on Tapes-G (Gallant and Wilson, 1996). This will allow a better indication of moisture variability within a given landscape.

4.3 CONTAMINANTS

A range of contaminant data was collected from existing G-Base data including antimony, arsenic, cadmium, chromium and lead.

5 Demonstration Version of an Underground Asset Management System.

One of the major problems in assessing soil corrosivity is that it can occur locally due to a small change in conditions e.g. difference in moisture content at top and bottom of slope, differences in resistivity with depth. These varying factors suggest that knowledge throughout the upper 10m is required (the potential depth to which assets can be placed). This must be a major consideration when assessing the type and presentation of data for any asset management system.

With knowledge of potential depth as an added factor, it is evident that a combined parameter approach providing users with a single corrosivity potential map would not be appropriate and could be very misleading. A system providing users with a list of parameters that could contribute to increasing the corrosion potential for a particular underground asset was identified as the preferred option and developed for the pilot tool. This system would enable users to rank parameters as more or less important depending on the particular type of asset being assessed.

The demonstration system is based on the Trent Humber area – 54NW02W, as it represents a variable range of geological environments. The project data, application and results can be found on W:\Teams\Dev_Prod\UndergroundAssetMang\Data\GIS. The GIS structure and report writing code were adapted from work done on the ConSept project (Ander et al 2003).

The demonstration version of the Asset Management tool seeks to:

1. Combine national and local scale geological information into one location.
2. Provide information down to 15 m below ground level
3. Output a report highlighting the presence of potential hazards and their effect on a range of construction materials

In this way users will be able to use the information to assess the risks to assets, either as a means of prioritising maintenance and liability, or of improving design for new installations. Figures 4 to 6 illustrate how simple the Underground Asset Management tool might be to use and the type of output created from it. (See Appendix 3 for a sample report).

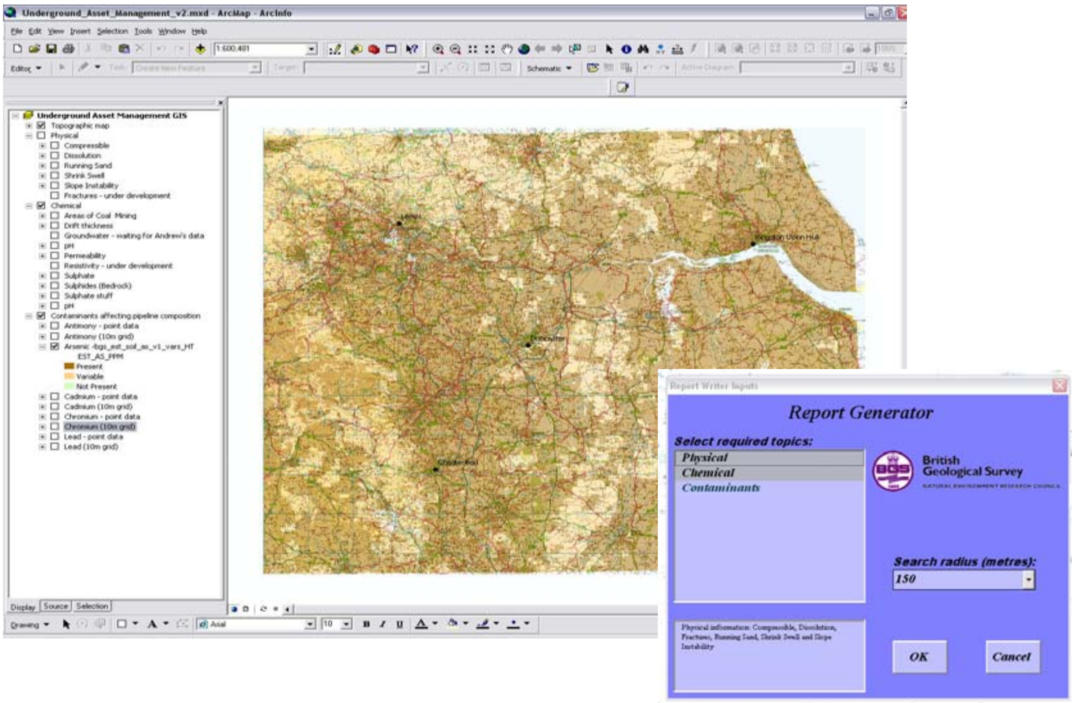


Figure 4: Underground Asset Management Report Generator.

The Report Generator allows the user to select the area, the parameters and properties of interest (Chemical, Physical or Contaminants) and define a search radius. The user can select an number parameters and properties in the selection list.

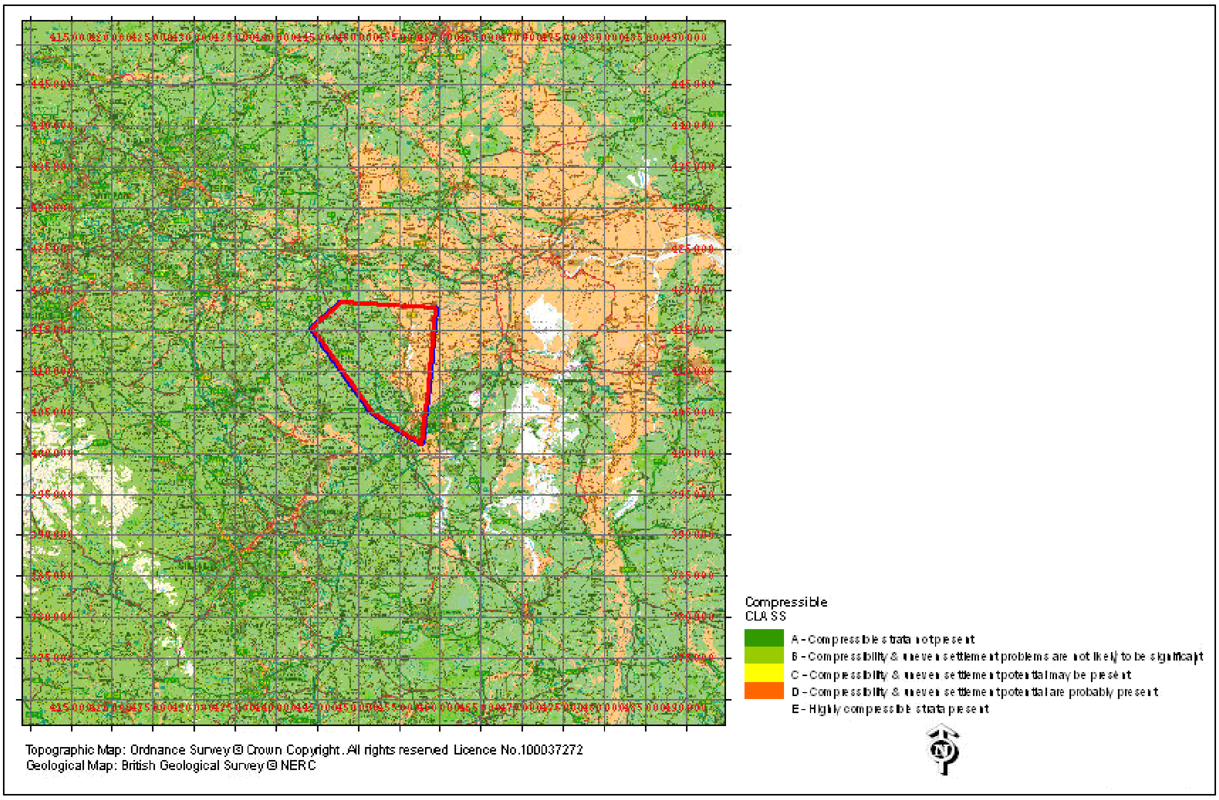
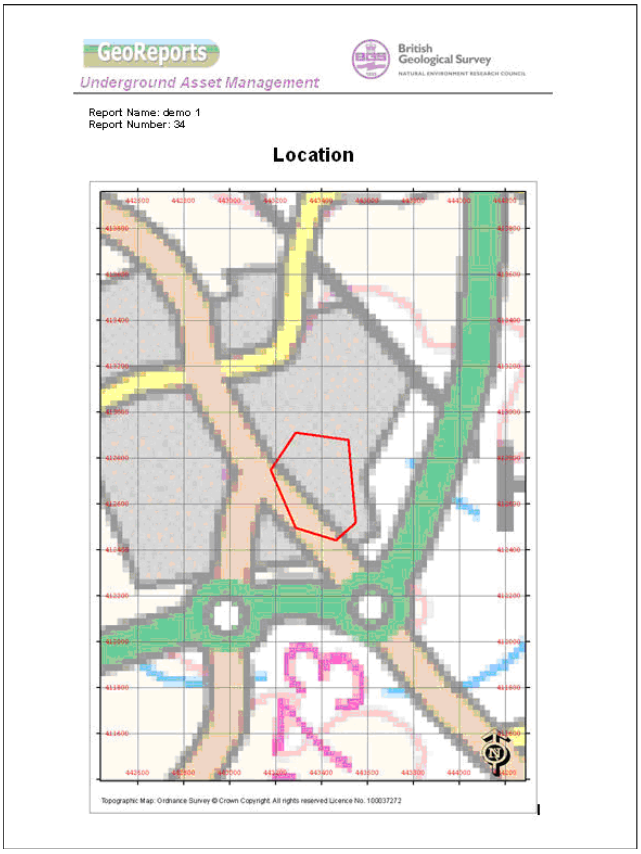
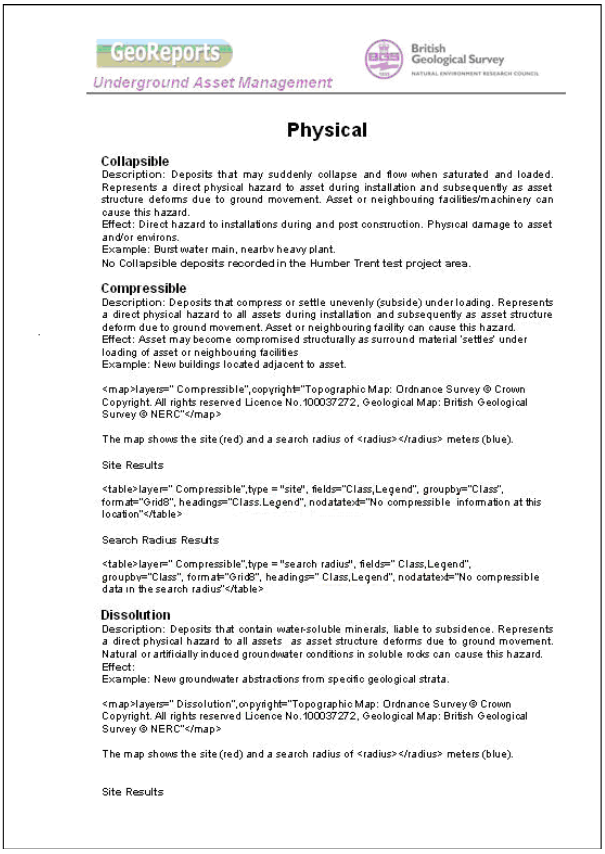


Figure 5: User defined area of interest




GeoReports

Underground Asset Management

British Geological Survey

Physical

Collapsible

Description: Deposits that may suddenly collapse and flow when saturated and loaded. Represents a direct physical hazard to asset during installation and subsequently as asset structure deforms due to ground movement. Asset or neighbouring facilities/machinery can cause this hazard.
Effect: Direct hazard to installations during and post construction. Physical damage to asset and/or environs.
Example: Burst water main, nearbv heavy plant.
No Collapsible deposits recorded in the Humber Trent test project area.

Compressible

Description: Deposits that compress or settle unevenly (subside) under loading. Represents a direct physical hazard to all assets during installation and subsequently as asset structure deform due to ground movement. Asset or neighbouring facility can cause this hazard.
Effect: Asset may become compromised structurally as surround material 'settles' under loading of asset or neighbouring facilities
Example: New buildings located adjacent to asset.

<map>layers=" Compressible",copyright="Topographic Map: Ordnance Survey © Crown Copyright. All rights reserved Licence No.100037272, Geological Map: British Geological Survey © NERC"</map>

The map shows the site (red) and a search radius of <radius></radius> meters (blue).

Site Results

<table>layer=" Compressible",type = "site", fields="Class,Legend", groupby="Class", format="Grid8", headings="Class.Legend", nodatatext="No compressible information at this location"</table>

Search Radius Results

<table>layer=" Compressible",type = "search radius", fields=" Class,Legend", groupby="Class", format="Grid8", headings=" Class,Legend", nodatatext="No compressible data in the search radius"</table>

Dissolution

Description: Deposits that contain water-soluble minerals, liable to subsidence. Represents a direct physical hazard to all assets as asset structure deforms due to ground movement. Natural or artificially induced groundwater conditions in soluble rocks can cause this hazard.
Effect:
Example: New groundwater abstractions from specific geological strata.

<map>layers=" Dissolution",copyright="Topographic Map: Ordnance Survey © Crown Copyright. All rights reserved Licence No.100037272, Geological Map: British Geological Survey © NERC"</map>

The map shows the site (red) and a search radius of <radius></radius> meters (blue).

Site Results

Figure 6: Example of report output (for further details see Appendix 3).

6 Conclusions

Evaluation of identified customer requirements for underground asset management information, (in particular Thames Waters requirement to satisfy PAS 55 recommendations), the types of products already on the market, the type of data that is needed and a demonstration tool have been presented in this report. This report has also highlighted BGS's ability to develop and produce an asset management tool to meet the market need, and improve on those currently available.

KEY FINDINGS

1. Due to the continued need to build new assets in potentially corrosive environments and to manage old assets particularly utility pipelines, to prolong their life or to tackle repairs in a systematic way, there is an increasing need within industry for detailed underground asset management information.
2. Current Underground Asset Management tools do not fulfil user requirements as systems do not contain information on all known variables and the information they do contain is of too lower resolution to meet most user needs.
3. The data requirements for an Underground Asset Management system would rely heavily on the completion of G-base in order to obtain national coverage. If this information isn't readily available it would be essential to obtain geochemical information for London and the South East of England in order to create complete and consistent data coverage suitable for VAR uptake and Utility company uptake.
4. The two essential datasets that need to be derived are those for thermal conductivity and resistivity. Using existing BGS data (some of which is still in paper form and would require digitisation) and published methodologies this information could be derived satisfactorily but would require significant investment of time and resources.
5. The more stochastic the dataset the better, as this will provide a higher resolution dataset. therefore an underground asset management system should aim to continually update parameters, using current data and integrating as and when new data where possible.
6. Asset management data is best presented as a set of related, complimentary data layers which could be interrogated and ranked depending on the end users specific requirements.
7. Potential exists for the development of an Underground Asset Management system but currently the focus needs to be on developing the missing but potentially valuable datasets rather than the technology to deploy such a system.

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

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Appendix 1 Corrosion Processes in Soils

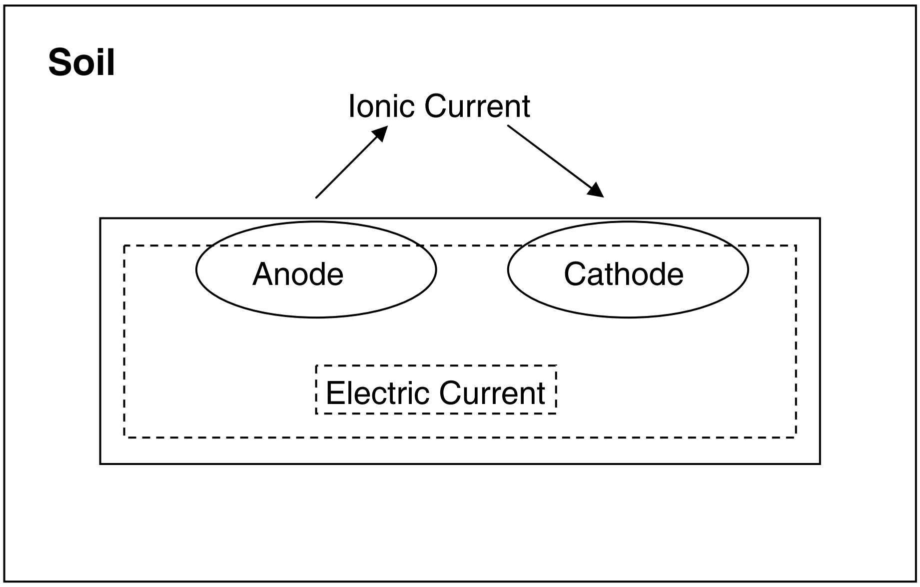
The corrosion of assets in soil is predominantly caused by the creation of corrosion cells. This is an electrochemical process that takes place in all soils to varying degrees. There are 3 types of natural corrosion cells:

1. composition or galvanic cells
2. concentration cells
3. stress cells.

In soils, composition and concentration corrosion cells are those most likely to occur. The general principle of corrosion cells is that currents are created by the formation of an electric potential between a cathode and anode. The current leaves the surface of a metal (i.e. a metal pipe) at the anode from where it enters the soil and travels by ionic conductivity. It then re-enters the metal at the cathode to complete the corrosion cell.

In general the part of a metal structure in the more conductive soil e.g. greater moisture content or higher salinity forms the anode whereas the soil in the less conductive soil forms the cathode. Corrosion is thus accelerated at the anode (Figure 1).

Figure A1: Formation of a corrosion cell. (Metal is corroded at the anode.)



COMPOSITION OR GALVANIC CELL CORROSION.

Composition or galvanic corrosion cells occur when two different metals are in contact with each other within an electrolyte. One of the metals will corrode preferentially according to their relative positions in the galvanic series (ie. a stainless steel pipe will corrode less quickly than a copper pipe). The galvanic potential represents the electrical potential that develops between different metals in a given electrolyte against a standard reference electrode. If the two metals have different electrode potentials, the electrolyte provides passage for the migration of metal ions from the anode to the cathode. Thus, the anode will corrode more quickly than it may otherwise have as the corrosion of the cathode is retarded. The relative position of the two metals in the galvanic series gives a good indication of which metal is more likely to corrode more quickly.

Factors such as moisture content and aeration can influence the rate of the process. It is possible for galvanic corrosion to occur on a single type of metal if the electrolyte varies in composition, thus forming a concentration cell.

CONCENTRATION CELL CORROSION

Concentration cell corrosion is probably the most common form of corrosion in soils and results from the formation of oxygen concentration cells. An good example is a pipeline that travels through two different types of soils that have different oxygen aeration characteristics (e.g. sand and clay). The sandy soil will be well aerated whilst the clay is impermeable. An oxygen concentration cell is then formed with the metal pipe in the clay soil being the anode and the metal in the sand the cathode. Concentration cells can also be formed in structures that cross the water table, since the supply of oxygen is abundant above and restricted below. This allows localized corrosion to take place below the water table where the metal constitutes the anode. In general, anodic regions can be formed under conditions of low pH, high salt content, low aeration and high moisture whereas cathodic regions exist in high pH, low moisture and good aeration.

MICROBIAL CORROSION

Microbially induced corrosion is caused by chemoautotrophs. Both metallic and non-metallic materials can be corroded. Micro-organisms in any aqueous environments (such as soil pore waters) will attach themselves to the surfaces of assets, causing a biofilm to be produced. Within this biofilm the organisms change local environmental variables including oxidising potential, temperature, elemental concentrations and the velocity of water through them. Thus, these local environments can vary considerably from the bulk soil conditions. Bacterial colonies and deposits form concentration cells, causing and enhancing galvanic corrosion cells to be formed.

In reducing conditions atmospheres sulphate-reducing bacteria are common. These include the genera *Desulfoubrio, Desulfomonus and Desulfotomaculum.* These produce H_2S that can react directly with iron, steel, stainless steel, copper, aluminium and zinc causing sulfide stress cracking.. Sulphate-reducing bacteria require an electrode potential of at least -100 mV to thrive.

Under aerobic conditions, some bacteria such as *Ferrobacillus ferrooxidans* can cause corrosion. These consume Fe^{2+} ions and convert them to Fe^{3+} hydroxides. The local deposition of Fe^{3+} hydroxides on metal surfaces can create local corrosion cells.

Sulphur oxidising bacteria can produce sulphuric acid causing biogenic sulfide corrosion, a bacterially mediated process whereby hydrogen sulfide gas is formed and its subsequent conversion to sulphuric acid attacks concrete and steel. The hydrogen sulfide gas is oxidized in the presence of moisture forming sulphuric acid.

STRAY CURRENT CORROSION

Stray current corrosion occurs independently of environmental factors such as Eh (redox potential) and pH (potential of H^+) and results from electrical currents following unintended pathways. The current leaves the intended path due to poor electrical connections or insulation around the conductive material. It flows through the soil until it finds a buried metal structure in the ground, such as a pipeline, that provides a lower resistance conducting pathway than the soil for the earth return currents, causing increased corrosion.

Examples include direct current systems (electric railways, electric installations and cathodic protection systems on pipe-works), interference currents from high voltage direct current power lines with full or partial returns, long line currents in long unprotected pipelines laid in along different soil types, electrical (magnetic) ground currents and stray currents from alternating current systems. Moisture and conductivity of the soil will have an effect on current passage.

Appendix 2 Asset List and Descriptions for Humber Trent Study Area

HAZARDS (Source)		CLASS	CLASS DESCRIPTION
PHYSICAL	Collapsible (No data for Humber Trent)	A	Class not used
		B	Class not used
		C	Deposits with the potential to collapse when saturated and loaded may be present in places.
		D	Deposits with the potential to collapse when saturated and loaded are probably present in places.
		E	Class not used
	Compressible	A	Compressible strata are not thought to occur.
		B	Compressibility and uneven settlement problems are not likely to be significant on the site for most land uses.
		C	Compressibility and uneven settlement potential may be present. Land use should consider specifically the compressibility and variability of the site.
		D	Compressibility and uneven settlement hazards are probably present. Land use should consider specifically the compressibility and variability of the site.
		E	Highly compressible strata present. Significant constraint on land use depending on thickness.
	Dissolution	A	Soluble rocks are present, but unlikely to cause problems except under exceptional conditions.
		B	Significant soluble rocks, but few dissolution features and no subsidence; unlikely to cause problems except with considerable surface or subsurface water flow.

		C	Significant soluble rocks, where there are dissolution features, and no or very little recorded subsidence, but a low possibility of it occurring naturally or in adverse conditions such as high surface or subsurface water flow.
		D	Very significant soluble rocks, where there are numerous dissolution features and/or some recorded subsidence with a moderate possibility of localised subsidence occurring naturally or in adverse conditions such as high surface or subsurface water flow
		E	Very significant soluble rocks, where there are numerous dissolution features and/or considerable recorded subsidence with high possibility of localised subsidence occurring naturally or in adverse conditions such as high surface or subsurface water flow
	Running sand	A	Running sand conditions are not thought to occur whatever the position of the water table. No identified constraints on lands use due to running conditions
		B	Running sand conditions may occur if the water table rises. Constraints may apply to land uses involving excavation or the addition or removal of water
		C	Running sand conditions may be present. Constraints may apply to land uses involving excavation or the addition or removal of water.
		D	Running sand conditions are probably present. Constraints may apply to land uses involving excavation or the addition or removal of water.
		E	Running sand conditions are almost certainly present. Constraints will apply to land uses involving excavation or the addition or removal of water.
	Shrink/Swell	A	Ground conditions predominantly non-plastic.
		B	Ground conditions predominantly low plasticity.
		C	Ground conditions predominantly medium plasticity.
		D	Ground conditions predominantly high plasticity.
		E	Class not used

	Slope Instability	A	Slope instability problems are not thought to occur but consideration to potential problems of adjacent areas impacting on the site should always be considered.
		B	Slope instability problems are not likely to occur but consideration to potential problems of adjacent areas impacting on the site should always be considered.
		C	Slope instability problems may be present or anticipated. Site investigation should consider specifically the slope stability of the site.
		D	Slope instability problems are probably present or have occurred in the past. Land use should consider specifically the stability of the site.
		E	Slope instability problems almost certainly present and may be active. Significant constraint on land use.
CHEMICAL (taken from G-base data or soil parent material data)	Chloride	No data	
	Salts	No data	
	Thermal conductivity	A	Heat flow is likely to be between 140 to 100 milliwatts per square metre. These values are above the national average
		B	Heat flow is likely to be between 70 to 100 milliwatts per square metre. These values are slightly higher than the national average
		C	Heat flow is likely to be between 40 to 70 milliwatts per square metre. These are within the range that is considered typical for much of the UK.
		D	Heat flow is likely to be lower than 40 milliwatts per square metre. These values are below the national average for the UK.
	Sulphate (no data)	Present	
		Not present	
		Variable	
	Sulphide	Present	Sulphides are probably present. If oxygen in the air or groundwater has access to unweathered deposits containing sulphides oxidation to sulphates can occur

		Not present	Sulphide bearing strata are not likely to occur in this area
		Variable	There is a possibility that sulphide may be present in these deposits
	pH	A	pH probably less than 5.
		B	pH likely to be between 5 and 9. Within the range of sulphate reducing bacteria
		C	pH probably greater than 8
	Resistivity/Conductivity*	No data	
	Areas of Coal Mining	Present	Areas of coal mining are likely to be present. There is a high possibility that mine waste with high concentrations of sulphides, sulphates and metals may be present.
		Not Present	Area unlikely to have been effected by coal mining
	Groundwater	Present	Area of ground likely to be permanently water saturated. Moisture content of these deposits are likely to be high
		Variable	Area of ground likely to be seasonally waterlogged
		Not present	Area of ground likely to be above the water table. Moisture contents of these deposits are likely to be low
	Permeability	Low	Deposits likely to have a low permeability. The redox state in these deposits is likely to be low unless the ground has been disturbed due to previous construction work
		Medium	Deposits likely to have a moderate permeability.
		High	Deposits likely to have a high permeability. The redox state in these deposits is likely to be high unless the ground has been disturbed due to previous construction work and backfill was with lower permeability deposits.
	Superficial Cover	Present	Drift deposits of thickness probably greater than 10 m are likely to be present. The thickness of drift deposits is likely to offer some protection against sulphate rich rocks if present below

		Variable	Drift deposits of thickness between 0 and 10 m are likely to be present. The thickness of drift deposits could offer some protection against sulphate rich rocks if present but this would depend on the type of construction proposed.
		Not Present	Drift deposits unlikely to be present. Bedrock likely to be unprotected.
CONTAMINANTS EFFECTING PIPELINE COMPOSITION	Arsenic	Present	It is likely that in these area levels of Arsenic are above 10 mg/kg. Further site investigation may be required
		Variable	Arsenic known to be present in the area at levels likely to be below 10 mg/kg
		Not present	Arsenic not thought to be present in the area
	Cadmium	present	It is likely that in this area levels of Cadmium are above 3 mg/kg. Further site investigation may be required
		Not present	Cadmium not thought to be present in the area
		variable	Cadmium known to be present in the area at levels likely to be below 3 mg/kg
	Chromium	Present	It is likely that in this area levels of Chromium are above 600 mg/kg. Further site investigation may be required
		Not present	Chromium not thought to be present in the area
		variable	Chromium known to be present in the area at levels likely to be below 600 mg/kg
	Lead	Present	It is likely that in this area levels of Lead are above 500 mg/kg. Further site investigation may be required
		Not present	Lead not thought to be present in the area
		variable	Lead known to be present in the area at levels likely to be below 500 mg/kg
	Antimony	Present	It is likely that in this area levels of Antimony are above 10 mg/kg. Further site investigation may be required
		Not present	Antimony not thought to be present in the area
		variable	Antimony known to be present in the area at levels likely to be below 10 mg/kg

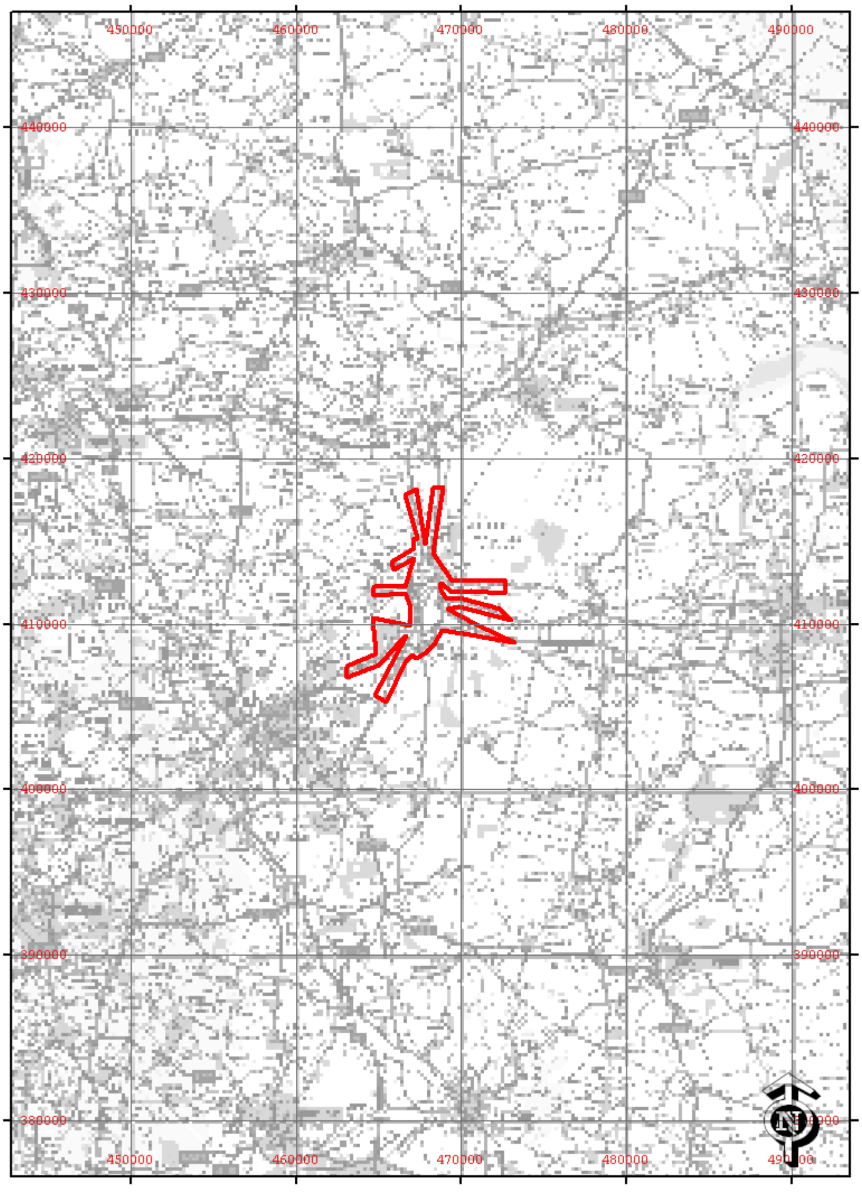
* Not currently being evaluated due to lack of data

Appendix 3 Sample Report

Report Name: **Underground Asset Management Test**

Report Number: **1**

Location



Topographic Map: Ordnance Survey © Crown Copyright. All rights reserved Licence No. 100037272

Physical

COLLAPSIBLE

Description: Deposits that may suddenly collapse and flow when saturated and loaded. Represents a direct physical hazard to asset during installation and subsequently as asset structure deforms due to ground movement. Asset or neighbouring facilities/machinery can cause this hazard.

Effect: Direct hazard to installations during and post construction. Physical damage to asset and/or environs.

Example: Burst water main, nearby heavy plant.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**

Data Resolution: 1: 50 000

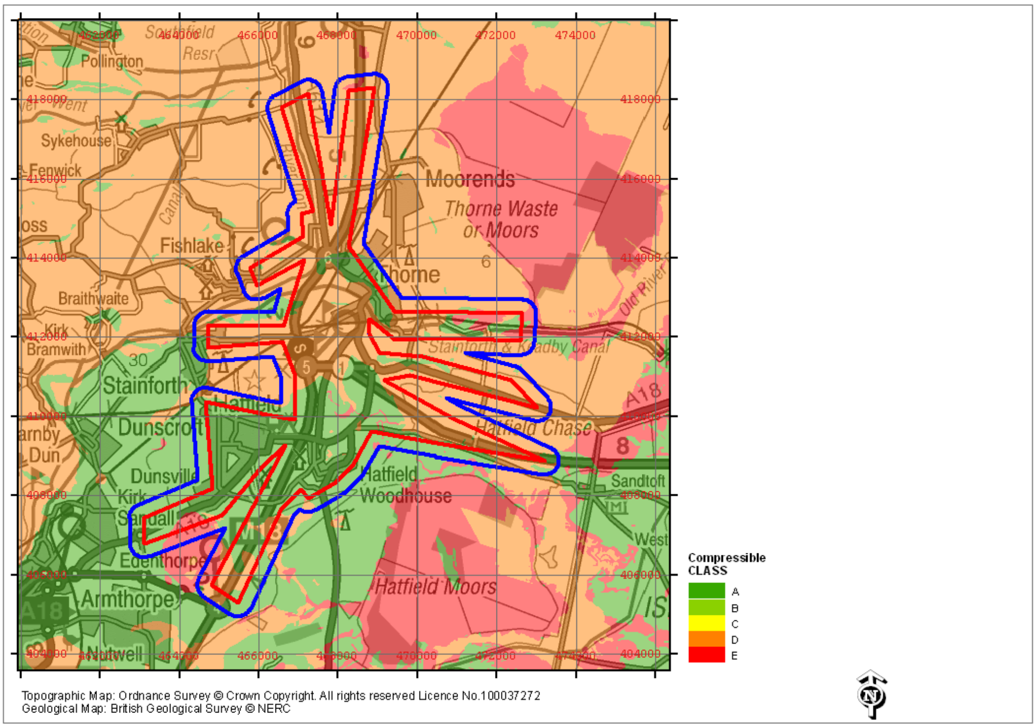
No Collapsible deposits recorded in the Humber Trent test project area.

COMPRESSIBLE

Description: Deposits that compress or settle unevenly (subside) under loading. Represents a direct physical hazard to all assets during installation and subsequently as asset structure deforms due to ground movement. The asset or a neighbouring facility can cause this hazard.

Effect: Asset may become compromised structurally as surround material ‘settles’ under loading of asset or neighbouring facilities.

Example: New buildings located adjacent to asset.



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Description
D	Compressibility and uneven settlement hazards are probably present. Asset managers should consider specifically the compressibility and variability of the site.
E	Highly compressible strata present. Significant constraint on Asset management
A	Compressible strata are not present

Search Radius Results

Class	Description
D	Compressibility and uneven settlement hazards are probably present. Asset managers should consider specifically the compressibility and variability of the site.
E	Highly compressible strata present. Significant constraint on Asset management
A	Compressible strata are not present

Data Resolution: 1: 50 000

DISSOLUTION

Description: Deposits that contain water-soluble minerals, liable to subsidence. Represents a direct physical hazard to all assets as asset structure deforms due to ground movement. Natural or artificially induced groundwater conditions in soluble rocks can cause this hazard.

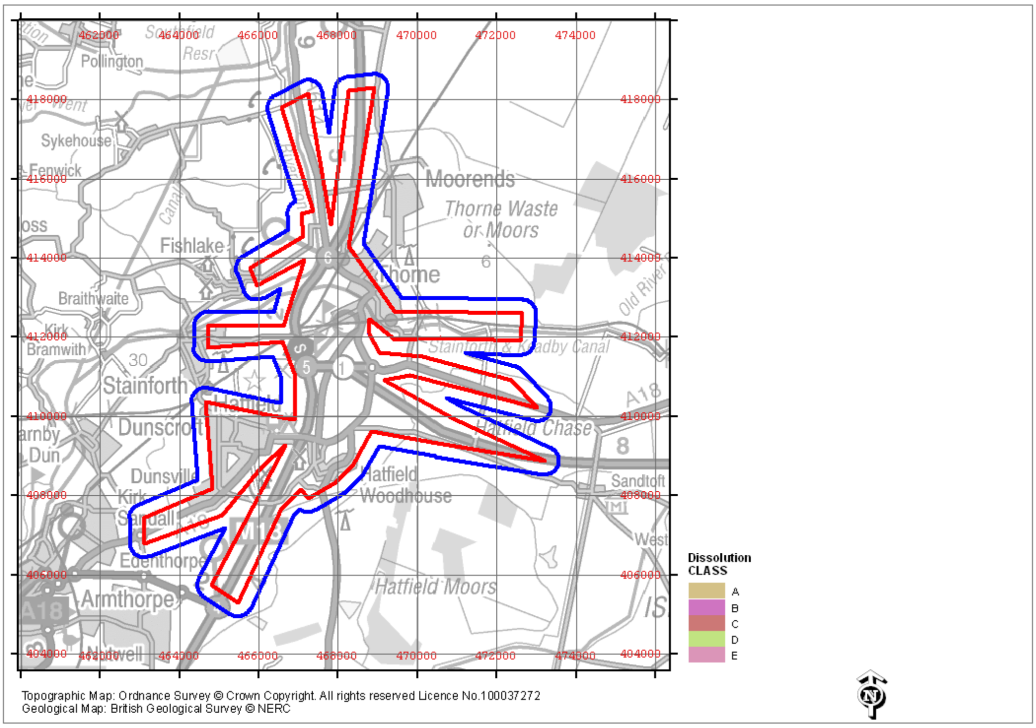
Effect:

Example: New groundwater abstractions from specific geological strata.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

No dissolution information at this location

Search Radius Results

No dissolution data in the search radius

Data Resolution: 1: 50 000

FRACTURES

Description: Deposits that is likely to contain a high proportion of discontinuities across which there has been a separation.

Effect: Direct hazard to installations during and post construction. Physical damage to asset

Example: Assets fracture and break up due to movement along faults **Recommendation:** Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**

Data Resolution:

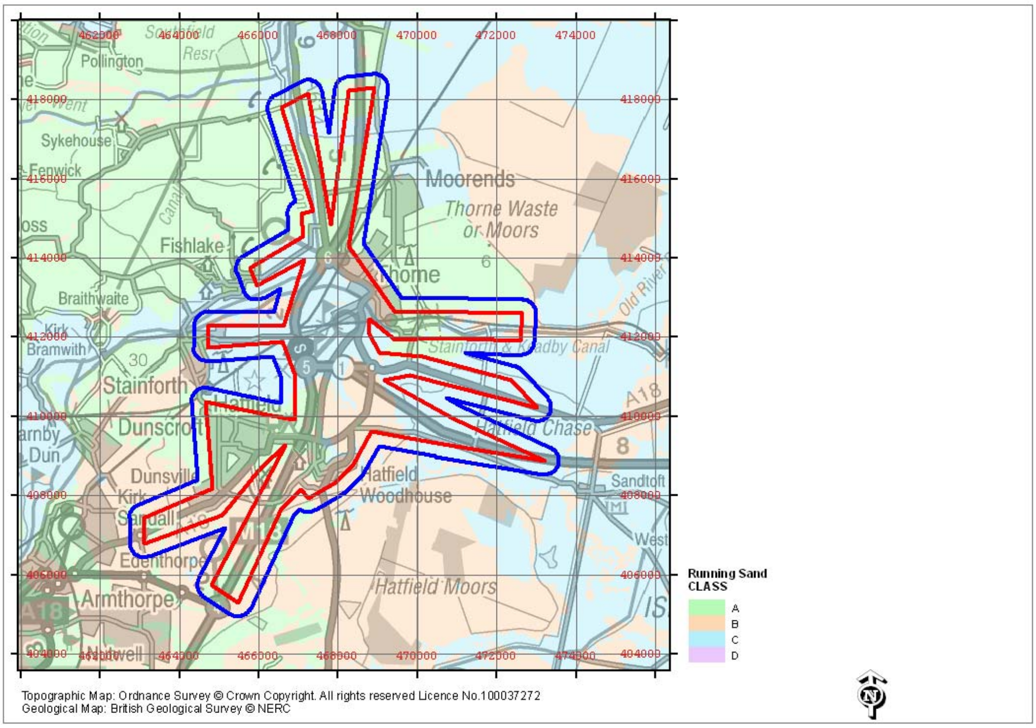
Data not currently available.

RUNNING SAND

Description: Deposits that flow due to saturation. Represents a direct physical hazard to all assets, mainly during installation but also subsequently as asset structure deforms due to ground movement.

Effect: Assets deformed or cracked.

Example: new excavations located adjacent to asset causing flow, or burst water main asset.



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Description
C	Running sand conditions may be present. Constraints may apply asset management involving excavation or the addition or removal of water.
A	Running sand conditions are not considered to be a threat to asset
B	Running sand conditions may occur if the water table is high (see groundwater). Constraints may apply to asset management involving excavation or the addition or removal of water

Search Radius Results

Class	Description
C	Running sand conditions may be present. Constraints may apply asset management involving excavation or the addition or removal of water.
A	Running sand conditions are not considered to be a threat to asset
B	Running sand conditions may occur if the water table is high (see groundwater). Constraints may apply to asset management involving excavation or the addition or removal of water

Data Resolution: 1: 50 000

SHRINK SWELL

Description: Deposits that swell or shrink unevenly as they dry out or become saturated. Represents a direct physical hazard to all assets as asset structure deforms due to ground movement. Natural or artificially induced groundwater conditions can cause this hazard.

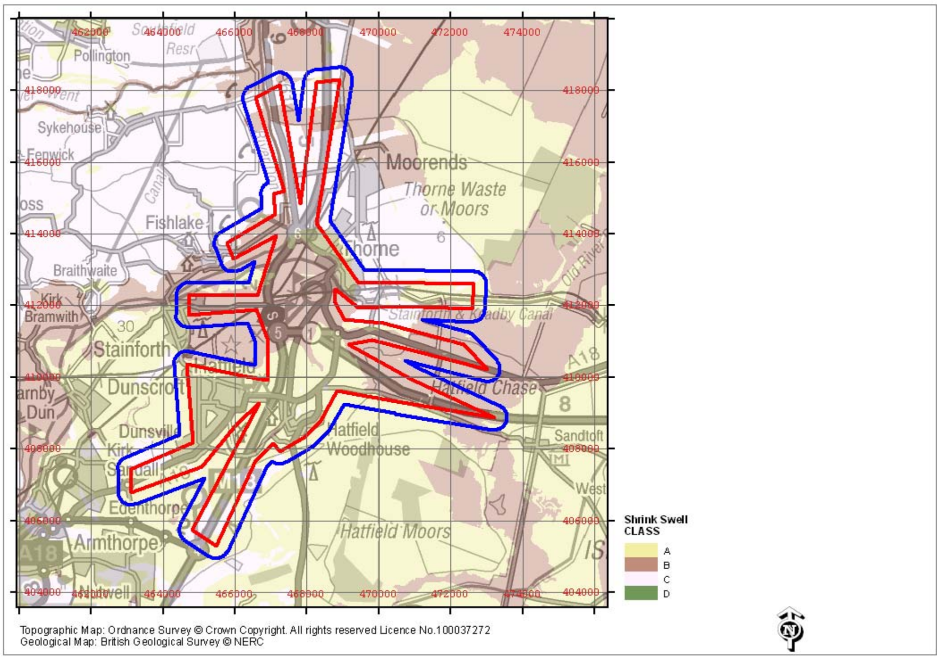
Effect: Assets cracked.

Example: Extensive drought, leaking water main.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Description
B	Ground conditions predominantly low plasticity.
C	Ground conditions predominantly medium plasticity.
A	Ground conditions predominantly non-plastic.

Search Radius Results

Class	Description
B	Ground conditions predominantly low plasticity.
C	Ground conditions predominantly medium plasticity.
A	Ground conditions predominantly non-plastic.

Data Resolution: 1: 50 000

SLOPE INSTABILITY

Description: Locations where ground may slump, slide, fall or flow as a result of deposit strength, saturation and topographic slope. Represents a direct physical hazard to all assets during installation and subsequently as asset structure deforms due to ground movement. Natural ground and drainage conditions can cause this hazard, although some slips can be induced by earth workings

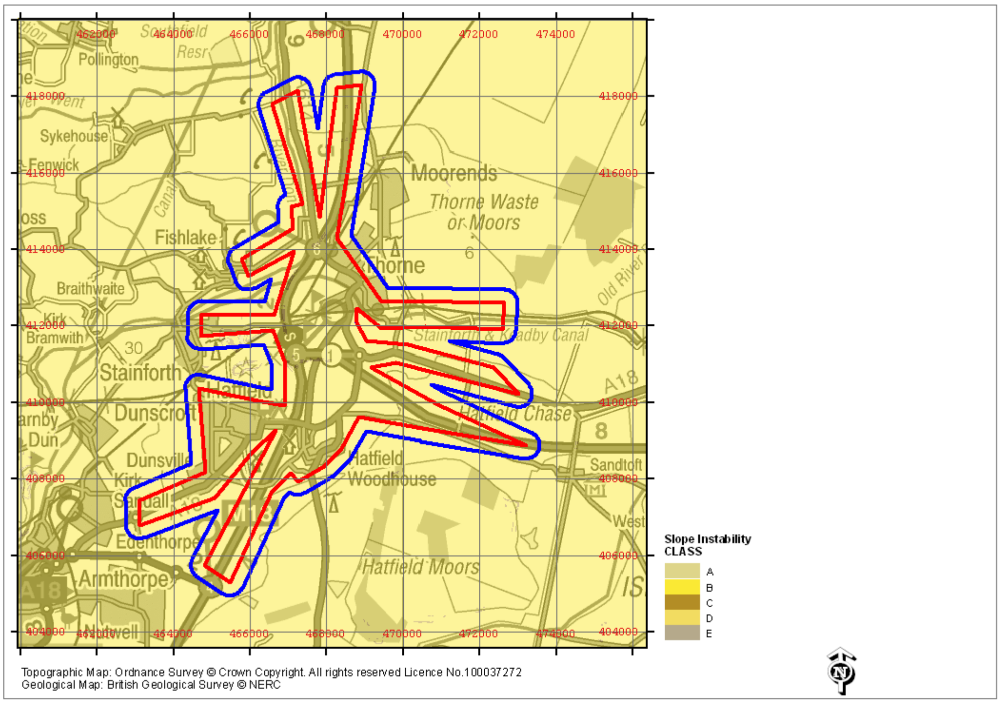
Effect: Deformation of asset structure.

Example: Prolonged heavy rainfall, slope steepness.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Description
C	Slope instability problems may be present or anticipated. Asset managers should consider specifically the threat of slope stability to the asset
B	Slope instability problems are not likely to occur but consideration to potential problems of adjacent areas impacting on the asset should always be considered.
D	Slope instability problems are probably present or have occurred in the past. Asset manager should consider specifically the threat of slope stability to the asset.

Search Radius Results

Class	Description
C	Slope instability problems may be present or anticipated. Asset managers should consider specifically the threat of slope stability to the asset
B	Slope instability problems are not likely to occur but consideration to potential problems of adjacent areas impacting on the asset should always be considered.
D	Slope instability problems are probably present or have occurred in the past. Asset manager should consider specifically the threat of slope stability to the asset.

Data Resolution: 1: 50 000

Chemical

AREAS OF COAL MINING

Description: Locations where colliery spoil (sulphide rich) material may be present or where undermining may have occurred: Represents a direct chemical hazard to metallic and concrete assets as chemical reactions between assets and host material cause corrosion (see section on sulphides). Artificially induced ground conditions cause this hazard.

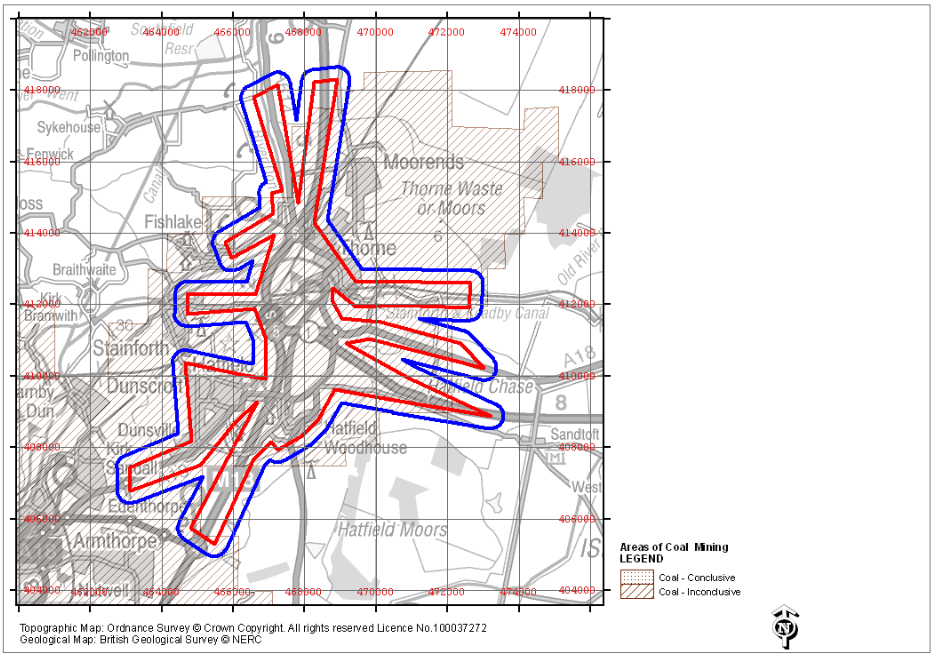
Effect: Asset managers should consider that there is a possibility that mine waste with high concentrations of sulphides, sulphates and toxic metals may be present and may affect a range of asset types.

Example: Acid corrosion of metallic materials.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Category	Coalfield	Description
Coalfield	South Yorkshire Coalfield	Coal - Inconclusive

Search Radius Results

Category	Coalfield	Description
Coalfield	South Yorkshire Coalfield	Coal - Inconclusive

Data Resolution: 1: 50 000

DRIFT THICKNESS

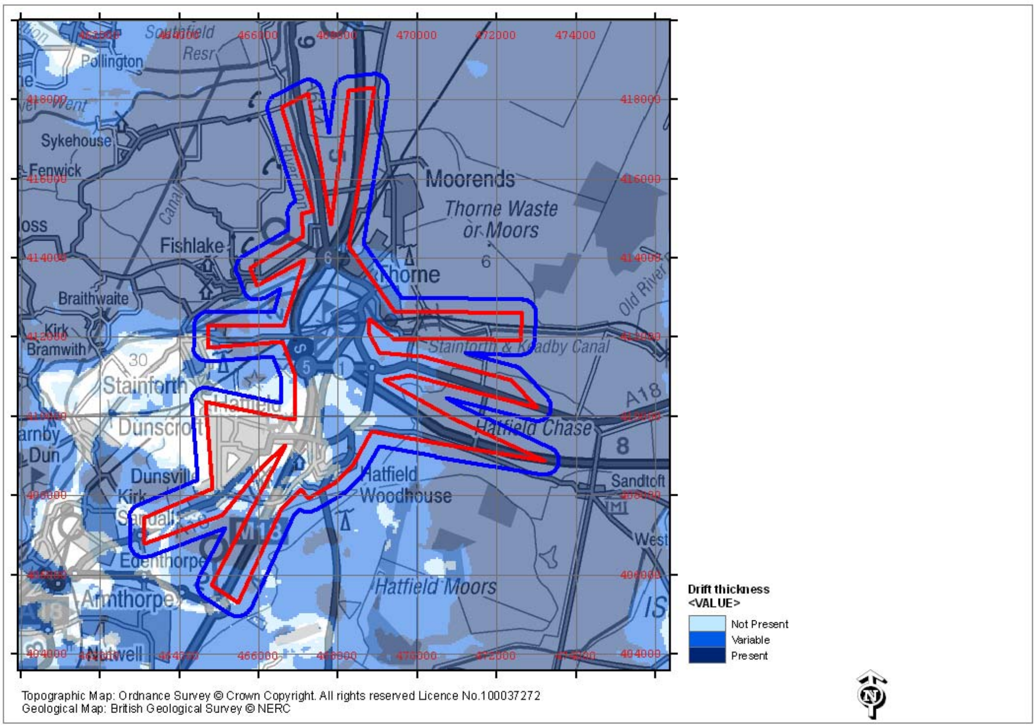
Description: Where there is thick drift (glacial) cover over sulphate and sulphide bearing strata it is likely that shallow foundations will not penetrate into sulphate rich rocks. The weathered zone in most geological deposits is between 2- 8m.

Effect: Assets protected from sulphate/ sulphide rich deposits due to thickness of drift cover.

Example: Thick till coverage in northern England.
Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Class	Description
Present	**Drift deposits of thickness greater than 10 m over your area. Thick drift deposits are likely to offer some protection against sulphate rich strata if present below.**
Variable	**Drift deposits thickness between 2 and 10m. The thickness of drift deposits may offer protection against sulphate bearing strata below but this will depend on the permeability of the strata.**
Not Present	**Drift deposits less than 2m thick. Thickness of drift deposits unlikely to offer protection against sulphate bearing strata below**

Data Resolution:

PH

Description: Deposits where measured pH is acidic or alkali. Represents a direct chemical hazard to metallic and concrete assets during installation and subsequently as chemical reactions between assets and host material cause corrosion. Natural ground conditions cause this hazard.

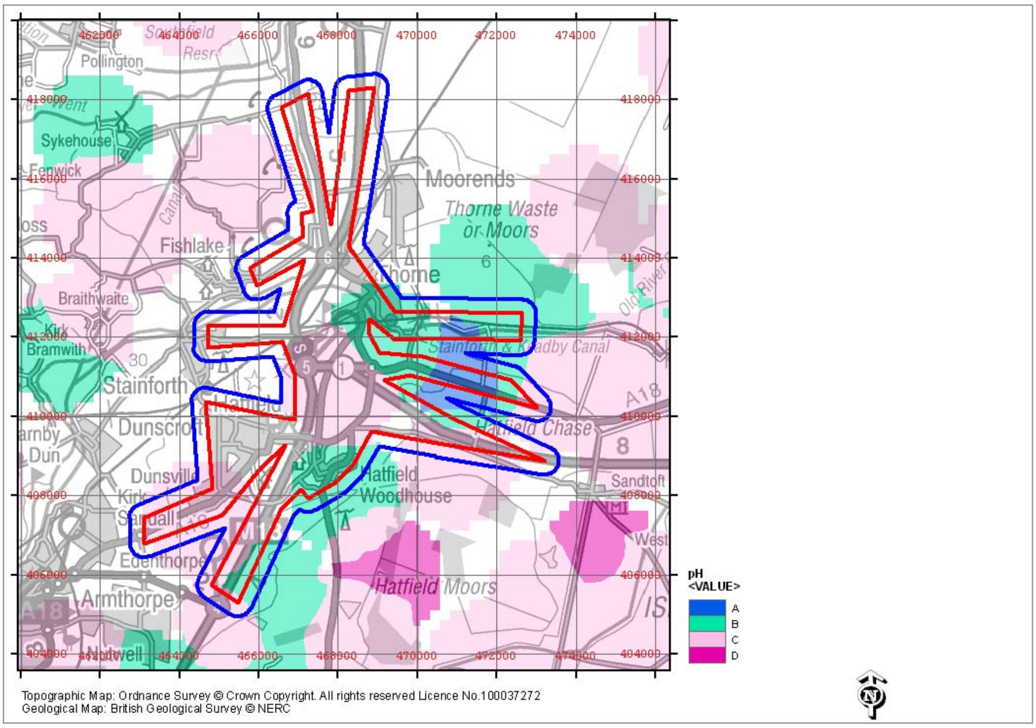
Effect: Corrosion of underground assets.

Example: Acid corrosion of metallic materials.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Data Resolution: 10m cells

PERMEABILITY

Description: When permeability is high it is likely that the redox state of the deposit is also high and when the permeability is low the redox state is likely to also be low.

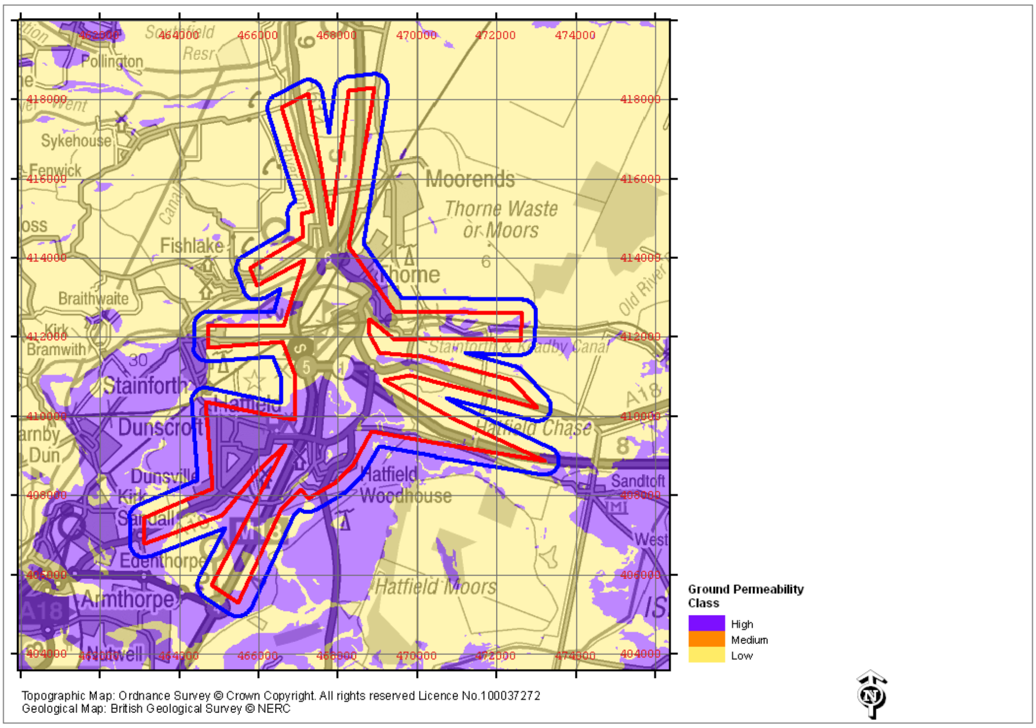
Effect: If the redox state is low and the area is high in sulphates, waterlogged and PH is between 5.5. and 9, conditions may be suitable for sulphate reducing bacteria.

Example: Corrosion of underground infrastructure.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Description	Maximum	Minimum	Flow Type
High	Deposits likely to have a high permeability. The redox state in these deposits is likely to be high	High	High	Mixed

Class	Description	Maximum	Minimum	Flow Type
	unless the ground has been disturbed due to previous construction work and backfill was with lower permeability deposits.			
Low	Deposits likely to have a low permeability. The redox state in these deposits is likely to be low unless the ground has been disturbed due to previous construction work	Low	Very Low	Mixed

Search Radius Results

Class	Description	Maximum	Minimum	Flow Type
High	Deposits likely to have a high permeability. The redox state in these deposits is likely to be high unless the ground has been disturbed due to previous construction work and backfill was with lower permeability deposits.	High	High	Mixed
Low	Deposits likely to have a low permeability. The redox state in these deposits is likely to be low unless the ground has been disturbed due to previous construction work	High	Very Low	Intergranular

Data Resolution: 1:50 000

ARTIFICIAL GROUND PERMEABILITY

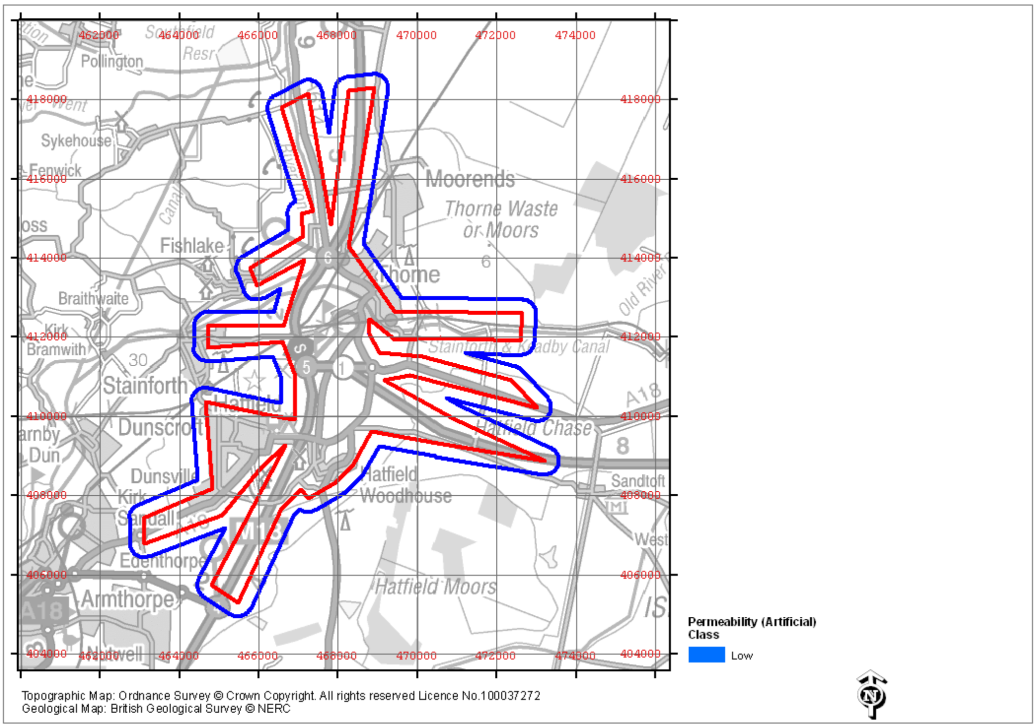
Description: When permeability is high it is likely that the redox state of the deposit is also high and when the permeability is low the redox state is likely to also be low**.**

Effect: If the redox state is low and the area is high in sulphates, waterlogged and PH is between 5.5 and 9, conditions may be suitable for sulphate reducing bacteria.

Example: Corrosion of underground infrastructure.
Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset Affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

No artificial ground permeability information at this location

Search Radius Results

No artificial ground permeability information at this location

Data Resolution: 1: 250 000

RESISTIVITY/CONDUCTIVITY

Description: Deposits where measured resistivity or conductivity are anomalous. Represents a direct chemical hazard to metallic and concrete assets during installation and subsequently as chemical reactions between assets and host material cause corrosion. Natural ground conditions cause this hazard.

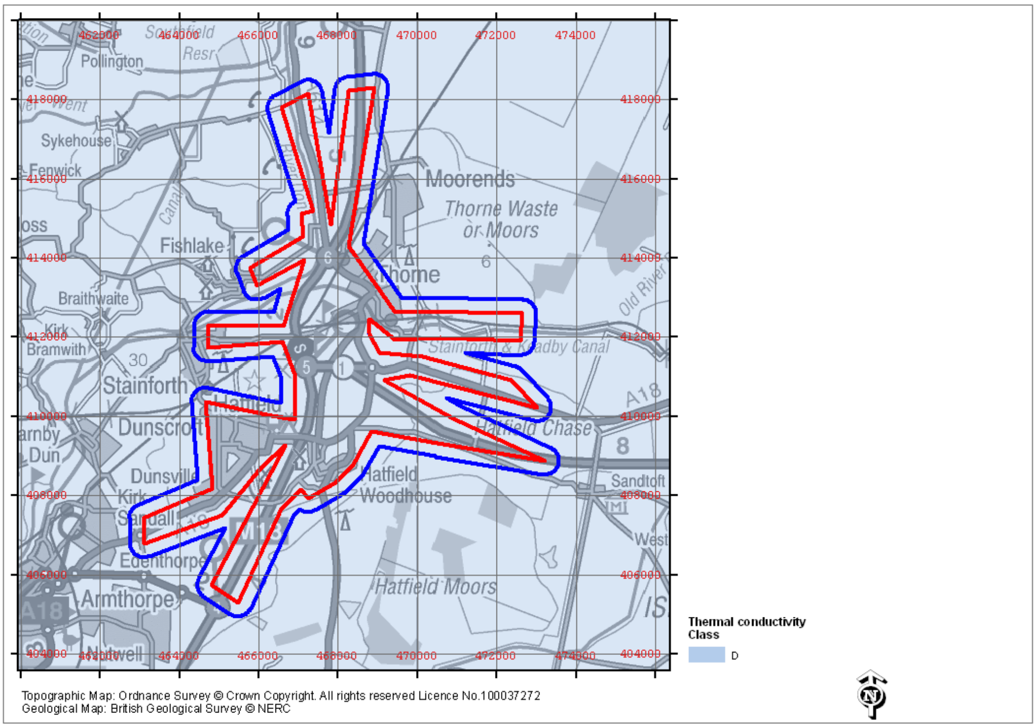
Effect: Increase potential of corrosion.

Example: Resistivity/conductivity are products of groundwater and deposit chemistry. Acidic, water/deposits bearing metallic salts are corrosive (and conductive).

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Legend	Thermal Conductivity
D	Heat flow is likely to be lower than 40 milliwatts per square metre. These values are below the national average for the UK.	2.9

Search Radius Results

Class	Legend	Thermal Conductivity
D	Heat flow is likely to be lower than 40 milliwatts per square metre. These values are below the national average for the UK.	2.9

Data Resolution: 1: 250 000

Resistivity data currently under construction.

SULPHATE

Description: Deposits bearing suphatic minerals (e.g. gypsum). Represents a direct chemical hazard to metallic and concrete assets as chemical reactions between assets and host material cause corrosion.

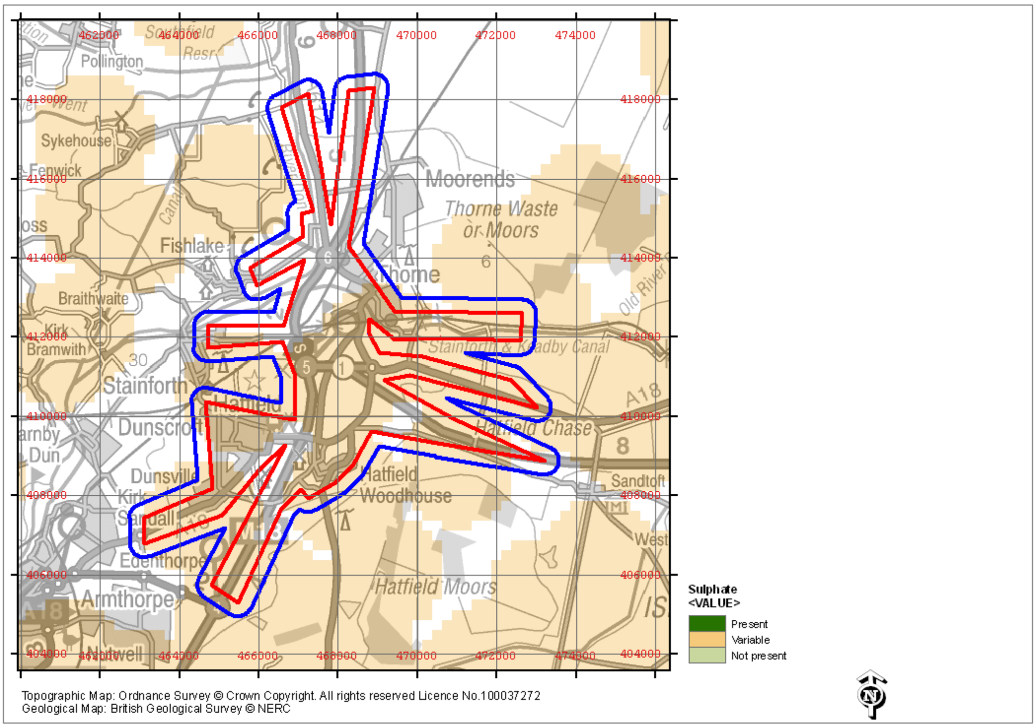
Effect: Can directly corrode concrete – acidity.

Example: Presence of gypsum causing weakened concrete.

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



Site Results

Class	Description
Present	
Variable	
Not Present	

Data Resolution: 1: 50 000

The map shows the site (red) and a search radius of 350 meters (blue).

SULPHIDE

Description: Deposits bearing metallic sulphide minerals (e.g. pyrite). Represents a direct chemical hazard to metallic and concrete assets during installation and subsequently as chemical reactions between assets and host material cause corrosion.

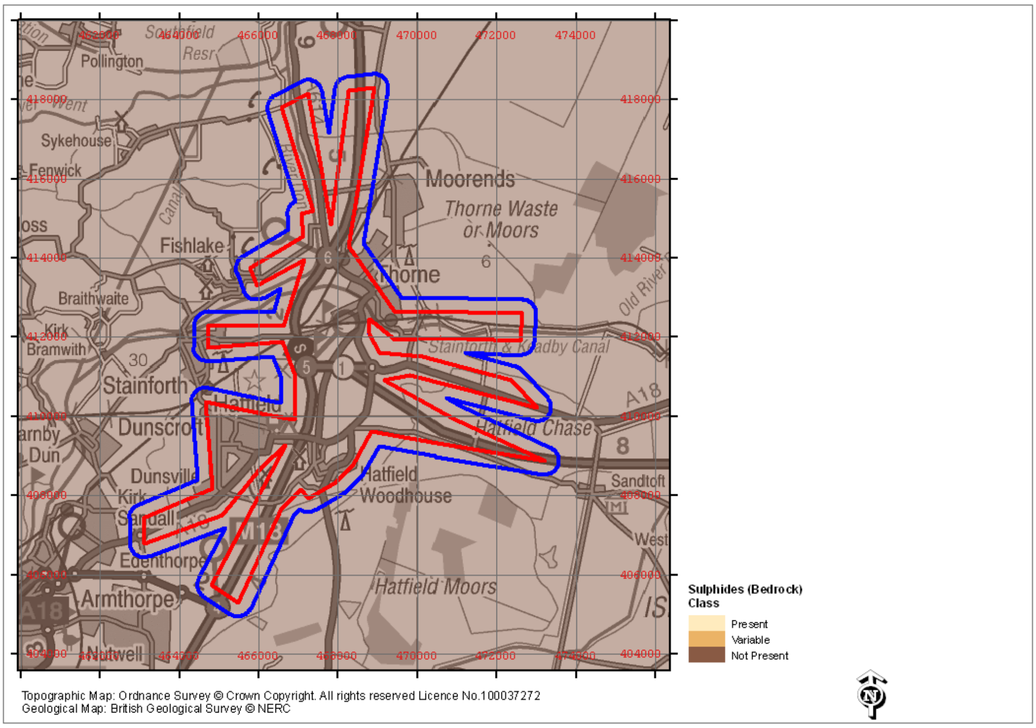
Effect: Sulphides can react with oxygen to form sulphates which have a corrosive effect on concrete.

Example: Oxidation of pyrite in backfill material creates sulphuric acid charged groundwater (corrosion) and also growth of sulphate (corrosion and ground displacement).

Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Description	Lex Description
Not Present	Sulphide bearing strata are not likely to occur in this area.	SHERWOOD SANDSTONE GROUP

Search Radius Results

Class	Description	Lex Description
Not Present	Sulphide bearing strata are not likely to occur in this area.	SHERWOOD SANDSTONE GROUP

Data Resolution: 1: 50 000

WATER SATURATED DEPOSITS

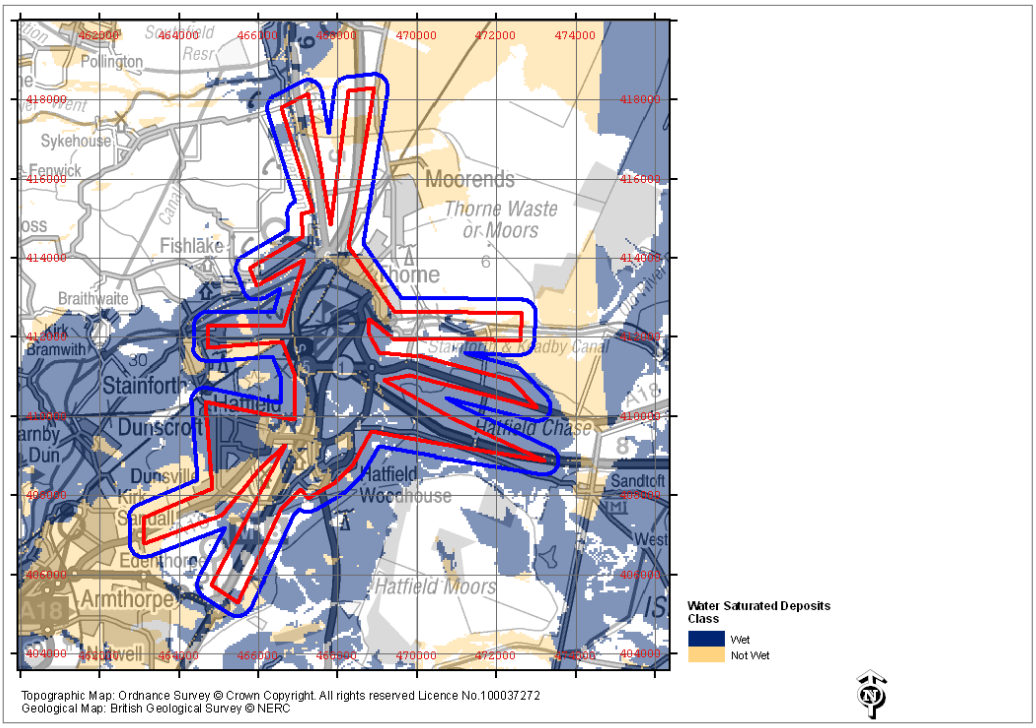
Description: : If the area is water logged there is likely to be the possibility of conditions being favourable for sulphate reducing bacteria and also a higher likelihood that transportation of sulphates and other chemicals to underground infrastructure.

Effect: Water saturated deposits providing appropriate conditions for sulphate reducing bacteria.

Example: Corrosion of pipelines.
Recommendation: Detailed site investigations may be necessary if in an area where hazard occurs at a level where there might be design implications.

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class
Not Wet
Wet

Search Radius Results

Class
Not Wet
Wet

Data Resolution:

Contaminants

ANTIMONY

Description: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of Antinomy.

Effect: Exposure to Antimony can cause irritation to the eyes, skin and lungs. If significant quantities are breathed in lung and heart problems may occur. If swallowed in large quantities (over 19ppm) vomiting will occur, joint and muscle pain, anaemia and heart problems have also been report.

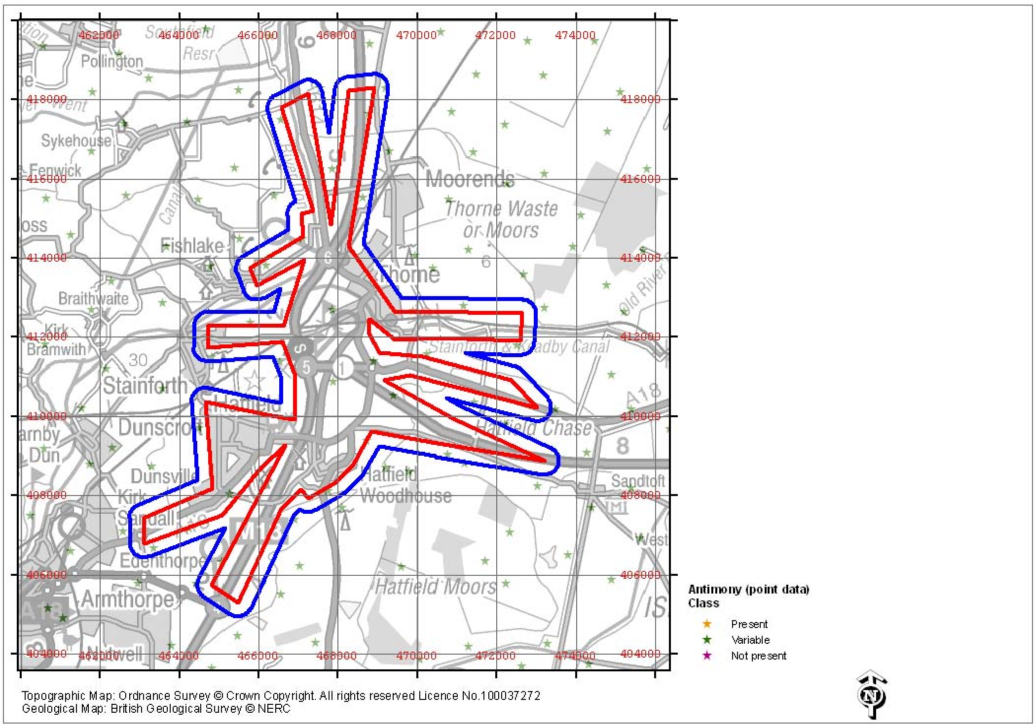
Example: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of Antimony.

Recommendation: Levels of Antimony exceeding 10 mg/kg alternative pipeline materials maybe required

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**

Antimony Point Data



The map shows the site (red) and a search radius of 350 meters (blue).

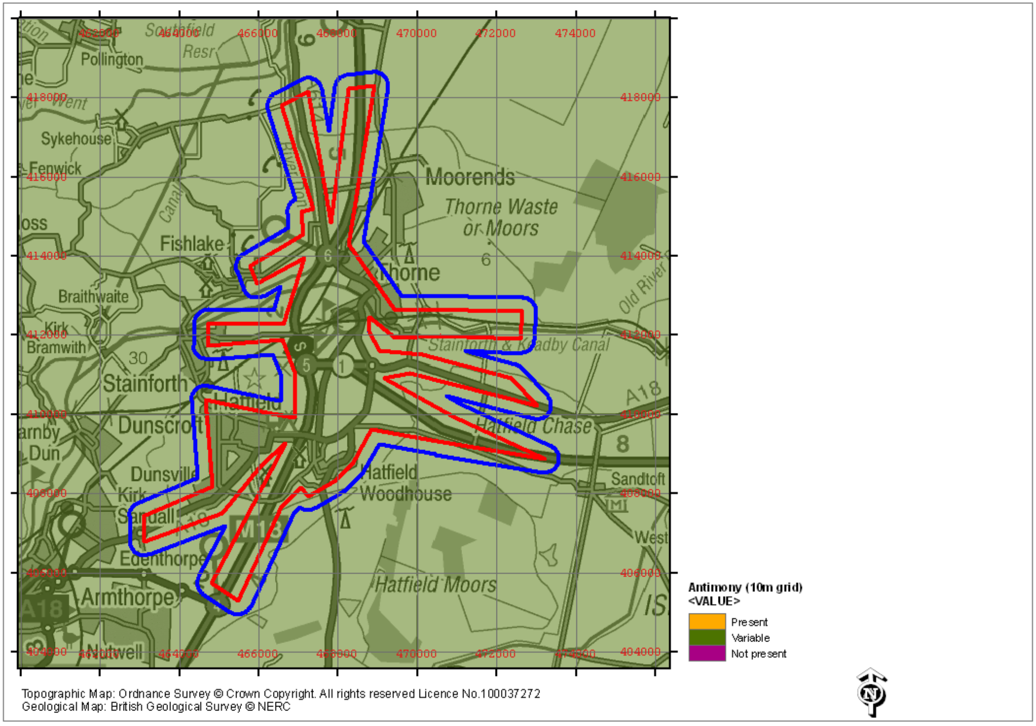
Site Results

Class	Description
Variable	Antimony known to be present in the area levels likely to be below 10 mg/kg

Search Radius Results

Class	Description
Variable	Antimony known to be present in the area levels likely to be below 10 mg/kg

Antimony 10m grid



The map shows the site (red) and a search radius of 350 meters (blue).

Class	Description
Present	**Likely that in this area levels of Antimony are above 10 mg/kg.**
Variable	**Antimony known to be present in the area, levels likely to be below 10 mg/kg.**
Not Present	**Antimony not thought to be present in this area.**

ARSENIC

Description: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of arsenic.

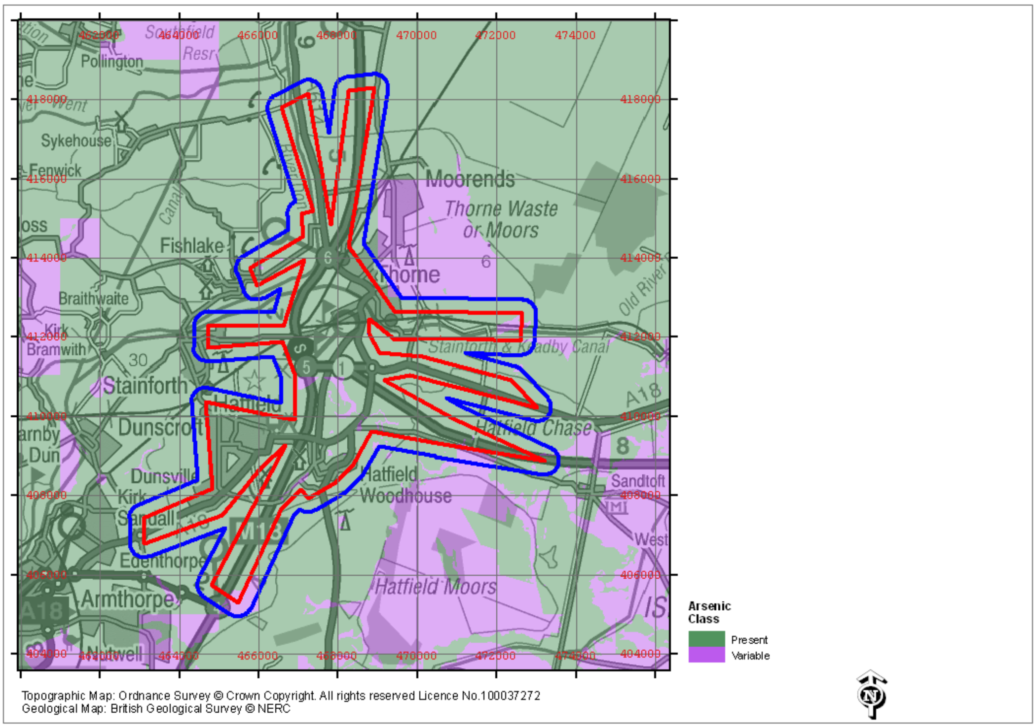
Effect: Exposure to large quantities of arsenic may have significant health consequences such as: irritation to the skin, lungs, stomach, and intestines; fatigue abnormal heart rhythm, bruising, impaired nerve function, cancer and even death.

Example: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of arsenic.

Recommendation: Levels of Arsenic exceeds 50mg/kg, protection measures may be required

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**



Data Resolution: 10m grid

The map shows the site (red) and a search radius of 350 meters (blue).

Site Results

Class	Description	Sample Type	Estimated As (ppm)
Present	Levels of Arsenic exceeds 10 mg/kg alternative pipeline materials may be required	Soil	10.2
Variable	Arsenic known to be present in this area	Soil	9.1

Search Radius Results

Class	Description	Sample Type	Estimated As (ppm)
Present	Levels of Arsenic exceeds 10 mg/kg alternative pipeline materials may be required	Soil	12.7
Variable	Arsenic known to be present in this area	Soil	9.1

CADMIUM

Description: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of cadmium.

Effect: Exposure to Cadmium can cause lung damage, brittle bones, possible kidney disease, stomach irritation and are likely to be carcinogens.

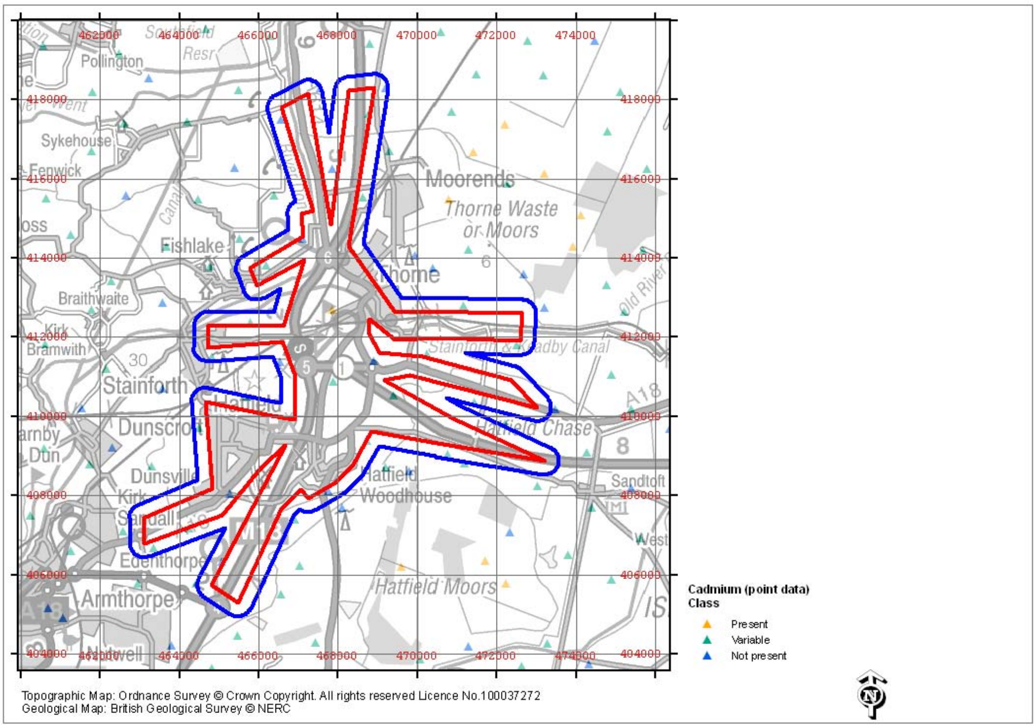
Example: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of cadmium.

Recommendation: Levels of Cadmium exceeds 3 mg/kg alternative pipeline materials may be required

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**

Cadmium Point Data



The map shows the site (red) and a search radius of 350 meters (blue).

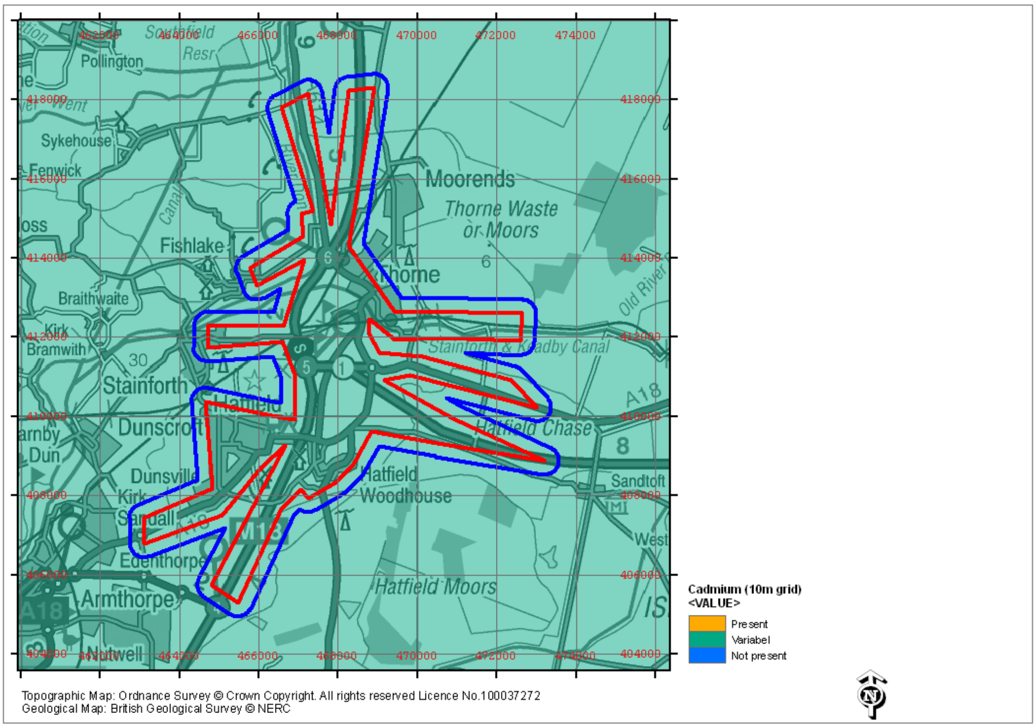
Site Results

Class	Description
Variable	Cadmium known to be present in the area at levels likely to be below 3 mg/kg
Not present	Cadmium not thought to be present in the area
Present	Area levels of cadmium above 3 mg/kg. Further site investigation may be required

Search Radius Results

Class	Description
Variable	Cadmium known to be present in the area at levels likely to be below 3 mg/kg
Not present	Cadmium not thought to be present in the area

Cadmium 10m grid



The map shows the site (red) and a search radius of 350 meters (blue).

Class	Description
Present	**Area levels of cadmium above 3 mg/kg. Further investigation may be required.**
Variable	**Cadmium known to be present in the area, levels likely to be below 3 mg/kg.**
Not Present	**Cadmium not thought to be present in this area.**

CHROMIUM

Description: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of Chromium.

Effect: Exposure to chromium can cause irritation to the nose. Long term exposure can cause lung cancer. Swallowing large amounts may cause stomach upsets, ulcers, convulsions, kidney and liver damage and even death.

Example: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of chromium.

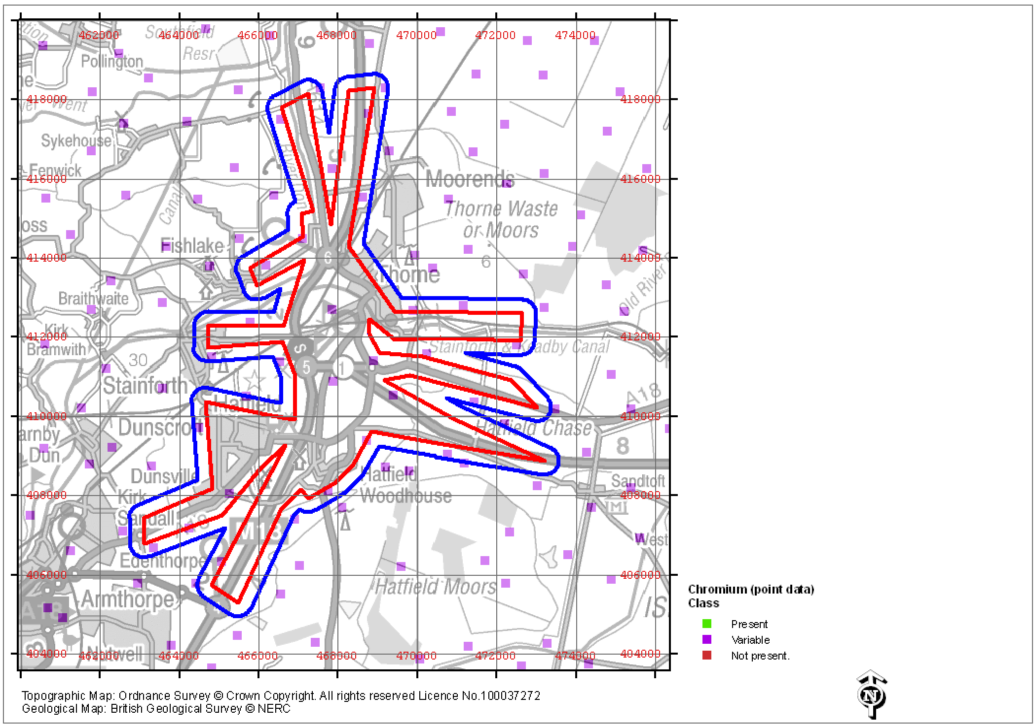
Recommendation: Levels of Chromium exceeds 600 mg/kg alternative pipeline materials may be required

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**

Data Resolution: 10m grid

Chromium Point Data



The map shows the site (red) and a search radius of 350 meters (blue).

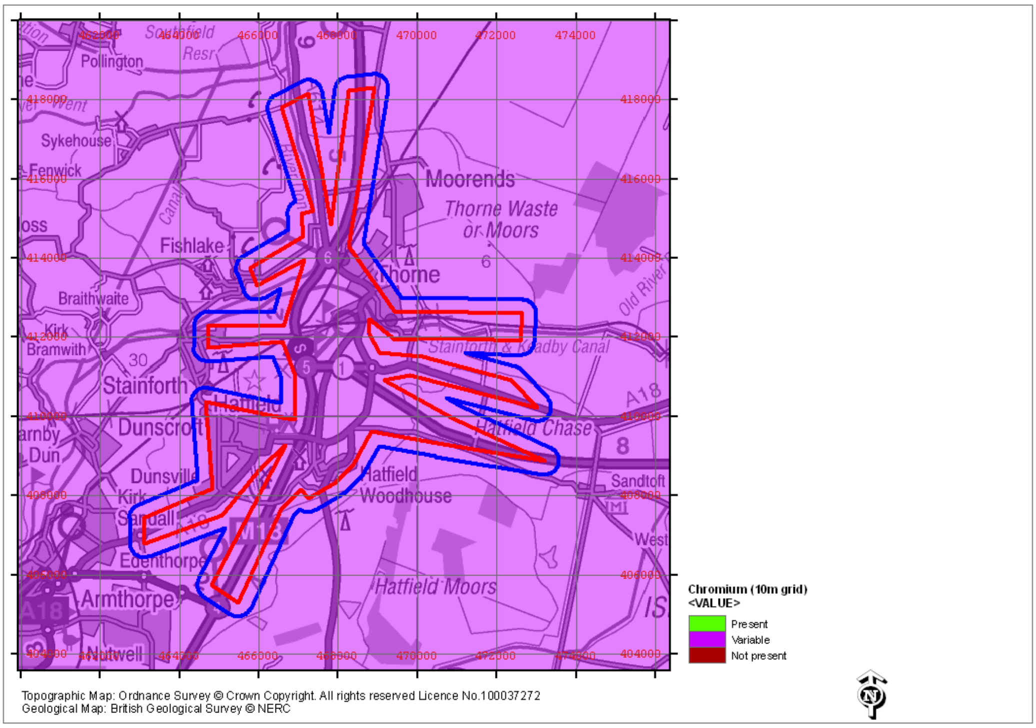
Site Results

Class	Description
Variable	Chromium known to be present in the area at levels likely to be below 600 mg/kg.

Search Radius Results

Class	Description
Variable	Chromium known to be present in the area at levels likely to be below 600 mg/kg.

Chromium 10m grid



The map shows the site (red) and a search radius of 350 meters (blue).

Class	Description
Present	**Levels of Chromium in this area likely to be greater than 600 mg/kg. Further investigation may be required.**
Variable	**Chromium known to be present in the area, levels likely to be below 600 mg/kg.**
Not Present	**Chromium not thought to be present in this area.**

LEAD

Description: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of Lead.

Effect: Exposure to lead can cause damage to the nervous system, kidney, cardiovascular and circulation, reproduction, personality, stomach and intestine and joints and muscles and cancer.

Example: For certain types of infrastructure the design and layout, material specifications and safety require a knowledge of the levels of lead.

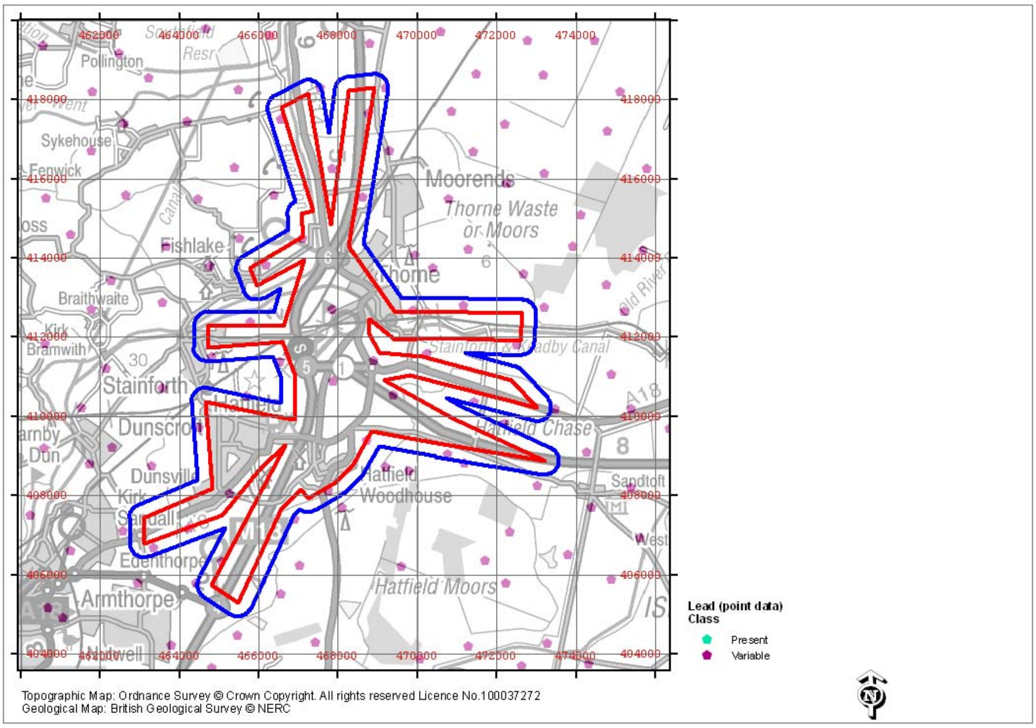
Recommendation: Levels of Lead exceeds 500 mg/kg alternative pipeline materials may be required

Types of Asset affected:

Asset	Type
Pipes	**Clay/Vitric, Copper, Plastic, Steel**
Foundations	**Concrete, Steel, Timber**
Cable	**Copper, Fibre Optic, Plastic**

Data Resolution: 10m grid

Lead Point Data



The map shows the site (red) and a search radius of 350 meters (blue).

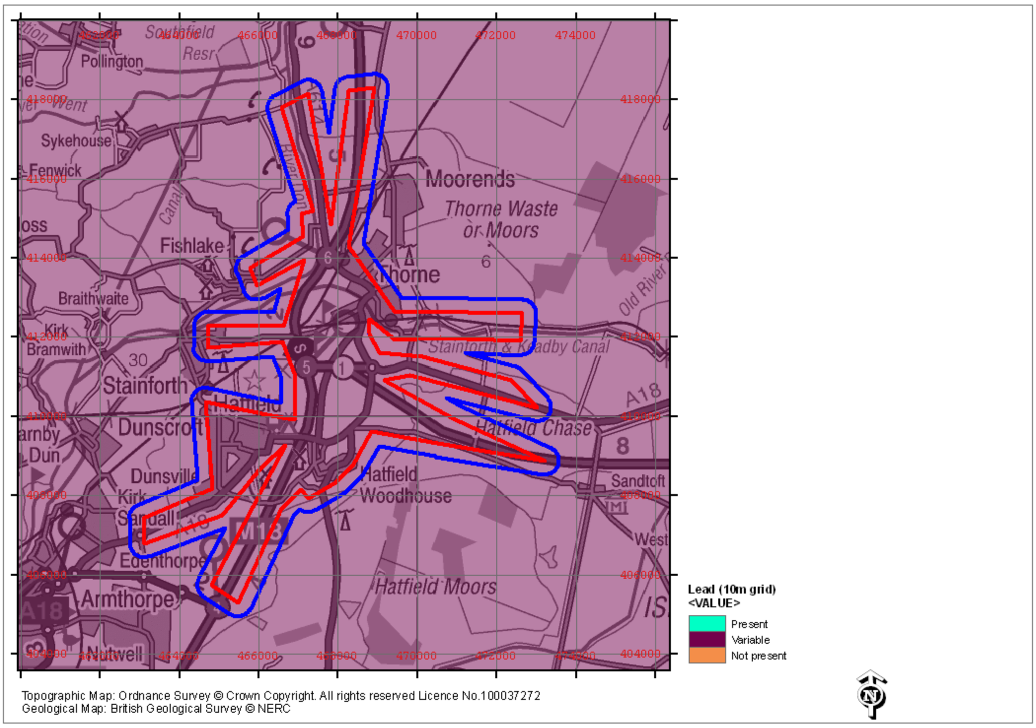
Site Results

Class	Description
Variable	Lead is known to be present in the area at levels likely to be below 500 mg/kg.

Search Radius Results

Class	Description
Variable	Lead is known to be present in the area at levels likely to be below 500 mg/kg.

Lead 10m grid



The map shows the site (red) and a search radius of 350 meters (blue).

Class	Description
Present	**Levels of Lead in this area likely to be greater than 500 mg/kg. Further investigation may be required.**
Variable	**Lead known to be present in the area, levels likely to be below 500 mg/kg.**
Not Present	**Lead not thought to be present in this area.**

Data Resolution: 10m grid

Additional Comments

This report is aimed at customers or clients carrying out preliminary assessments of their underground assets, who require a brief indication of the geological, physical and chemical factors that might influence the management of assets underground.

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