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Scott Wilson

Rolls-Royce plc

Land at Coxmoor Road
Sutton in Ashfield

Geotechnical and Environmental Land Quality Audit Report

Final Report

August 1998

LAND AT COXMOOR ROAD
SUTTON IN ASHFIELD

GEOTECHNICAL AND ENVIRONMENTAL LAND QUALITY AUDIT REPORT

Rolls-Royce plc
65 Buckingham Gate
LONDON
SW1E 6AT

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Scott Wilson Kirkpatrick & Co Ltd.
Bayheath House
Rose Hill West
Chesterfield
Derbyshire
S40 1JF

Tel: 01246 209221
Fax: 01246 210349

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EXECUTIVE SUMMARY

This report presents the findings of a geotechnical and environmental land quality audit of a former landfill on the edge of Sutton in Ashfield, Nottinghamshire. The 4 hectare site is part of an 11.3 hectare site currently in agricultural use but proposed for residential development. The investigation was carried out by Scott Wilson Kirkpatrick & Co Ltd ("Scott Wilson") on behalf of Rolls-Royce plc.

The Site lies on the Lower Mottled Sandstone, part of the Sherwood Sandstone Group, which is a major aquifer.

From the early 1900's to 1980, the site was occupied by a disused sand pit. In 1980, a licence for the disposal of inert waste in the pit was granted by Nottinghamshire County Council. Disposal of combustible, putrescible or potentially polluting material was prohibited under the terms of the licence. The pit was filled and returned to agricultural use.

The ground investigation designed by Scott Wilson included 13 trial pits and 5 boreholes. In addition to the inert materials permitted by the landfill licence, slightly contaminated materials were found in minor quantities in some of the exploratory holes.

Standard penetration tests revealed the fill to be of very variable density. Improvement of the fill density and use of raft foundations are recommended in order to avoid problems with differential settlements under structures. Ground improvement by vibro replacement is considered most appropriate. Dynamic compaction could also be effective, although environmentally less desirable.

Initial readings in the gas standpipes revealed that concentrations of methane and carbon dioxide may be elevated slightly, although further monitoring is required to confirm this. Chemical analysis of samples from selected exploratory holes showed that contamination was only sporadic and slight. Concentrations of a number of heavy metals and other metals marginally exceeded the ICRCL trigger concentrations for domestic gardens and allotments in some samples.

There are potential, albeit low-level risks to the eventual residents of the site and to the underlying aquifer, associated with the presence of contaminants and gases in the landfill. However, a number of engineering measures can be taken in order to reduce the risks further, to allow development to proceed with a high standard of environmental protection.

The measures recommended include incorporation of a low permeability capping of clay over the areas of landscape and gardens, and incorporation of a gas-barrier membrane into the raft foundations of buildings.

If the above precautions are taken, and subject to satisfactory results of gas monitoring, it is considered that the site is suitable for residential development with a high standard of environmental protection.

A risk assessment is recommended in order to assess the level of risk of pollution of the Sherwood Sandstone aquifer and of potable abstraction facilities by leachate from the site.

1.0 INTRODUCTION

1.1 This report describes the results of a geotechnical and environmental investigation of a former landfill site. The investigation was carried out by Scott Wilson Kirkpatrick & Co Ltd. on behalf of Rolls-Royce plc. The Site is situated adjacent to Coxmoor Road and Newark Road, near Sutton in Ashfield in Nottinghamshire (see Figure 1.1). The approximate grid reference is SK 515585.

1.2 The Site covers an area of approximately 4 hectares, as shown in Figure 1.2. It forms part of an 11.3 hectare area currently in agricultural use but proposed for residential development.

1.3 The investigation was commissioned by Rolls-Royce to establish whether the former landfill site would compromise first the case being promoted in favour of development and second, the achievement of best value if the land were sold for residential development.

1.4 This report therefore describes the investigation and identifies the materials found within the landfill, including the cost of any necessary remediation together with the identification of the likely risks to Rolls-Royce plc

1.5 Tenders for the ground investigation were invited from two specialist contractors, of which Norwest Holst Soil Engineering Ltd submitted the lower price and was granted the contract.

2.0 GEOLOGY AND HYDROGEOLOGY

2.1 The geology of the site is shown on Geological Survey of Great Britain Sheet 112 of the one inch to one mile series. The map shows Lower Mottled Sandstone outcropping at the Site, underlain by Middle Permian Marl, Lower Magnesian Limestone and Lower Permian Marl. The Lower Mottled Sandstone, which forms part of the Sherwood Sandstone Group, generally comprises fine to medium grained silty sandstones, with thin beds of mudstone and siltstone, and occasional breccias.

2.2 The Sherwood Sandstone Group is a potable aquifer of regional importance. The Institute of Geological Sciences Hydrogeological Map of the Northern East Midlands (1981), shows four licensed abstraction points within 5 km of the site. Two of these are pumped for public supply. The NRA Groundwater Vulnerability Map Sheet 18 shows that the area of the site falls into the highest Vulnerability Class for groundwater pollution: Major Aquifer with Soils of High Leaching Potential.

3.0 HISTORICAL DEVELOPMENT OF SAND PIT AND LANDFILL

3.1 The history of the Site was investigated from Ordnance Survey maps published in 1916, 1920, 1921, 1938, 1939, 1955, 1959, 1967, 1976 and 1992. A sand pit was already in existence on the site in 1916. Subsequent maps show no change to the workings until 1959, by which time a playing field and pavilion had been constructed in the disused sand pit. From 1959 to 1992 the maps show no change to the Site, except the demolition of Greenhill Farm, which stood between the sand pit and Newark Road. The 1992 map is misleading, however, as in 1980 a licence for the disposal of inert waste in the pit was granted and the pit was subsequently infilled. Copies of the historical maps are given in Appendix A.

4.0 TERMS AND CONDITIONS OF LANDFILL LICENCE

4.1 On 19 March 1980, Nottinghamshire County Council granted a licence under the Control of Pollution (Licensing of Waste Disposal) Regulations 1976 to Stamford Waste Disposal Ltd for the use of the sand pit as a landfill. The licence permitted disposal of up to 250 tonnes per day of construction industry waste, consisting of soil, spoil, rubble, excavated materials and demolition materials. Disposal of any combustible or putrescible material or other waste likely to cause a nuisance or pollution was prohibited, and a record of the types and quantities of materials deposited was required.

4.2 The licence required that the material be compacted in layers not exceeding 2.4 m in depth. A final layer of at least 0.5 m depth was required to be kept free of materials likely to interfere with final restoration or subsequent cultivation.

4.3 The landfill operations were also covered by planning permission granted in February 1980 by Ashfield District Council, for restoration of the land to its original level and return to agricultural use. A condition of the planning consent was restoration with 18 inches (450 mm) of subsoil and 9 inches (225 mm) of topsoil, on top of the final layer of waste.

4.4 Measures can be taken to reassure both the local authority and the Environment Agency that the landfill does not present a significant risk to site occupants or to surrounding land or property, neither at present nor in the future developed conditions. Mitigation by virtue of engineering measures is described in Section 8. A recommendation for a risk assessment relating to surrounding land is outlined in Section 9, and this is likely to provide the desired reassurance.

5.0 PREVIOUS SITE INVESTIGATION

5.1 During a site investigation by Nicholls Colton and Partners in 1981, three shell and auger boreholes 5.5 to 6.0 m deep were dug in the sand pit area. The purpose of the investigation was to assess the potential for further sand abstraction from the site. The following geological succession was encountered:

i) topsoil and / or fill
ii) sand (weathered and partially weathered Lower Mottled Sandstone)
iii) sandstone (Lower Mottled Sandstone)

5.2 Although no levels were given on the borehole logs, the fact that no significant thickness of fill was encountered suggests that the holes were dug prior to commencement of landfill operations. The fill encountered in this investigation was probably placed in connection with the construction of a playing field in the pit between 1916 and 1959.

6.0 CURRENT GROUND INVESTIGATION

6.1 Objectives of Ground Investigation

6.1.1 The aim of the ground investigation designed by Scott Wilson and carried out by Norwest Holst Soil Engineering Ltd was threefold:

i) to identify the ground conditions in the area of the sand pit;
ii) to attempt to delineate the boundaries of the pit;
iii) to identify any environmental or geotechnical factors which could affect the proposed residential development on the site.

6.2 Methodology

6.1.2 A "spike survey" was conducted, to assess the concentrations of carbon dioxide, hydrogen, methane, nitrogen dioxide, oxygen and hydrogen sulphide in the fill at 36 locations across the site. The survey was conducted prior to disturbance of the ground in connection with boreholes and trial pits.

6.1.3 Thirteen trial pits were dug to depths varying between 0.25 m and 3.80 m, at the locations shown in Figure 1.2. The ground conditions found in the trial pits were logged in accordance with the standard methods set out in BS5930. An indication of the undrained shear strength of the strata, where appropriate, was obtained using a hand shear vane.

6.1.4 Five 150 mm diameter boreholes varying between 1.8 m and 10 m in depth were carried out using cable percussion methods, in the locations shown in Figure 1.2. Standard Penetration Tests (SPT) were conducted in the boreholes, at 1 m vertical intervals. In an SPT test, an indication of the density of the ground is obtained by counting the number of blows from a standard weight required to drive a standard sampler a set distance into the ground. Gas monitoring standpipes were installed in three of the boreholes.

6.1.5 Selected samples taken from the boreholes and trial pits were submitted for a range of geotechnical and chemical tests.

7.0 GROUND CONDITIONS ENCOUNTERED

7.1 Nature and Extent of Landfill Materials

The approximate extent of the landfill, as determined in the ground investigation, is shown in Figure 1.2. Copies of the trial pit and borehole logs together with the geotechnical test results are given in Appendix B.

7.1.1 The surface layer of sandy topsoil and subsoil is generally about 1.2 m thick, thicker than the 0.7 m required under the terms of the planning consent. However, it varies between 0.6 m and 1.8 m. Underlying the surface layer, landfill waste fills the remainder of the old sand pit, increasing from 2.6 m thick in BH2 to 7.9 m thick in BH4.

7.1.2 The boreholes and trial pits revealed that the bulk of the fill comprises sandy clay or clayey sand and gravel to cobble sized fragments of concrete, brick and tiles. At TP1, TP2 and TP3 the JCB was unable to break through a hard layer of tarmac, bricks and concrete at 0.9 m to 1.4 m depth. Borehole BH3 was terminated in a hard stratum at 1.8 m .

7.1.3 The SPT results varied considerably and erratically with depth in all four boreholes. In some locations the SPT "N" value was as low as 3 to 5, indicating very loose material or voids. At other locations, incomplete penetration of the sampler after 50 blows indicated very dense or hard material, or obstructions.

7.1.4 The fill in some of the exploratory holes was found to contain materials such as wood, paper and cloth which contravene the terms of the landfill licence, although they formed only a minor constituent within the bulk of the fill. Other combustible or potentially polluting materials encountered in minor quantities were coal, asphalt, plastic, car parts, lead pipes and steel drums filled with ash.

7.1.5 Odours were encountered in boreholes 1 and 3A and in trial pits 7, 10 and 11 during digging and drilling, variously described as " chemical odour" "diesel odour", hydrocarbon odour" and "landfill odour".

7.1.6 The presence of methane in relatively low concentrations was recorded by the initial readings in the gas monitoring standpipes in BH1 and BH3. In BH1, concentrations of CH_4 and CO_2 were measured at 1.3% and 1.9% respectively. The corresponding O_2 level was 8.2%. By comparison with published data for landfills made up of decomposing domestic refuse, the concentrations of methane and carbon dioxide are relatively low and do not indicate high rates of gas emission, nor do they suggest the presence of substantial deposits of decomposing materials. The implications of these results are discussed in Section 8 below. Table 7.1 gives the initial measured concentrations of CH_4, CO_2, O_2,, NO_2, H_2, and O_2, H_2S in the three standpipes, together with published data for comparison. The results of the spike survey, given in Table 7.2, show oxygen levels consistent with atmospheric concentrations and negligible concentrations of the harmful gases.

7.1.7 Table 7.3 summarises the results of chemical tests on selected soil samples. Overall the results indicate that contamination is present only sporadically, and is only slight where it does occur. Of the twelve samples tested, six samples indicated that concentrations of all the various determinands were lower than the ICRCL threshold trigger concentration; five further samples showed concentrations in all but one determinand lower than the ICRCL threshold trigger concentration (arsenic or zinc marginally exceeding the trigger); and one sample, TP7 at 1.2 m depth, showed concentrations in nine determinands exceeding the trigger.

The samples from TP7 and TP10 contained diesel-range hydrocarbons (DRO) consistent with the odours noted in para 7.1.5 above. The sample from TP10 also contained semi-volatile organic carbons including polyaromatic nuclear hydrocarbons, which are likely to originate in the diesel range hydrocarbons referred to above. Published guidelines [2, 3] for the classification of contaminated soils indicate the DRO (cyclohexane extract) concentrations up to 2000 mg/kg represent "uncontaminated" whilst 2000 - 5000 mg/kg represents "slight contamination". Thus the sample in TP7 is "slightly contaminated" whilst that from TP10 is "Uncontaminated"; with respect to diesel-range organics.

7.2 Nature and Profile of Base of Sand Pit

7.2.1 The base of the sand pit was not encountered in any of the trial pits, therefore the only available information about it was obtained from the four full depth boreholes. In BH2, at the western side of the landfill, the base of the fill was encountered at 4.3 m depth. Towards the middle of the site, in BH1 and BH3A respectively, the base of the pit was penetrated at 7.0 m and 7.4 m depth, compared to 9.3 m in BH4, at the eastern side of the site.

7.2.2 Dense reddish brown sands were found at the base of the sand pit in BH1 and BH2, and reddish brown mudstone in BH3A and BH4. This is consistent with the published geology, as the Lower Mottled Sandstone contains thin beds and lenses of mudstone.

7.3 Groundwater Conditions Encountered

7.3.1 Slight groundwater seepage was observed at a depth of 4.8 m in Borehole 2, probably from a localised pocket of perched water. No groundwater was encountered in any of the other trial pits or boreholes, indicating that the water table within the Sherwood Sandstone aquifer lies at some depth, at present unknown, below the landfill. Recommendations for further assessment of groundwater conditions, in particular of risks to the aquifer from leachate, are given in Section 9.

8.0 PRELIMINARY RECOMMENDATIONS

8.1 Foundations and Ground Improvement

8.1.1 Due to the variability of the strength and density of the fill, it is unreliable as a founding stratum in its present condition. Excessive differential settlement beneath structural foundations is considered likely, as a result of the decomposition of pockets of organic matter, and settlement of loose material. However, with suitable treatment, the geotechnical properties of the ground could be improved sufficiently to allow development.

8.1.2 Three ground improvement techniques have been considered, all of which could achieve the desired improvement in the load-bearing properties of the fill:

i) excavation and re-compaction of the fill;

ii) dynamic compaction ("D.C.") in which a weight of about 10 tonnes is repeatedly raised and dropped onto the ground surface from a height of 10 - 15 m;

iii) vibro replacement in which some "stone columns" are formed in the ground using a large diameter vibrating poker.

8.1.3 Excavation and re-compaction would require a general treatment of the whole site, whereas D.C. and vibro replacement would allow localised treatment of proposed building footprints. Thus the latter two methods would be carried out by the developer once the house locations were known. Excavation and re-compaction is not considered a suitable option, due to the large volume of fill involved, the lack of space for temporary stockpiles of material, and the potential for generation of air-borne dust from the fill.

8.1.4 Dynamic compaction should not be used in the vicinity of existing structures or services, due to potentially damaging vibrations caused by the impact of the weight on the ground. Thus a solution including D.C. would involve use of vibro replacement within 40 m of buildings along Searby Road and Newark Road and use of D.C. over the remainder of the site. Estimates indicate that this could cost in the order of £80,000, assuming that houses will cover 20% of the total site area. The corresponding cost if only localised vibro replacement was used would be in the order of £110,000.

8.1.5 However, the use of D.C. is likely to be strongly opposed by local residents. Thus the planning application could be prejudiced if it were known that D.C. was proposed for the site. In addition the potential for damage to structures would oblige the developer to treat the whole site at the outset if using D.C., whereas use of vibro replacement would allow treatment of some areas of the site in advance of others if a staged development over several years was desired.

8.1.6 As a result of the above considerations, vibro replacement is considered to be the most cost effective means of improving the properties of the fill material.

8.1.7 Following ground improvement, it is recommended that for residential buildings reinforced concrete raft foundations be required, in order to minimise differential settlements arising from any residual compression of the treated fill .

8.2 Environmental Assessment

8.2.1 Published guidance on construction near landfills (Ref. 1) recommends that protection from gas emissions be incorporated in the design of buildings where methane and carbon dioxide concentrations exceed 1% by volume and 1.5% by volume respectively. These levels were both exceeded slightly in the initial concentrations measured in the gas monitoring standpipe in BH1. However, the gas concentrations measured during the progress of boring may be higher than long term steady-state concentrations, and may therefore be unrepresentative of those generally prevailing in the fill. Further monitoring of gas concentrations in the boreholes is therefore recommended.

8.2.2 In view of the relatively low concentrations of gas and contaminants measured in the investigation and described in para,s 7.1.6 and 7.1.7 above, the potential risks to the eventual residents of the site and to the underlying aquifer associated with the presence of contaminants and gases in the landfill are considered to be relatively low. However, a number of engineering measures can be taken in order to reduce the risks further, to allow the development to proceed with a high standard of environmental protection viz:-

i) isolation of the development from underlying landfill

ii) prevention of rainwater infiltration into the landfill

iii) control of gas releases from the landfill such that a build-up of gas beneath properties, or migrations of gas into adjacent property is obviated.

8.2.4 Isolation of the development can achieved by placing a low-permeability capping of clay over the fill after the ground improvement. The construction of the development itself including raft foundations, hard standings and roads will provide a low permeability cap over much of the site. Landscape areas and gardens can be isolated by placing a low-permeability cover or clay, say 400 mm thick over the landfill and beneath the topsoil. This will also serve to reduce the current rate of rainwater infiltration into the fill, such that the potential for leachate generation is reduced. Gas would be vented passively by constructing passive relief wells through the clay capping if monitoring results from the existing boreholes showed significant steady-state gas emissions.

8.2.5 The clay cover to landscape areas and gardens is estimated to cost in the order of £100,000 for the whole site, although the cost of imported fill is highly dependent on the availability of local materials at the time when the work is being carried out.

The protection of buildings from gas ingress can be achieved by incorporating a gas-barrier membrane into the raft foundations, continued into the walls and tied in to the

REFERENCES

1. Protecting development from methane, CIRIA Report 149

2. Interim Guidance on the Disposal of contaminated soils, (1st edition 5 March 1997), Environment Agency.

3. Protection of Workers and the General Public During the Development of Contaminated Land. Health and Safety Executive 1991.

TABLES AND FIGURES

Table 7.1 Initial Gas Concentration in Standpipes, and published Data for Comparison

Standpipe	BH1	BH2	BH3
CH_4(%)	0	1.3	0.4
CO_2(%)	0	1.9	0.9
O_2(%)	20.8	8.2	16.7
Pressure (mb)	1004	1003	1002
NO_2(ppm)	0.1	0.2	0.1
H_2S(ppm)	0.2	0.5-0.2	0.4
H_2(PPM)	2	2-4	8

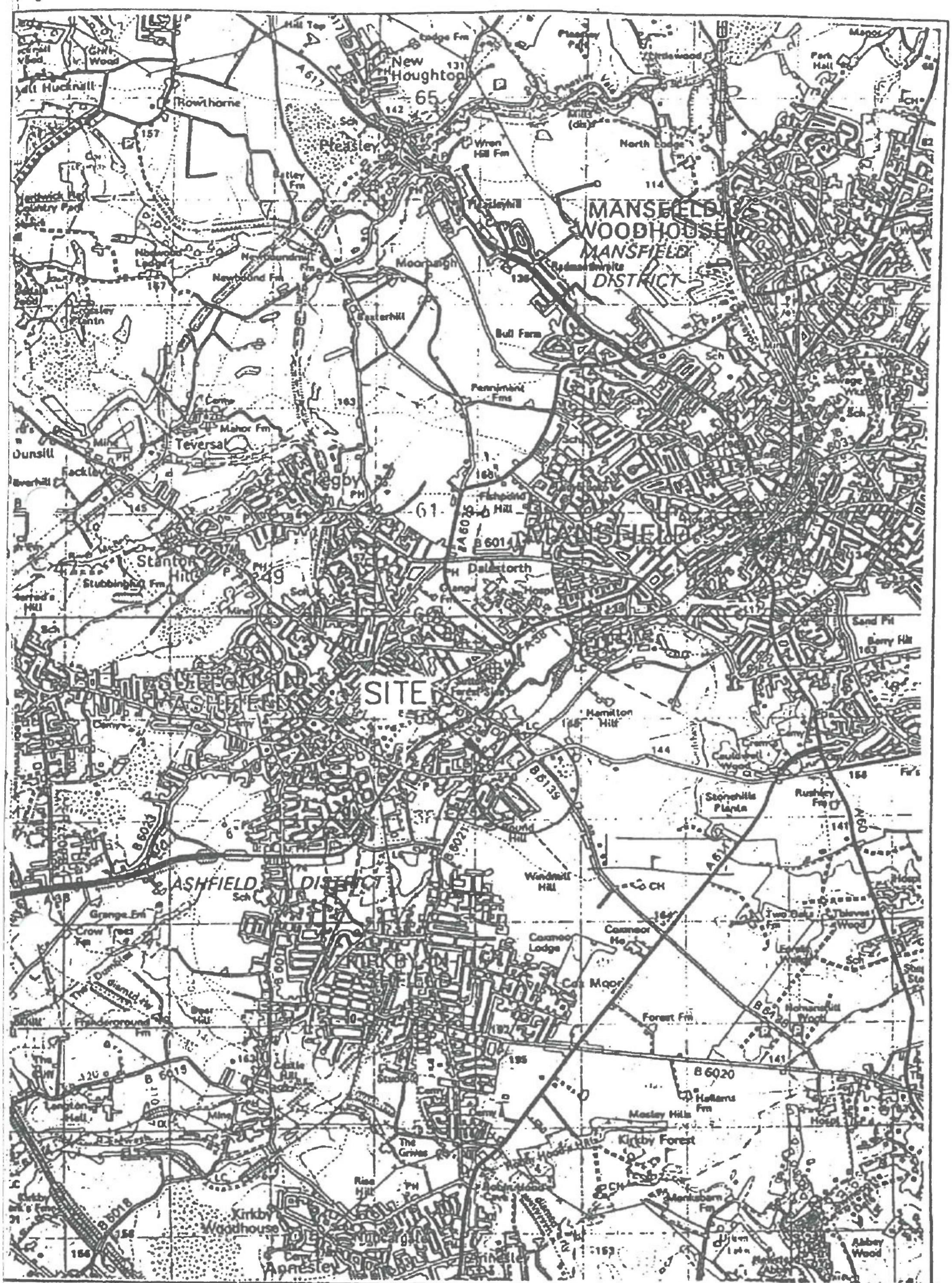
Published Data

Source	CH_4(%)	CO_2(%)	H_2S(%)	O_2(%)
Domestic refuse landfill	20-65	16-57	2×10^{-5}	<0.3

Table 7.3 - Summary Of Results Of Chemical Testing

ANALYTES	UNITS	TP4 2 (1.70m)	TP6 1 (0.60m)	TP7 2 (1.20m)	TP7 1 (0.50m)	TP9 2 (1.30m)	TP9 3 (3.00m)	TP10 2 (1.00m)	TP11 1 (0.50m)	TP11 2 (1.50m)	TP12 1 (0.80m)	TP12 2 (2.00m)	BH2 3 (2.50 - 2.95m)	I.C.R.C.L Trigger concentration for domestic gardens and allotments.
Arsenic	mg/kg	8.4	10.8	19.5	2.6	[illegible]	[illegible]	5	3.5	6.7	4.3	10.5	7.2	10
Cadmium	mg/kg	1	1.6	10.2	1.3	1.4	1.7	3.9	1.4	1.8	0.9	1.7	0.5	3
Chromium (hexavalent	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	25
Chromium (total)	mg/kg	30.8	49.2	155.9	43.8	57.9	48.9	173.6	48.3	37.4	45.4	49.2	28.8	600
Lead	mg/kg	90.4	111.1	[illegible]	28.2	115.8	129.9	136.3	13.2	138	12.4	145.5	53.3	500
Mercury	mg/kg	<1.0	<1.0	[illegible]	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1
Sselenium	mg/kg	<1.0	<1.0	7.8	<1.0	<1.0	<1.0	<1.0	<1.0	1.3	<1.0	<1.0	<1.0	3
Boron (water soluble)	mg/kg	2.9	<1.0	[illegible]	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.3	<1.0	3
Copper	mg/kg	32.2	57.4	[illegible]	13.1	114.5	61.5	61.4	8.2	57.9	8.4	51.7	23.5	130
Nickel	mg/kg	18.7	27.9	[illegible]	26.1	38.4	28.8	44.5	27.2	22.6	25.9	28	21.8	70
Zinc	mg/kg	119.4	171.8	[illegible]	86.1	148.9	292.6	213.7	57.9	312.9	61.6	377.1	76.2	300
pH	N/A	6.8	7.7	7.4	7.8	7.2	7.4	7.3	7.8	7.4	7.6	7.7	7.4	5
DRO	mg/kg	-	-	2180.7	-	-	-	48.5	-	-	-	-	-	-
Mineral Oil	mg/kg	-	-	1468.4	-	-	-	<0.1	-	-	-	-	-	-
SVOC's	mg/kg	-	-	-	-	-	-	37.8	-	-	-	-	-	-

[shaded box] = Exceeds ICRCL threshold trigger concentration for domestic gardens and allotments.



Drawing Title

ROLLS–ROYCE PLC
LAND AT COXMOOR ROAD
SUTTON IN ASHFIELD

FIGURE 1.1

Scale at A4 :		
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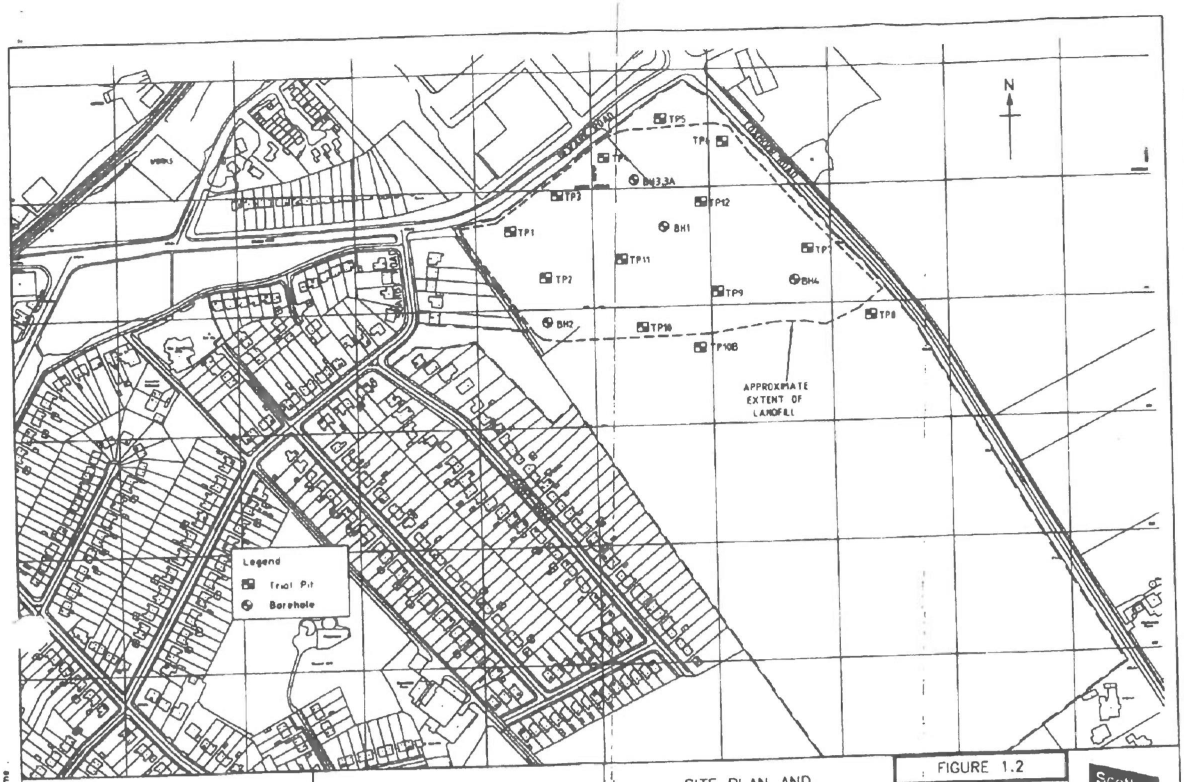
Table 7.2 Spike Test Results

	O_2(%)	CO_2(%)	CH_4(%)	NO_2(ppm)	H_2(ppm)	H_2S(ppm)	Atmospheric Pressure
1	19.4	0	0				1000
2	19.7	0	0			0	1000
3	19.7	0	0			0	999
4	19.8	0	0			0	999
5	19.5	0.2	0			0	1000
6	18.5	1.2	0			0	997
7	20.2	0	0			0	996
8	20.1	0.3	0			0	996
9	19.6	0.4	0			0	996
10	18.9	0.2	0			0	996
11	19.4	0.2	0			0	997
12	19.5	0.2	0			0	996
13	19.7	0.2	0			0	996
14	20.2	0	0			0	996
15	20.6	0.1	0	0	2-4	2	1003
16	20.9	0	0	0	2	0	1003
17	20.7	0.1	0	0.1	4	0.1	1003
18	20.6	0.1	0	0	4	0	1003
19	20.9	0.3	0	0.2	17	0.1	1003
20	20.4	0	0	0.4	6	0.1	1003
21	20.3	0.1	0	0.2	6	0	1003
22	20.4	0.2	0	0.3	2	3	1003
23	20.4	0.2	0	0.2	8-10	0	1003
24	20.5	0.2	0	0.1	2	0.1	1003
25	20.3	0.1	0	0.1	4	0	1003
26	20.4	0	0	0	6	0.2	1003
27	20.1	0.2	0	0.1	7	0	1003
28	20.4	0.2	0	0.1	4	0.1-0.2	1003
29	20.6	0.2	0	0.3	2	0	1003
30	20.1	0.1	0	0.1	6	1-2	1003
31	20.1	0.1	0	0.2	6	0	1003
32	20.6	0	0	0.1	2-4	0.1	1003
33	20.1	0.3	0	0.2	4	0	1003
34	20.1	0.2	0	0.1	4	0.2	1003
35	20.6	0.1	0	0.1	2	0	1003
36	20.4	0.3	0	0.1	2	0.1	1003



ROLLS-ROYCE PLC	LAND AT COXMOOR ROAD SUTTON-IN-ASHFIELD	SITE PLAN AND EXPLORATORY HOLE LOCATIONS	FIGURE 1.2 Scale at A3 : 1:2500 Drn / Appd / Revised Chk / Date / Date

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