



STAGE 2 GEO-ENVIRONMENTAL REPORT

AT

CATHERINE'S WALK

BARNSELY

ON BEHALF OF

**LEEDS AND YORKSHIRE
HOUSING ASSOCIATION**

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1.0 EXECUTIVE SUMMARY

The pertinent conclusions of the report are tabulated below. However, the information below is not exhaustive, and it is recommended the report is read in its entirety.

Proposed Development	Residential dwellings with private gardens.
Existing Site Description	Most of site - grass playing fields. Previously developed area on the northwest, partly covered by concrete flags.
Site History	Most of the site has remained undeveloped, with the exception of the northwest, which once formed landscaping and hardstanding to part of a Junior School complex.
Geology	Glacial clay (north, west and northwest only), overlying Woolley Edge Rock (sandstone). Fault 3m outside northwest of site.
Coal Mining	Rotary boreholes required to determine if the southern section of the site may be underlain by shallow coal workings requiring grout treatment. Slight risk of unrecorded shafts and bell pits.
Radon	Basic protection measures recommended.
Landfill and Mine/Coal Gas	No landfills within 500m of the site. Mine gas risk dependent on depth of any seams and workings.
Ground Conditions	Made ground up to 0.5m thick on the northwestern rectangle. Sporadic localised made ground elsewhere, up to 0.7m thick. Natural strata comprise subsoils derived from weathering of sandstone, overlain by glacial clays on all but the south of site. No groundwater seepages. Clay strata has High Volume Change Potential.
Contamination	Made ground including clinker, on the formerly developed northwestern rectangle, was found to contain elevated arsenic.
Remediation Strategy	0.6m cover soils in proposed soft areas, retention below hard areas.
Foundations	Strip/trench fill foundations considered suitable. Tree survey may be required to allow a foundation schedule to be prepared. Shallow coal workings may be present below south of site and require grout treatment. Foundations will need to be reinforced. Foundations will also need to be reinforced in this event within 20m of the fault to the northwest.
Excavations	Should remain generally stable and dry.
Concrete	GEN1 designation for unreinforced buried concrete. For any reinforced concrete, other design-specific mixes will apply.
Soakaways	Percolation testing has indicated the site is not suitable for soakaway drainage.

2.0 TERMS OF REFERENCE

- 2.1 Leeds and Yorkshire Housing Association is considering developing the site at Catherine's Walk, Barnsley, with residential properties. It was considered appropriate to provide information to aid viability assessment and design of any subsequent development. In October 2017, ARP Geotechnical Ltd issued a Stage 1 Desk Study Report (Reference LYH/01r1). This involved an assessment of the geological and coal mining aspects, Ordnance Survey archive maps, radon gas, indicative flood risk, hydrogeology, landfill, and other environmental issues, primarily by assessment of a Landmark Envirocheck Report. In addition to comments and conclusions on a wide range of environmental and geotechnical issues, the report also provided recommendations for intrusive investigation and assessment.
- 2.2 ARP Geotechnical Ltd was appointed by Leeds and Yorkshire Housing Association to undertake the recommended further works, with the intrusive investigation comprising trial pits and window sample boreholes to assess the ground conditions.
- 2.3 The investigation was implemented generally in accordance with BS 5930 : 2015 "Code of practice for site investigations", NHBC Standard Chapter 4.1 "Land quality - managing ground conditions", Environment Agency CLR 11 "Model Procedures for the Management of Land Contamination" and BS10175 : 2011 + A1 : 2013 "Investigation of potentially contaminated sites - Code of practice". This report is limited to the data obtained as part of this investigation. It should be noted that there is a possibility of variation in ground conditions between test locations and interpretation of strata is given for guidance only. No liability is accepted for changes to site conditions, including groundwater levels, after the preparation of this report.
- 2.4 The findings or contents of the Stage 1 Desk Study Report are not reproduced here in full, and it is recommended that this report is read in conjunction with the Stage 1 Report.
- 2.5 The general observation and assessment of the ground surface, and the identification/classification of vegetation, is made in general terms only. It would be prudent

for a specialist to undertake a more detailed survey, including for any invasive/harmful weeds.

- 2.6 The assessment of any topsoil is carried out in terms of potential chemical effects on human health only, and no account is taken of aesthetic or horticultural properties. Such considerations should be referred to a horticulturist or landscape architect.
- 2.7 The report has been prepared for the use and reliance of the Client only. The report shall not be relied upon or transferred to any other parties without the written agreement of ARP Geotechnical Ltd. For the avoidance of any doubt, where ARP Geotechnical Ltd enters into a letter of reliance for the benefit of a third party, that third party will be permitted to rely on the report. No responsibility will be accepted where this report is used, either in its entirety or in part, by any other party without ARP Geotechnical Ltd.'s consent.

3.0 THE SITE

Site Location

- 3.1 The site, which is centred on Ordnance Survey Grid Reference 434990, 409230, is located off Catherine's Walk, in the village of Athersley North, which is located approximately 3km to the north of Barnsley town centre.
- 3.2 A site location plan, site plan, and proposed layout, are presented in Appendix A.

Site Description

- 3.3 The site is an irregular shaped piece of land extending to an area of 1.61 hectares, with overall dimensions of approximately 210m (north - south) by 135m (east - west) at roughly the widest part of the site, and by 80m (east - west) along the southern boundary.
- 3.4 At the time of the investigation, the northwest of the site comprised a rectangular area of undeveloped land, partially covered with hardstanding (typically concrete flags), and vegetated with weeds/bushes and sporadic trees. The rest of the site comprises well-kept grass, generally used as playing fields. A series of manhole covers, slightly raised above the grassed surface, crossed the site from the north to the southwest, crossing where the northwest of the site joins the with the main site area. A low, but raised (0.5m high), mound of earth was present, running just inside the eastern site boundary.
- 3.5 The site slopes down gently to the northwest. There is one large tree on the northwest of the site, and occasional sporadic trees just outside the boundaries elsewhere.

Site History

- 3.6 Ordnance Survey archive maps show that most of the site has remained part of a grass field since at least 1854, with the exception of the northwestern rectangular portion which formed

landscaping and hardstanding to part of a Junior School complex from 1959 until sometime after 2000. A small section of the east of the site was once occupied by Athersley Wood, which was felled by 1959. As is common in coal mining areas, collieries were once present in the area, the nearest being 400m to the southwest.

4.0 ENVIRONMENTAL SETTING

- 4.1 The environmental setting for the site was established by the Stage 1 Desk Study Report undertaken by ARP Geotechnical Ltd, under reference LYH/01r1 and dated October 2017. The findings of the Desk Study Report, updated and amended where deemed appropriate, are summarised below.

Geology

- 4.2 Geological maps show the north, west and northwest of the site to be covered by diamicton (cohesive glacial deposit) of Mid Pleistocene age. The remaining areas of the site show no drift cover. The bedrock across the site comprises sandstone of the Wooley Edge Rock Formation.
- 4.3 A fault is indicated just beyond (approximately 3m outside) the northwestern boundary of the site. There are no coal seam outcrops within at least 400m of the site. However, coal seams are present within the geological succession beneath the site. This is discussed in more detail below.

Coal Mining Report

- 4.4 A Coal Mining Report was obtained from The Coal Authority. A copy of the report is included in Appendix B, and a summary is given below.
- 4.5 The site is in the likely zone of influence of known workings in eight seams of coal at shallow (less than 30m) to 380m depth, and last worked in 1955. The shallow seams are likely to be the Meltonfield and the Two Foot. Abandonment plans are available for the shallow workings.

- 4.6 The site is not affected by any present or future proposed underground coal mining. The Authority refers to reserves in the locality that could be worked at some time in the future. However, given the effective abandonment of the coalfields in this area, any future workings are considered highly unlikely.
- 4.7 There are no recorded mine entries on or within 20m of the site. However, there is a theoretical risk of unrecorded mine entries in the locality. The site is unaffected by any past, present, or future proposed, opencast coal mining.
- 4.8 The Coal Authority Comments section of the Coal Mining Report states that "if development proposals are being considered, technical advice relating to both the investigation of coal and former coal mines and their treatment should be obtained before beginning work on site". This indicates that the Coal Authority views the risk of recorded and unrecorded mine workings beneath the site to be significant.

Abandonment Plans and Coal Mining Stability

- 4.9 The site is located on the British Geological Survey (BGS) 1:10,000 scale paper maps, referenced SE30NE and SE30NW.
- 4.10 The generalised vertical section, on Sheet SE30NW, shows the shallowest coal seam beneath the Woolley Edge Rock (WER) to be the Meltonfield Coal (MC), with a thickness of around 0.7m to 0.9m. The seam is approximately 5m beneath the base of the WER. The lower boundary of the WER does not outcrop nearby and its elevation beneath the site is uncertain. As a worst case, in the absence of any local information, the MC could be assumed to be present at a depth of six to seven metres beneath the site. Around 12m beneath the MC, the Two Foot Coal (TF) is indicated to be present, with a thickness of up to 0.63m in the locality. Approximately 18m beneath the TF is the Abdy (also called the Winter) coal seam, with a thickness of up to 1.4m.

- 4.11 Abandonment Plans were obtained from The Coal Authority, for the upper three seams, for the site and the surrounding area. Copies of the plans are included in Appendix B.
- 4.12 The plans show that the MC has been worked beneath a limited area in the northeast of the site only, although it has been worked extensively beyond the site, to the east and north. The TF has been worked extensively beneath the west and northwest of the site, whereas beneath the east and south of the site, only limited passages between worked areas, with non-worked areas in between, are shown. The Abdy is not shown to have been worked beneath the site, although is shown to have been worked extensively more than 300m to the northeast of the site.
- 4.13 There is a generalised rule of thumb that voids from any pillar and stall workings (the dominant method in old workings too deep to be worked by bell pits and before the adoption of longwall mining) may adversely affect stability on the site unless rock cover is present, above the original seam roof, of at least ten times the extracted thickness. In the case of the seams identified above, only the upper two seams (the MC and the TF) have the potential to adversely affect ground stability. Their respective maximum thicknesses are 0.9m and 0.63m.
- 4.14 The Abandonment Plan for the MC only indicates one reliable level for the workings (156.38m above Ordnance Datum (AOD)), at the top of a drift between the MC and the TF beneath, at a point approximately 230m east of the site. The drift follows the strike direction (perpendicular to dip direction). A nearby level for the lower seam indicates the separation of the two seams to be 9m.
- 4.15 Several levels are provided on the abandonment plan for the TF along with a dip of strata at around 1 in 18 (three degrees) towards the northeast. The levels indicate that the top of the TF is present at depths of around 31m on the north of the site and 20m on the south of the site. The TF is up to 0.63m thick. Therefore, any void migration from workings in the (0.63m maximum thickness) TF should not reach the overlying MC. Furthermore, given the 9m separation, the depth to the MC should range from around 22m on the north of the site to 11m on the south. For 11m depth to be sufficient to provide adequate cover to the MC workings,

the soil cover on the south of the site would need to be no more than 2m thick, which may not be the case. In addition, the estimated depths have used a degree of extrapolation. It would, therefore, be prudent to confirm the depth of cover to the workings on the south of the site by means of a rotary borehole investigation.

Coal Recovery

- 4.16 Any seams beneath the site are likely to be overlain by at least 5m of rock, including sandstone, and it is unlikely to be viable to remove any coal from the site by excavation prior to development.

Hydrogeology

- 4.17 The Bedrock Aquifer Designation is "Secondary A" and there are no groundwater abstractions within 1km of the site. The site is not within a groundwater Source Protection Zone.

Hydrology

- 4.18 The site slopes down gently to the northwest, but further from the site, the downward slope direction turns to the west-southwest. The nearest downslope surface water is an unnamed stream or open drain 351m to the southwest. There are no surface water abstractions within 1km of the site.
- 4.19 The site is not in an area at risk from river flooding. The risks of flooding from other causes such as adverse topography or insufficient surface water drainage, are not considered here, and a separate specialist Flood Risk and Drainage Report should be commissioned if such risk needs to be quantified.

Other Relevant Environmental Data

- 4.20 There are no closed or currently licenced landfills within 500m of the site.
- 4.21 At least part of the site is within an area where radon protective measures are stated to be necessary for new dwellings on the site. Unless a site-specific radon report is obtained, which indicates otherwise, it would be prudent to install basic protection to all proposed properties on the site. This is normally achieved by incorporating a radon barrier within a solid floor system, and extending the barrier through the cavity wall.

Potential Contamination Sources

- 4.22 The following potential sources of contamination were identified in the Stage 1 Desk Study Report
- 4.22.1 Possible made ground (most likely on the former school area of the site, in the northwest): - metals inorganics, total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAH), phenol, asbestos.
- 4.22.2 Possible harmful gases from coal/shallow workings: - methane, carbon dioxide.

5.0 SITE INVESTIGATION

5.1 A site investigation was undertaken by ARP Geotechnical Ltd on 19th October 2017. The purpose of the investigation was to produce an assessment of the site in accordance with BS10175 : 2011 + A1 : 2013 "Investigation of potentially contaminated sites - Code of practice", and to provide geotechnical information to aid design of the development.

5.2 To satisfy the requirements of the British Standard, the site was gridded on a maximum 25m spacing and trial pits were excavated, and windowless sampling boreholes were drilled, and sampled on the grid. Nine trial pits (TP1 to TP9) were excavated, to depths of between 1.3m and 4m. Eleven boreholes were drilled, to depths of between 1.03m and 4.44m. The trial pits and boreholes were organised, supervised and logged by an Engineer from ARP Geotechnical Ltd. Justifications for the trial pit locations are given below.

LOCATION	REASON
TP1 to TP4	Part of the grid, and to target proposed open/grassed areas of the future development, for percolation testing
TP5 to TP9	Part of the grid
WS1 to WS11	Part of the grid

5.3 The trial pit and borehole location plan and logs are included in Appendix C.

5.4 Four percolation tests were carried out in TP1, TP2, TP3 and TP4. The test readings, curves and calculations are included in Appendix D.

5.5 Chemical analysis of twenty one soil samples for metals, inorganics, speciated PAH, TPH, phenols, and asbestos was undertaken by the UKAS accredited Derwentside Environmental Testing Services (DETS) laboratory in Consett. Elevated determinands were tested further for leachability to determine the potential mobility of the contaminants. The test certificates are included in Appendix E.

- 5.6 Analysis for Atterberg Limits and moisture content was undertaken by the UKAS accredited Professional Soils Laboratory (PSL) in Doncaster. Geochemical testing comprising pH and water soluble sulphate was undertaken by DETS. The test certificates are included in Appendix E.

6.0 SUMMARY OF GROUND CONDITIONS

Strata and Groundwater

- 6.1 In the main site area (TP2 to TP8 and WS1 to WS9), topsoil or made ground topsoil, typically 0.2m to 0.45m thick, was found to be present at the surface. The topsoil was generally slightly clayey, slightly sandy, and slightly gravelly, with the gravel fraction including sandstone and mixed lithologies, and locally trace plastic (TP8) and glass (TP2 and TP8) fragments.
- 6.2 In the northwestern rectangular area of the site, it was evident that development had previously taken place in the locality. The surface covering generally comprised hardstanding, with localised areas of weeds/grasses. In the areas of hardstanding (TP1, TP9, WS10), concrete flags were present, overlying granular made ground, typically comprising engineering sand and gravel, and then gravel of sandstone and clinker, locally with angular cobbles of brick, to depths of between 0.1m (TP1) and 0.5m (WS10). Elsewhere (WS11) on the northwestern rectangle, sandy made ground topsoil was present, with a high cobble content of sandstone and brick, to 0.4m depth.
- 6.3 In the north of the site (TP8), it was evident that the topsoil was reworked, and was overlying backfilled granular made ground, of 0.7m thickness, with an organic content, and with occasional ceramic inclusions, and with trace coal and glass fragments. This backfilled material was not identified in any other locations (the closest was WS7, at approximately 20m to the south-southwest). It is likely that ground levels in the north and northeast of the site, locally, have been overfilled by approximately 1m, and levelled.
- 6.4 At TP5, below the made ground topsoil, possible made ground was present, comprising gravelly clay (reworked natural clay), with mixed lithologies, and with trace coal fragments, of 0.3m thickness. This material was not identified at any other locations (WS3 and WS8, are the closest).

- 6.5 Across the site, but not including the southeast, the surface cover was found to be underlain by natural cohesive glacial deposits, generally comprising medium strength (firm) to very high strength (very stiff) clays, typically between 1.7m (TP6, WS3 and WS6) and at least 4m (WS11) in thickness, with the thickest deposits underlying the northwestern rectangular area of the site. In the north of the site (TP8 and WS7), medium strength (firm) cohesive deposits, to between 2.6m and 2.8m depth, to the base of the deposits, were present. The cohesive glacial deposits had a variable granular content, generally comprising sand and gravel of mixed lithologies, and locally cobbles (TP1, TP6 and TP8) and boulders (TP6 and TP7) of sandstone. Trace gravel sized coal fragments were present locally (TP1, WS3 and WS11).
- 6.6 Competent Woolley Edge Rock sandstone was proven beneath the cohesive glacial deposits, at depths of between 1.9m (TP6) and 2.8m (TP7 and TP8), whilst probable bedrock was encountered from depths of between 2.45m (WS3 and WS6) and 3.65m (WS7). Exceptions include TP3 (in the north of the site), and TP1, TP9, WS10 and WS11 (in the northwest of the site), where the base of the cohesive glacial clays could not be reached by the termination depths of between 3.4m (TP1) and 4.44m (WS10).
- 6.7 In the southeast of the site (TP2, TP4, TP5, WS1, WS2, WS8 and WS9), the topsoil was found to be underlain by completely weathered Woolley Edge Rock sandstone, consisting of clay, sand and gravel, with increasingly coarser material with depth. At TP2, TP5, WS1, WS2, WS8 and WS9, the clay was firm to high strength (stiff), and contained sand, and angular gravel of sandstone. Competent Woolley Edge Rock sandstone was present from depths of between 0.8m (WS02) and 1.6m (TP2), whilst probable bedrock was present from depths of between 1.55m (WS9) and 1.7m (WS8).
- 6.8 The trial pits and boreholes generally remained stable for the short period of exposure, with the exception of the trial pits at TP8 and TP9, where slight instability of the pit sides was noted from the surface to 1m and 0.4m depth, respectively, associated with the made ground. No groundwater entries were recorded during the excavations, and in boreholes the strata appeared dry.

Percolation Testing

6.9 Percolation testing was implemented in TP1, TP2, TP3 and TP4 using a 1,500 gallon tractor towed water bowser to discharge water quickly into each hole. The intention was to monitor the water levels for a period until either the level had fallen to below 25% of the maximum filled level, or the end of the working day had been reached. If time permitted, a further two tests were to be carried out in each pit.

6.10 The water level did not fall significantly in three of the pits, and in one pit, fell only slightly over a period of almost three hours. A table showing the results is provided below.

Location	Water Level Drop (m)	Time (mins)	Infiltration Rate (m/s)
TP1, Test 1	0.01	150	Unable to calculate
TP2, Test 1	0.14	171	Unable to calculate
TP3, Test 1	0.01	124	Unable to calculate
TP4, Test 1	0.00	88	Unable to calculate

6.11 Given the very slow or minimal water level drops, it was not possible to calculate infiltration rates. As a result, the disposal of surface water on the site using soakaways, is not considered to be feasible. A drainage feasibility design should be carried out to determine the appropriate solution.

7.0 CONTAMINATION ANALYSIS

Screening Values - Soils

- 7.1 There is presently conflicting opinion with regard to the appropriate generic assessment criteria, or screening values, for soils which should be used in contamination assessment for proposed development. In March 2014, DEFRA published Category 4 Screening Levels (C4SLs) for six contaminants: arsenic, benzene, benzo(a)pyrene, cadmium, chromium VI and lead. The values are based on the toxicological benchmark of a "low level of toxicological concern" (LLTC) rather than the previous regulatory approach of "minimal or tolerable level of risk". As the C4SLs are less protective of health than the previous approach, the Chartered Institute of Environmental Health (CIEH) has advocated an alternative approach based on minimal risk, but with some adjustment of exposure parameters to more realistic scenarios than those previously used. To this end, the CIEH has collaborated with Land Quality Management to publish "Suitable 4 Use Levels" (S4ULs) "The LQM/CIEH S4ULs for Human Health Risk Assessment", November 2014 (LQM/CIEH). However, DEFRA has reiterated its intention that the C4SLs should be used in generic risk assessment for proposed development, and there is indication that other parties will collaborate, in the near future, to extend the range of C4SL determinands beyond the six published so far.
- 7.2 In the absence of a final resolution to the debate, soil contamination test results in this report have been compared first against the more conservative S4UL, and where a C4SL exists for the same determinand, consideration given to the use of the C4SL for any exceedences of the S4UL, within the site specific context. Where no S4UL exists for a determinand, for example lead, the C4SL has been used. The LQM/CIEH screening values have been calculated for soil organic matter contents of 1% and 2.5%, as well as 6%, and the appropriate screening value is used for the organic matter content of the soil. All the C4SL values published are for a soil organic matter content of 6%.
- 7.3 A table showing the screening values utilised is included in Appendix E.

Screening Values - Leachability and Groundwater

- 7.4 In order of preference, the Environmental Quality Standards (EQS) annual averages for freshwater have been used as generic screening values for these results. Where no EQS is available, the stringent UK Drinking Water Standards (DWS) have been used, and other sources in the absence of EQS and DWS, as indicated on the groundwater screening values table in Appendix E.

Soils Analysis

- 7.5 Twenty one soil samples were issued to DETS for the suite of testing (As, Cd, Cr (VI), Cr(III), Cu, Hg, Ni, Pb, Se, Zn, Total Sulphate, Water Soluble Sulphate, pH, Phenol-monohydric, Speciated PAH, Total TPH, Asbestos, and Organic Matter). The testing comprised:
- Sixteen samples of **Topsoil/Made Ground Topsoil** from TP2 to TP7, WS1 to WS9, and WS11
 - Two samples of **Made Ground**, present locally beneath the main site area, from TP5 and TP8
 - Three samples of **Made Ground Including Clinker**, underlying the northwest of the site, from TP1, TP9 and WS10
- 7.6 For each material, concentrations of determinands were compared against the relevant screening value, to identify any exceedances.

Topsoil/Made Ground Topsoil

- 7.7 The samples of topsoil/made ground topsoil tested were shown to be free from elevated concentrations of determinands, when compared to residential with home-grown produce screening values. The topsoil requires no further consideration in the risk assessment.

Made Ground – Main Site Area

- 7.8 The samples of the localised made ground tested, from TP5 and TP8, were shown to be free from elevated concentrations of determinands, when compared to residential with home-grown produce screening values. The material requires no further consideration in the risk assessment.

Made Ground Including Clinker –Northwest of the Site

- 7.9 A results summary table for determinands found to be above screening values, within the clinker containing made ground, below the northwest of the site, is given below.

Sample Reference	Depth (m)	Arsenic
TP1	0.05-0.10	6.1
TP9	0.10-0.40	70
WS10	0.10-0.30	18
Screening Value		37

All values in mg/kg unless indicated otherwise

Exceedance

- 7.10 It can be seen from the table that at TP9, concentrations of arsenic, up to 70mg/kg, were found to be elevated above the residential with home-grown produce screening value (the screening value is 37mg/kg). This exceedance will need to be considered further in the risk assessment.

Water/Leachability Analysis

- 7.11 The laboratory test certificates for leachability analysis are presented in Appendix E. The analysis which has been carried out shows the determinands have negligible leachability. Therefore, if the contamination was to be retained on site below a cover material, the contamination would be effectively immobile with respect to water/groundwater transport.

Updated Risk Assessment and Conceptual Model

- 7.12 The categorisations of risk adopted in this report are adapted from CIRIA Report C552 (Contaminated Land Risk Assessment: A Guide to Good Practice, 2001). This approach assesses the potential severity of any pollution event and the probability of the event occurring, to arrive at a risk category, for the various potential source - pathway - receptor linkages. The relevant tables used, with the definitions, are presented in Appendix F.
- 7.13 The updated source – pathway – receptor matrix is presented below, taking into account the findings of the investigation. Any pathways in italics are deemed not to be viable and the reason given.

Updated Source - Pathway - Receptor Matrix (Finished Development)

Contamination Sources	Pathways	Receptors	Severity of Consequence	Probability of Event	Risk
Made ground including Clinker, underlying the northwest of the site: - arsenic up to 70mg/kg.	- Inhalation, ingestion and dermal contact with soil and dust - Fruit and vegetable intake, with soil <i>Vapour inhalation outdoor (No significant volatility)</i> <i>Vapour inhalation indoor (No significant volatility)</i>	Humans:- - Future occupants - Maintenance workers - Adjacent residents and general public	Medium	Low Likelihood	Moderate/ Low
	<i>Migration in surface water (no leachable component)</i>	Surface water (nearest downslope is 351m to southwest. There are no abstractions within 1km)	Not Applicable	Not Applicable	Not Applicable
	<i>Migration in groundwater (no leachable component)</i>	Groundwater (Secondary A Aquifer, no abstractions within 1km)	Not Applicable	Not Applicable	Not Applicable
	Root uptake	Vegetation:- - Landscape areas - Private gardens	Medium	Low Likelihood	Moderate/ Low
	Migration	Services/Utilities:- <i>Potable water supply (no leachable component)</i>	Not Applicable	Not Applicable	Not Applicable

7.14 It can be seen from the above matrix that pathways to receptors are operative from the made ground including clinker, on the northwest of the site, and this may affect users of the finished

development, with a moderate to low risk applicable. Some form of remedial action is, therefore, considered necessary to allow residential development without excess risk.

Risk Based Assessment of Remedial Options

Made Ground Including Clinker on the Northwest of the Site - Ingestion, Dust Inhalation, Dermal Contact, Root Uptake, and Fruit and Vegetable Intake, with Soil

- 7.15 This pathway is automatically blocked where buildings or hardstanding are present above the made ground. However, where the material is retained below garden or soft/landscaped areas, provision of a cover blanket of a minimum 600mm thickness will be required, to reduce the risk to future users of the site to acceptable levels from these pathways. This assumes a worst case double dig scenario (i.e. 2 x spade depths).

Risks During Construction Period

- 7.16 It is also necessary to consider the effects of the contamination present on the site in relation to the risks to adjacent residents, construction workers and the general public during construction. This is assessed in the following matrix.

Source	Pathway	Potential risk	Risk after employing suitable Health and Safety plan.
Made ground With Clinker on the northwest	Inhalation	Moderate	Damping down of the site during dry periods and timely placement of the existing made ground below barriers should block this pathway and reduce the risk to negligible.
Made ground With Clinker on the northwest	Ingestion	Moderate	Site fencing will exclude access to members of the public. Existing made ground will be contained within the site boundary, and placed below barriers as soon as possible. Washing facilities and a clean mess room from which work boots and overalls are excluded should be provided. These measures should block this pathway and reduce the risk to negligible.
Made ground With Clinker on the northwest	Contact	Moderate	Education of workers to use adequate hygiene and PPE should block this pathway and reduce the risk to negligible.

- 7.17 Provision of all the above measures will ensure that all the identified pathways for the contamination will be blocked.

Summary of Contamination Identified and Remedial Options

- 7.18 The investigation revealed a surface cover of topsoil, and locally made ground topsoil, up to 0.45m thick, across the main site area. In the northwest of the site, a surface cover of made ground, up to 0.5m thick, including thin layers of engineering materials, and including ash and clinker, was present. Made ground was also present, locally, on the northern tip of the site (TP8), and locally in the southwest of the site (TP5), between 0.3m and 0.7m in thickness. Natural cohesive glacial deposits were present underlying the majority of the site, between 1.7m and at least 4m in thickness whilst in the southeast, the underlying Woolley Edge Rock sandstone was present, completely weathered in the upper few metres.
- 7.19 The made ground including clinker, on the formerly developed northwestern rectangle of the site, was found to contain elevated arsenic, up to 70mg/kg at TP9 (the screening value is 37mg/kg). The arsenic at TP9 was shown to have negligible leachability. No other elevated determinands were detected in any other samples across the site.
- 7.20 The contamination risk assessment, and assessment of remedial options, has indicated that, provided that the following remedial measures are adopted then the risks to the identified receptors are deemed acceptable for the proposed development of residential properties with private gardens.
- 7.20.1 Where any garden or landscape areas overlie the made ground including clinker, which is present underlying the northwest of the site, a minimum 600mm thickness of uncontaminated soils (topsoil and subsoil) should be provided. In areas of hardstanding or building footprints, the cover blanket is not required.
- 7.20.2 Any soils used within the cover blanket, whether imported or site-won, will need to be verified as suitable by inspection and testing, in accordance with guidance

supplied in the document produced by the Yorkshire and Lincolnshire Pollution Advisory Group (YALPAG): "Guidance on the Verification Requirements for Cover Systems".

7.21 A Contamination Remediation Statement is included in Appendix G.

8.0 GEOTECHNICAL TESTING

8.1 Selected samples of the natural strata were delivered to PSL in Doncaster for testing with regard to plasticity indices and moisture content. Test certificates are presented in Appendix E and a summary of the results, including Modified Plasticity Indices, is given below.

Location	Depth (m)	MC	LL	PL	PI	<425µm	I'p
TP1	2.4-2.5	17	43	21	22	94	20.7
TP3	4.0-4.1	22	44	22	22	95	20.9
TP6	1.0-1.2	21	38	20	18	97	17.5
TP7	1.0-1.2	35	67	27	40	96	38.4
WS4	0.9-1.0	34	65	26	39	97	37.8
WS8	0.5-0.7	36	79	29	50	97	48.5
WS10	1.6-1.8	29	67	26	41	95	39.0
Number of Results		7	7	7	7	7	7
Minimum		17	38	20	18	94	17.5
Maximum		36	79	29	50	97	48.5

I'p	VCP
>40%	High
20% - <40%	Medium
10% - <20%	Low

MC= Moisture Content (%) LL= Liquid Limit (%) PL= Plastic Limit (%)
 PI= Plasticity Index (%) I'p= Modified PI (%) VCP= NHBC Standard Chapter 4.2 Volume Change Potential

8.2 The plasticity test data shows the clay strata to be of intermediate to very high plasticity, in accordance with BS 5930 (1999) "Code of Practice for Site Investigations". When the percentage retained on the 425 micron BS sieve is considered, the Modified Plasticity Index, in accordance with NHBC Standard Chapter 4.2 "Building Near Trees" is a maximum of 48.5. In accordance with the Standard, this equates to High Volume Change Potential.

8.3 Geochemical testing (water soluble sulphate and pH) was undertaken on selected samples by DETS, comprising five samples of made ground, and nine samples of natural strata. In

accordance with the BRE Special Digest 1 "Concrete in aggressive ground", the characteristic values for the two materials are given below:

Characteristic Values

Material	pH	SO₄
Made Ground	6.3	41.5
Natural Strata	5.5	90

SO₄ = Sulphate content in mg/l on a 2:1 water : soil extract pH = Acidity

- 8.4 The geochemical analyses show the natural strata to have low water soluble sulphate content and slightly acidic pH. The groundwater conditions are considered to be essentially static. Therefore, the Aggressive Chemical Environment for Concrete (ACEC) class indicated for the site is AC-1s. Therefore, the use of GEN1 designated concrete will be satisfactory for unreinforced buried concrete, in accordance with BS 8500-1:2006. For any reinforced buried concrete, other design-specific mixes will apply.

9.0 COMMENTS AND CONCLUSIONS

Site Description

- 9.1 At the time of the investigation, the northwest of the site comprised a rectangular area of undeveloped land, partially covered with hardstanding (typically concrete flags), and vegetated with weeds/bushes and sporadic trees. The rest of the site comprises well-kept grass, generally used as playing fields. A series of manhole covers, slightly raised above the grassed surface, crossed the site from the north to the southwest, crossing where the northwest of the site joins the with the main site area. A low, but raised (0.5m high), mound of earth was present, running just inside the eastern site boundary.
- 9.2 The site slopes down gently to the northwest. There is one large tree on the northwest of the site, and occasional sporadic trees just outside the boundaries elsewhere.

Site History

- 9.3 Ordnance Survey archive maps show that most of the site has remained undeveloped, with the exception of the northwestern rectangular portion which, formed landscaping and hardstanding to part of a Junior School complex from 1959 until sometime after 2000.

Geology

- 9.4 Geological maps show the site to be covered by diamicton (cohesive glacial deposit) of Mid Pleistocene age. The remaining areas of the site show no drift cover. The bedrock across the site comprises sandstone of the Wooley Edge Rock Formation. A fault is indicated just beyond (approximately 3m outside) the northwestern boundary of the site.

Coal Mining and Coal Recovery

- 9.5 The ARP Stage 1 Desk Study Report identified the possibility of workings within the Meltonfield Coal and the Two Foot Coal to be present at shallow depth beneath the site (the Meltonfield Coal being the shallowest). Abandonment Plans have been obtained subsequently from The Coal Authority, and assessed. The plans indicate that the strata dip is 1 in 18 (three degrees) towards the northeast, in the vicinity of the site. Interpolation of the levels provided on the plans indicates the depth to the Meltonfield Coal (up to 0.9m thick) should range from around 22m on the north of the site to 11m on the south, whilst the Two Foot Coal (up to 0.63m thick) is present 9m below the Meltonfield Coal, at depths of around 31m below the north of the site and 20m below the south of the site.
- 9.6 It is, therefore, concluded from the plans that the majority of the site will have sufficient cover to any workings present, with the possible exception of the southern end of the site, where workings in the Meltonfield Coal may be sufficiently shallow to pose a risk to ground stability. It would, therefore, be prudent to confirm the depth of cover to the workings on the south of the site by means of a rotary borehole investigation.
- 9.7 There is a risk that unrecorded mine entries may be present on the site. If any suspect features are identified during site preparation or development works, these should be inspected by a Geotechnical Engineer.
- 9.8 There will be no arisings of coal during proposed development works, and it will not be possible to win any coal from the by open excavation before development.

Environmental Data

- 9.9 The strata beneath the site are classed as a Secondary A Aquifer. There are no groundwater abstractions within 1km of the site.

- 9.10 The nearest downslope surface water is an unnamed stream or open drain 351m to the southwest. There are no surface water abstractions within 1km of the site.
- 9.11 The site is not at risk from river flooding. The risks of flooding from other causes such as adverse topography or insufficient surface water drainage, are not considered here, and a separate specialist Flood Risk and Drainage Report should be commissioned if such risk needs to be quantified.
- 9.12 At least part of the site is within an area where radon protective measures are stated to be necessary for new dwellings on the site. Unless a site-specific radon report is obtained, which indicates otherwise, it would be prudent to install basic protection to all proposed properties on the site. This is normally achieved by incorporating a radon barrier within a solid floor system, and extending the barrier through the cavity wall.
- 9.13 There are no landfills within 500m of the site. Therefore, the risk from landfill gases is negligible. However, there may be a potential risk of harmful gases from any shallow coal workings on the south of the site. If coal seams/workings are encountered at shallow depth then gas monitoring wells should be installed, and monitored on six occasions.

Ground Conditions Encountered

- 9.14 The ground investigation revealed a surface cover of topsoil, and locally made ground topsoil, up to 0.45m thick, across the main site area. In the northwest of the site, a surface cover of made ground, up to 0.5m thick, including thin layers of engineering materials, and including ash and clinker, was present. Made ground was also present, locally, on the northern tip of the site (TP8), and locally in the southwest of the site (TP5), between 0.3m and 0.7m in thickness. Natural cohesive glacial deposits were present underlying the majority of the site, between 1.7m and at least 4m in thickness whilst in the southeast, the underlying Woolley Edge Rock sandstone was present, completely weathered in the upper few metres.

- 9.15 The trial pits and boreholes generally remained stable for the short period of exposure, with the exception of the trial pits at TP8 and TP9, where slight instability of the pit sides was noted from the surface to 1m and 0.4m depth, respectively, associated with the made ground. No groundwater entries were recorded during the excavations, and in boreholes the strata appeared dry.

Contamination Assessment

- 9.16 The contamination testing revealed the made ground including clinker, on the formerly developed northwestern rectangle of the site, was found to contain elevated arsenic, up to 70mg/kg at TP9 (the screening value is 37mg/kg). The arsenic at TP9 was shown to have negligible leachability.
- 9.17 The contamination risk assessment confirmed that, provided remedial measures are implemented, comprising the provision of a 600mm thick cover blanket of clean soils where the material is present below any proposed garden or landscaped areas, the materials present on the site are compatible with the proposed residential development. A Contamination Remediation Statement, which includes further detail on the remediation measures for the site, is presented in Appendix G

Foundations

- 9.18 The natural strata beneath the site are considered suitable for support of foundations using strip/trench fill foundations. An allowable bearing pressure of 150kN/m² is considered applicable on the cohesive and granular residual soils (completely weathered sandstone), exposed on the south of the site (TP2, TP4, TP5, WS1, WS2, WS8 and WS9), with an increased allowable bearing pressure of 300kN/m² considered applicable for the underlying intact sandstone.

- 9.19 The glacial clays, covering the rest of the site, to the north and northwest, indicated a minimum SPT “N” value of 8 within the windowless sample boreholes (indicating a potential allowable bearing pressure as low as 80kN/m²), whilst the hand shear vane readings, including positions nearby to the low “N” value locations, showed values of at least 70kN/m² (indicating an allowable bearing pressure of at least 140kN/m²). In this case, the shear vane readings are considered to be more likely to be representative of the clay strength, as they comprise a direct measurement by the Engineer. On this basis, a conservative allowable bearing pressure of 100kN/m² is proposed for the glacial clays.
- 9.20 The above comments are subject to the findings of a rotary borehole investigation to verify the depth of potential shallow workings beneath the site. The area at potential risk is likely to be the south of the site. If shallow workings are present, these may need to be treated by means of injection of grout through a grid of boreholes, beneath proposed roads and buildings. Following any treatment (if required), the foundations would need to be 300mm thick and reinforced using two layers of B503 mesh – one near the bottom and one near the top. If any bell pits are found to be present, alternative founding solutions, such as piles, may be required.
- 9.21 Foundations are recommended to be reinforced within 20m of the fault close to the northwest of the site, using two layers of B503 mesh (one near the bottom and one near the top). This is likely to only impact up to three plots, based on the proposed site layout.
- 9.22 The clays were shown to be up to High Volume Change Potential. Therefore, in accordance with NHBC Standard Chapter 4.2 "Building Near trees", in the absence of trees, a minimum foundation depth of 1.0m below existing or proposed ground level is applicable, whichever is the lower. However, in the presence of any proposed, existing or removed trees, the foundation may need to be deepened, depending on the type of tree and its distance from the face of the foundation. If not already available, a tree survey may be required to enable a foundation schedule to be prepared.

- 9.23 On the south of the site, where the glacial clays are absent, the founding strata may be non-plastic in localised areas, and, therefore, the minimum foundation depths given in NHBC Standard Chapter 4.2 "Building Near Trees" do not apply. However, to protect against fines washing subsidence in the event of a burst water supply pipe, it is recommended that a foundation depth of 0.9m is adopted in proximity to any such pipes.
- 9.24 The foundation should be taken below the depth of any existing foundations or obstructions, onto natural ground. The whole plan area of the foundation should be placed on similar natural material. Foundations should be reinforced where it is necessary to transition from suitable granular to suitable cohesive strata within a proposed building footprint.
- 9.25 If bedrock is encountered on part of a foundation excavation, the rest of the plot should be deepened to ensure founding on similar material. However, if rock is not encountered by 2.5m depth on the remainder of the plot, then the Engineer should be contacted for further advice.

Excavations

- 9.26 It is likely that excavations into the natural strata will remain stable in the short term, requiring minimal trench support, in accordance with the prevailing statutory guidance. However, instability may be anticipated within the localised made ground present on the site.
- 9.27 Groundwater seepages are unlikely to occur within typical excavation depths. Any such encounters should be controllable by pumping from an artificial sump.
- 9.28 Excavations should be readily achieved using conventional hydraulic plant. However, excavations into intact bedrock are likely to require a hydraulic breaker. A breaker may also be required for any buried foundations and structures (only likely to be present on the northwestern rectangular area, although none were encountered during the investigation).

Chemical Precautions

- 9.29 The Aggressive Chemical Environment for Concrete (ACEC) class is AC-1s for the site. Therefore, the use of GEN1 designated concrete will be satisfactory for unreinforced buried concrete, in accordance with BS 8500-1:2006. For any reinforced buried concrete, other design-specific mixes will apply.

Road Pavement Construction

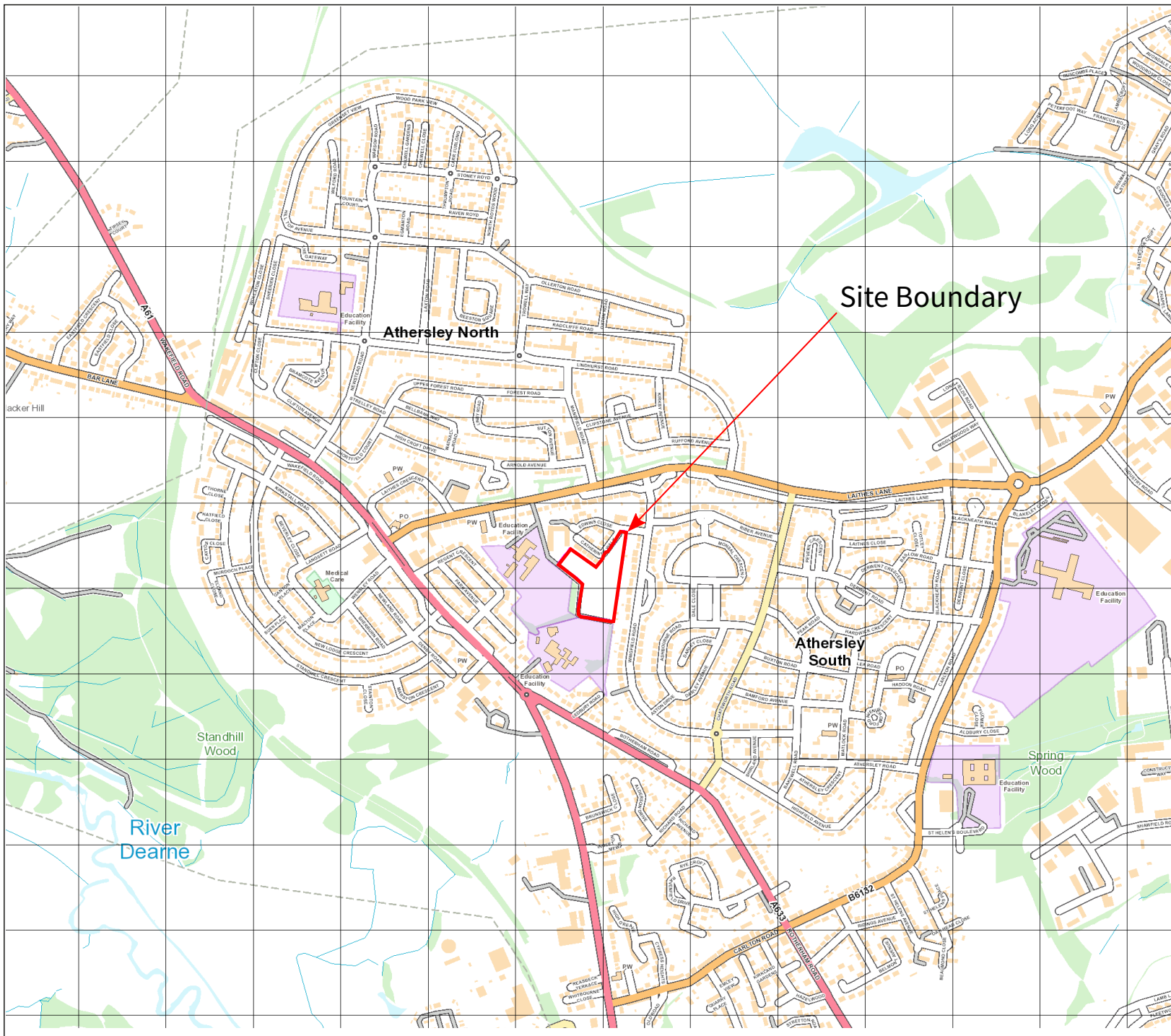
- 9.30 For any areas of road pavement, including parking areas, the formation will be natural clays on the vast majority of the site, and locally on the south of the site, granular subsoils. Below any obvious soft spots, and at equilibrium moisture content, a design California Bearing Ratio (CBR) value of 2% is considered applicable on the clays. On granular material, a design CBR value of at least 20% is likely to be applicable. Formation of roads on any existing made ground will not be acceptable.

Soakaways

- 9.31 In the light of percolation testing carried out as part of the investigation, the disposal of surface water using soakaways is not considered to be feasible on the site. A drainage feasibility design should be carried out to determine the appropriate solution.

APPENDIX A

SITE LOCATION PLAN, SITE PLAN AND PROPOSED LAYOUT



0m 400m

Approximate Scale



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Project

LAND AT CATHERINE'S WALK
BARNLEY

Client

LEEDS AND YORKSHIRE
HOUSING ASSOCIATION

Title

SITE LOCATION PLAN

Date

NOVEMBER 2017

Drawn

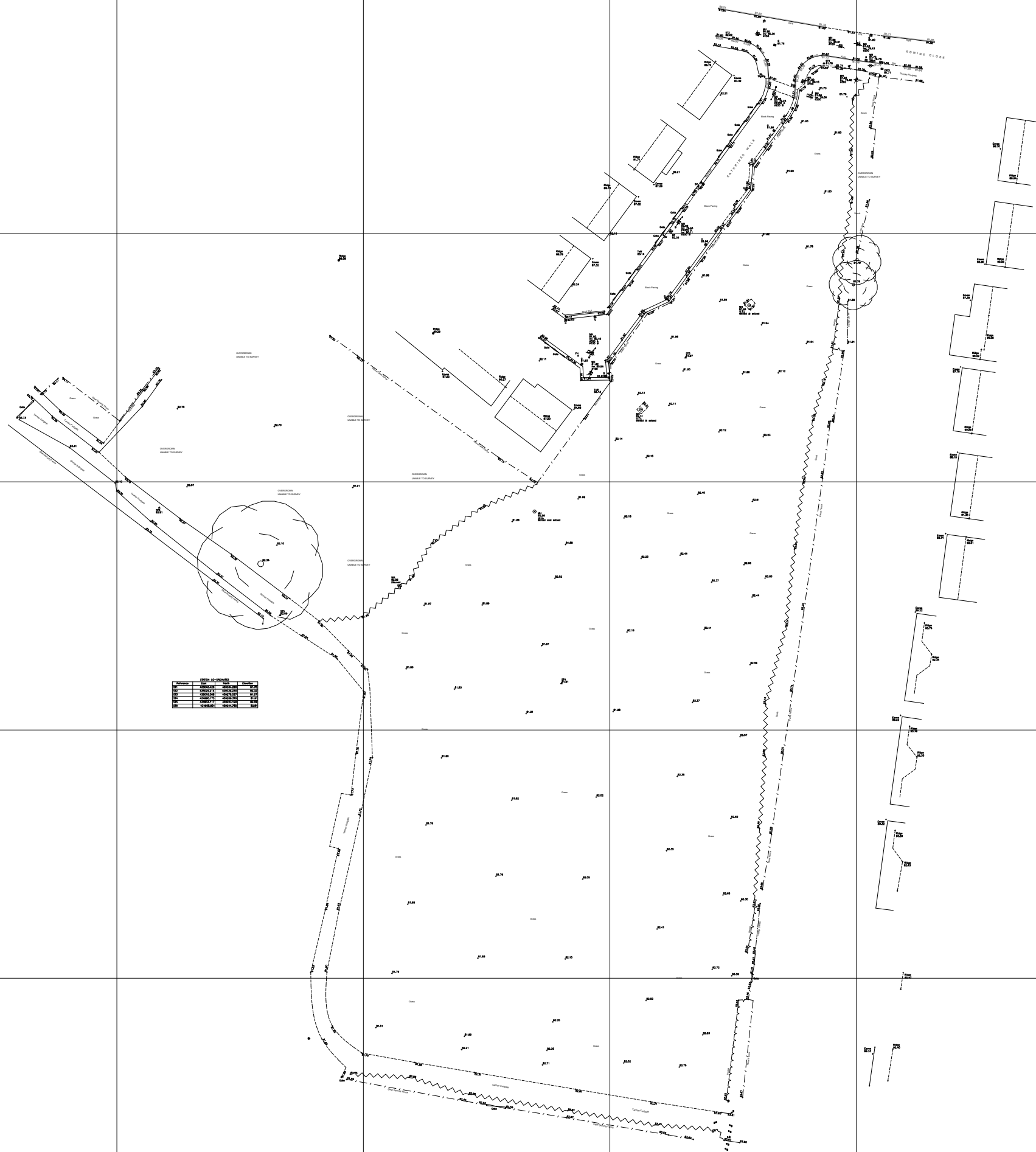
@ A4

Scale

AS SHOWN

Job No.

LYH/01



0m 50m
Approximate Scale



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Project
LAND AT CATHERINE'S WALK
BARNSLEY

Client
LEEDS AND YORKSHIRE
HOUSING ASSOCIATION

Title
SITE PLAN

Date
NOVEMBER 2017

Drawn @ A3	Scale AS SHOWN
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Job No.
LYH/01