CAPITA

Killingworth Moor

Phase 1 Geo-Environmental Desk Study

July 2015

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Quality Management

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Contents

1. Introduction 1
1.1 Background 1
1.2 Proposed Development 1
1.3 Objective and Scope of Work 1
2. Site Characteristics 2
2.1 Site Location 2
2.2 Site Description 2
2.3 Surrounding Land-use 3
3. Environmental Setting 4
3.1 Geology 4
3.2 Coal Mining, Mineral Extraction and Subsidence 6
3.3 Hydrogeology 7
3.4 Hydrology 7
3.5 Potential Flood Risks 8
3.6 Landfill and Waste Management Activity 8
3.7 Industrial Land Use Information 9
3.8 Environmental Permits, Incidents and Registers 9
3.9 Ecology 10
4. Site History 11
4.1 Historical Map Review 11
4.2 Summary 13
5. Conceptual Site Model 14
5.1 Introduction 14
5.2 Contamination Sources 14
5.3 Pathways 15
5.4 Receptors 16
5.5 Preliminary Risk Assessment 17
5.6 Discussion 18
6. Conclusion & Recommendations 20
6.1 Overview 20
6.2 Geo-Environmental Risks 20
6.3 Geotechnical Hazards & Coal Mining Related Risks 20
6.4 Preliminary Geotechnical Appraisal 21
6.5 Recommendations 22
7. References 24

Appendices

Appendix A Drawings
Appendix B Photographs
Appendix C GroundSure Report
Appendix D BGS Borehole Records
Appendix E Terraconsult Borehole Logs
Appendix F Coal Authority Report & Mine Abandonment Plans

1. Introduction

1.1 Background

1.1.1 Capita Property & Infrastructure Ltd ("Capita") was commissioned by North Tyneside Council to undertake a Phase I Geo-Environmental Desk Study for the potential residential development of the Killingworth Moor site in North Tyneside.

1.1.2 A site location and existing site layout plan is presented on drawing KM-01 in Appendix A.

1.2 Proposed Development

1.2.1 Detailed development plans have not yet been made available however it is understood that Killingworth Moor is one of two sites which have been identified in the 2015 Draft Local Plan as together having the potential to accommodate up to 4,500 required new homes.

1.2.2 It can be assumed that the development would include the construction of mixed style residential housing, with associated gardens, landscaping, driveways and access roads.

1.3 Objective and Scope of Work

1.3.1 The objective of this assessment was to collate and review the available geo-environmental information to determine potential constraints on the development proposals such as ground contamination risks and geotechnical hazards.

1.3.2 To achieve the objective the following scope of work was defined and undertaken:

- A site visit to establish the site setting and visible ground conditions (photographs from a site reconnaissance are presented in Appendix B);
- Review of published and readily available information concerning the site:
  - Recent Ordnance Survey (OS) Map;
  - British Geological Survey (BGS) Published Maps;
  - A site-specific GroundSure Report (Appendix C);
  - OS Historical Map Archive (included in the GroundSure Report – Appendix C);
  - BGS GeoIndex Service (borehole logs reproduced in Appendix D);
  - Previous investigation data (Factual data included in Appendix E); and
  - A site-specific Coal Authority Report and available Mine Abandonment Plans (Appendix F);
- Develop a preliminary Conceptual Site Model (CSM) that relates the anticipated ground conditions at the site to the proposed development.
- Establish areas of potential concern based on identified risks and/or potential risks and produce Geotechnical Hazards & Geo-Environmental Constraints Plans.
- Identify any actions (e.g. intrusive site investigation) required to reduce risks and/or minimise any uncertainties.

2. Site Characteristics

2.1 Site Location

2.1.1 The subject site occupies an area of land approximately 6km northeast of Newcastle City Centre. The site lies southeast of Killingworth, north of Palmersville, west of Holystone and south of the A19.

2.1.2 The site is bounded by the A19 to the north, the metroline to the southeast, a stream to the south, field boundaries and B1317 along the western perimeter and the dismantled Seatonburn Wagonway track to the northwest.

2.1.3 The approximate centre of the subject site is located at Ordnance Survey National Grid Reference 429345, 571000. An indicative postcode for the site is NE27 0DJ.

2.1.4 A site location and existing site layout plan is presented on drawing KM-01 in Appendix A.

2.2 Site Description

2.2.1 With reference to drawing KM-01, the subject site is an irregular shape in plan; covering an area of approximately 192.7ha.

2.2.2 The majority of the site area is formed of a number of fields (defined by various discontinuous hedgerows, field drains and tracks), interspersed with mature trees.

2.2.3 A number of above ground structures/developed parcels are currently present on the site, including:

- Holystone Farm located in the eastern corner of the site;
- High Farm located in the north-western corner of the site;
- A poultry farm and farm shop located in the north-western corner of the site; and
- Electricity pylons running in a southeast to northwest orientation through the centre of the site.
- A slightly mounded area in the southeast of the site which has been used as a landfill.

2.2.4 A former depot is also currently being demolished in the southwest of the site. A number of large stockpiles of demolition material are present in the area.

2.2.5 In the north of the site the topography is ostensibly level, with only minor undulations noted. Towards the south the site appears to slope gently to the south.

2.2.6 Access can be gained to the site at various locations around the perimeter. Two tracks run northwest-southeast across the length of the site in the north. Access can also be gained via the three farms located onsite and the entrance to the former depot facilities in the southwest off the B1317.

2.2.7 Photographs of the site taken during the site walkover survey are presented in Appendix B.

2.3 Surrounding Land-use

2.3.1 To the **NORTH**, the subject site is bounded by the A19, beyond which lie further open fields and residential developments.

2.3.2 To the **SOUTHEAST**, the subject site is bounded by the metro line, beyond which lies the community of Holystone with a school, residential developments and Benton Square Industrial Estate.

2.3.3 To the **SOUTH**, the subject site is bounded by a stream, beyond which lies the town of Palmersville with residential developments and a sports ground.

2.3.4 To the **WEST,** the subject site is bounded by fields and the B1317, beyond which lies residential housing.

2.3.5 To the **NORTHWEST**, the subject site is bounded by the dismantled Seatonburn Wagonway track, beyond which lies further residential housing.

3. Environmental Setting

3.1 Geology

3.1.1 The regional geological information pertaining to the site was gained from a review of the BGS Digital Geological Map of Great Britain (DiGMapGB-50; available as a Web Map Service) and a 1:10 000 Series Solid and Drift Geology Map (NZ 27 SE). Additional reference has been made to a site-specific GroundSure Report (reproduced within Appendix C) and the findings of a TerraConsult Site Investigation Report (relevant *factual* extracts reproduced in Appendix E).

3.1.2 The majority of the subject site is indicated to be directly underlain by Drift Deposits of (Devensian) Glacial Till. Alluvium may be present along the course of the stream forming the southern boundary of the site (shown on drawing KM-02).

3.1.3 The bedrock geology (of Carboniferous age) appears to have been heavily affected by faulting across the site area. The three major faults influencing the geology are shown in Section 1.3 of the GroundSure Geoinsight Report in Appendix C and reproduced on drawing KM-02 from the 1:10 000 geological mapping. The “Burradon Fault” and another unlabelled fault (in the far north of the site) cross the site in a northwest-southeast orientation with the downthrown sides to the northeast. A third major fault, “the Ninety Fathom Fault”, crosses the southern portion of the site in a northeast-southwest orientation with the downthrown side to the northwest.

3.1.4 The bedrock geology can be described in the fault blocks present across the site. The majority of the site lies within the three aforementioned faults; the Solid geology of which comprises the Pennine Middle Coal Measures (PMCM) Formation which is indicated to comprise undifferentiated strata of mudstone, siltstone, sandstone and subordinate coal seams. In the central portion of the fault block prominent unnamed sandstone units are indicated to be present.

3.1.5 A number of coal seams are indicated to subcrop (beneath the Drift) across the site in a southwest-northeast trend throughout this geological sequence. The PMCM strata within this fault block are indicated to dip to the southeast. The generalized vertical geological section provided on the BGS mapping suggests the coal seams may range in thickness from 0.25m up to 1.5m; with the Bottom Hebburn Fell and the Ryhope Five-Quarter indicated to be the thickest reaching up to 1.37 and 1.5m respectively.

3.1.6 The south-eastern area of the site lies on the upthrown side of the Ninety Fathom Fault. The bedrock geology here is indicated to comprise an alternating sequence of undifferentiated PMCM and sandstone of the PMCM. A number of coal seams are again indicated to subcrop across this area in a northwest-southeast trend throughout this sequence. The PMCM strata within this fault block are indicated to dip to the southwest.

3.1.7 Additionally a Microgabbro dyke of the Mull Dyke Swarm is present in the southeast of the site in an east-west orientation.

3.1.8 TerraConsult have produced a Site Investigation Report for the residential development at the proposed Palmersville extension, located immediately south of the site. The full report reference is as follows:

- Phase 1 & 2 Site Investigation Report, Palmersville Extnesion, Newcastle Upon Tyne. TerraConsult Ltd, Ref: 1664/06 dated August 2013.

3.1.9 The intrusive investigation comprised a total of 6no trial pits, 4no dynamic window sample boreholes and 4no cable percussive boreholes. The TerraConsult site area and the current subject site overlap and as such 4no exploratory holes fall within the subject site including 2no trial pits (TP5-6), 1no window sample borehole (WS4) and 1no cable percussive borehole (BH4).

3.1.10 The TerraConsult exploratory hole logs are presented in Appendix E. In general the ground conditions encountered comprised (in order of increasing depth):

- **Made Ground** deposits to depths of between 0.6 and 1.7mbgl, comprised of firm sandy gravelly clay with gravel of sandstone and brick and rare fragments of coal.
- **Glacial Till** to depths of between 2.9 and 4.8mbgl comprised of firm to stiff slightly sandy slightly gravelly clay with occasional cobbles of sandstone.
- **Sandstone** proven to a depth of 5.45mbgl (base not seen) recovered as fine to coarse gravel.

3.1.11 Additional ground condition information pertaining to the site and surrounding area (and indicative of deeper ground conditions on site) has been obtained from a search of the BGS GeoIndex service. The following exploratory logs have been identified:

- NZ27SE/58. Located in the southeast of the site, the record is for a borehole advanced to a depth of 134.5m in 1760. Black soil overlying stony clay is recorded to a depth of 6.1mbgl. Alternating sandstone and shale is then recorded to the base. The Ryhope Five-Quarter coal seam is recorded at 25.1mbgl and is indicated to be 0.15m thick. The Ryhope Little coal seam is recorded at 43.1mbgl and is indicated to be 1.0m thick.
- NZ37SW/86S. Located along the north-eastern border of the site, the record is for a cable percussion borehole with rotary follow on, advanced in 1966 to a depth of 32.6m. Topsoil is recorded overlying firm to stiff sandy clay to a depth of 2.1mbgl. Stiff boulder clay was then recorded to 15.2mbgl. This is underlain by sandstone with siltstone bands and thin coal veins to 29.6m and then siltstone to 32.6m (bas not proven). A void is highlighted as a possible coal working between 25.4 and 26.5mbgl.
- NZ27SE/50. Located approximately 250m east of the northern site boundary, the record is for a borehole advanced to a depth of 267m in 1864. Clay drift is recorded to a depth of 4.1mbgl and is underlain by alternating sandstone and shale. The Ryhope Five-Quarter and the Ryhope Little coal seams are recorded at 28.3mbgl and 59.5mbgl respectively and are indicated to be 0.38m thick and 0.83m thick. The High Main coal seam is recorded at 140.2m and is indicated to comprise 5.6m of coal.

3.1.12 Given the size of the subject site, the information provided in these boreholes can only provide an indication of the likely geology in the area. The borehole logs are reproduced in Appendix D.

3.1.13 The site is in a lower probability radon area, as less than 1% of homes are above the action level. No radon protective measures are therefore considered necessary for new structures at this time.

3.2 Coal Mining, Mineral Extraction and Subsidence

3.2.1 The GroundSure report has identified the subject site as being within an area which may be affected by coal mining activity.

3.2.2 The Coal Authority (CA) report presented in Appendix F states that the subject site is in the likely zone of influence from workings of 9 seams of coal at shallow to 440m depth, and last worked in 1971.

3.2.3 The site is not in an area likely to be affected at the surface by present or future underground coal workings; however reserves of coal exist in the local area which could be worked at some time in the future.

3.2.4 The CA report also states that there are 14no known mine entries within, or within 20 metres of the site boundary. The locations of these are shown in the CA plan of the area. 10no of these mine entries may have been partially or fully removed by opencast mining methods; these are clustered in the northern eastern corner of the site. There are no treatment details for the remaining entries.

3.2.5 The CA report states that the subject site is within the bounds of a past opencast coal mining site. The site is not in an area from which coal is currently being removed by opencast methods or likely to be affected by future opencast coal mining.

3.2.6 Finally the CA report states that there are no records of mine gas emissions within the site boundary.

3.2.7 According to the CA interactive map viewer, the northeast of the site is within an area of recorded past shallow coal mine workings and past surface mining. The High Main and Moorland coal seams sub crop beneath the Glacial Till in this area. The 1:10 000 geological map of the area shows a number of old pits within the sandstone and states the High Main seam was proven by opencast boring.

3.2.8 A Geotechnical Hazards Constraints Plan is presented on drawing KM-02 in Appendix A. This has been produced using information provided on 1:10 000 and 1:50 000 geological maps, a Coal Authority report, mine abandonment plans (obtained via a visit to the CA records office in Mansfield), the CA Interactive Map Viewer and historical mapping.

3.2.9 Pillar and stall workings of the High Main coal seam are present across the southeast, southwest, and the north-western tip of the site at known depths of between 60-149mbgl. The Moorland coal seam was worked in the southwest of the site at a depth of around 100mbgl. In the east of the site the Yard seam was worked at depths of around 80-120mbgl.

3.2.10 Given the depth of these workings any associated ground movement should have ceased by now; the site is therefore considered to be stable with respect to any subsidence arising due to the recorded deep mining and the primary concern relates to any historic shallow coal workings at or close to the surface.

3.2.11 A number of coal seams subcrop near to the surface across the site beneath the superficial Glacial Till (assumed to be around 5m thick) and therefore there is the potential for unrecorded shallow workings to be present. Furthermore mapping indicates a number of sandstone quarries located around the site.

3.2.12 Information in the GroundSure Report indicates that there is:

- "Negligible" risk from:
  - Soluble Rocks stability hazards; and
  - Compressible Ground Stability Hazards.
- "Very Low" risk from:
  - Landslide Ground Stability Hazards;
  - Collapsible Ground hazards; and
  - Running sand hazards.
- "Low" risk from:
  - Shrinking or swelling clay ground stability hazards.

3.3 Hydrogeology

3.3.1 According to information presented in the GroundSure Report, the underlying superficial Glacial Till deposits are classified as "Unproductive Strata". These drift deposits with low permeability that have negligible significance for water supply or river base flow.

3.3.2 The majority of the Bedrock is classified as a Secondary A Aquifer. These are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

3.3.3 The dyke in the south-eastern corner of the site is classified as a Secondary B Aquifer. These are lower permeability layers which may store or yield limited amounts of groundwater due to localised features.

3.3.4 2no groundwater abstractions are located within 1km; these relate to heat pumps 887m southeast and 901m south of the site. The site does not lie within a Source Protection Zone.

3.4 Hydrology

3.4.1 The nearest major surface watercourse/feature to the subject site, as shown on OS mapping, is a drain shown as a primary river which forms much of the southern perimeter of the site. 2no further tertiary rivers (Brierdene Burn and an unnamed watercourse) are shown to encroach onto the north-eastern site area. It is anticipated that any shallow groundwater in the southern site area would flow in a south westerly direction towards Ouse Burn and ultimately the River Tyne. In the northern site area it is assumed that shallow groundwater may flow to the northeast towards Seaton Burn.

3.4.2 In consideration of the local topography and the absence of widespread hardstanding, a degree of infiltration of rainfall is likely with any residual surface water run-off from the site entering the local land drainage system.

3.5 Potential Flood Risks

3.5.1 The majority of the site is situated in an area considered to be at a very low risk of coast or river flooding. A very low risk rating indicates that the site has a less than 1 in 1000 chance of flooding in any given year.

3.5.2 The nearest major surface water feature is a drain immediately south of the site, which has an area recorded as having a medium flood risk rating.

3.5.3 Along the southwest and south-central boundary of the site is an area classified as a Zone 3 floodplain corresponding to a greater than 1 in 100 chance of flooding in any given year.

3.5.4 The site does not benefit from any form of flood defences or flood storage.

3.5.5 The site however is considered to be within an area which is susceptible to groundwater flooding, which primarily relates to natural superficial deposits beneath the subject site.

3.6 Landfill and Waste Management Activity

3.6.1 According to the GroundSure Report there is 1no active EA landfill located onsite. The record relates to a closed landfill located to the north of Great Lime Road, Palmersville which was licensed to accept household, commercial and industrial waste.

3.6.2 There is 1no historic EA landfill located immediately south of the south-eastern corner of the subject site. This record relates to a site called Benton Square, off Great Lime Road in Palmerville which was last recorded in 1968 and was licensed to accept industrial and household waste.

3.6.3 The TerraConsult report provides an historical summary of these two landfills as they are located either side of the parcel of land of interest in their investigation. The historic landfill was described as an old tip used for the deposition of household waste during the 1950's and 60's. The active landfill was developed in 2002 by excavating a borrow pit, lining it with engineered clay and using it to accept the waste formerly held at the historic landfill. The waste was described as comprising ash, glass, demolition materials and clay. The TerraConsult report reviewed a large body of gas monitoring data for the engineered containment landfill located on the subject site. Monitoring recorded high concentrations of methane and carbon dioxide, however the amount/volume of gas being produced was said to be low. Concentrations of methane recorded in 2012 show maximum values of between 16.2% and 93.6% v/v. Concentrations of carbon dioxide show maximum values between 2.2% and 7.2% v/v.

3.6.4 1no further historic EA landfill is located within a 250m search buffer of the subject site. This record relates to a landfill in Burradon approximately 173m west of the north-western corner of the site which was licensed to accept inert waste. The license was surrendered in 2004.

3.6.5 5no records of EA licensed waste sites are found within 500m of the site. 1no entry is located within the subject site and this relates to the active landfill identified above. The nearest offsite entries relate to waste transfer stations located at Wesley Way approximately 50 and 63m southeast of the subject site. Further entries relate to special waste transfer stations approximately 138m and 312m southeast of the site.

3.7 Industrial Land Use Information

3.7.1 Current Land Use data presented in the GroundSure Report indicates that there are 14no "potentially contaminative industrial sites" on-site and a further 44no located within a 250m search buffer of the site.

3.7.2 The majority of on-site records relate to electrical features such as electricity poles and pylons trending in a linear path from the southeast to the northwest of the site. Further on-site records include a poultry farm and telecommunication mast in the northwest of the site and tanks in the southwest of the site.

3.7.3 The surrounding land-use generally relates to commercial or light industrial processes and services including:

- Electrical features – 8no electricity sub stations, 2no electricity poles and 2no pylons.
- Manufacture of industrial and consumer products.
- Vehicle repair, testing, servicing and sales.
- Petrol and fuel stations – 1no located approximately 55m south.
- Extractive Industries – disused mine shaft located 62m southwest.
- Gas Features – 1no gas station.
- Industrial infrastructure – 7no tanks.

3.8 Environmental Permits, Incidents and Registers

3.8.1 There is 1no Part A(1) and IPPC Authorised Activities recorded within a 500m radius of the site. This relates to waste landfilling in the southeast of the site.

3.8.2 7no entries of Part A(2) and Part B Activities are recorded within 500m. The nearest entry is 54m south of the site at Holystone Service Station for unloading of petrol into storage.

3.8.3 10no entries of Category 3 or 4 Radioactive Substances Authorisations are recorded approximately 171m southeast of the site at Procter and Gamble Technical Centres Ltd, regarding the keeping and use of radioactive materials, and the disposal of radioactive waste.

3.8.4 5no discharge consents are located within 500m of the site. 3no of these are located onsite, in the southeast for site drainage and in the northeast for mineral working discharges. The other 2no entries relate to sewerage discharges, at locations 14m southwest and 195m west of the site.

3.8.5 National Incidents Recording System List 2 has highlighted 30no incidents within 250m of the study site. The nearest of these relate to crude sewerage 3m and 6m southwest of the site causing a Category 3 (Minor) and Category 2 (Significant) impact to water. Many of the other incidents occurred between 40 and 200m southeast of the subject site throughout the Benton Square Industrial Estate. These included numerous minor and significant impacts to air from landfill odours, smoke, dust and other atmospheric pollutants. The nearest pollution incident impacting the land occurred at a location 23m southeast of the site and involved construction and demolition materials, vegetable cuttings and batteries resulting in a Category 3 (Minor) impact to land.

3.9 Ecology

3.9.1 With respect to the specific definition of Contaminated Land, the site does not lie within 1km of one of the following *sensitive* sites: Site of Special Scientific Interest (SSSI), National Nature Reserve, Marine Nature Reserve, Ramsar Site, Special Area of Conservation, Special Protection Area or World Heritage Site. However the North East Greenbelt is located approximately 10m northwest of the site.

4. Site History

4.1 Historical Map Review

4.1.1 The following summary of the site's history is based on a review of historical 1:10000, 1:10560, 1:2500, 1:1250 and 1:500 scale Ordnance Survey maps as presented in the GroundSure Report (presented in Appendix C), as well as internet sources and previous investigative reports.

4.1.2 With reference to the available historical maps, the subject site has largely comprised fields separated by hedgerows and several public footpaths from 1858 (the earliest available map) to the present day.

4.1.3 Noteworthy features of the subject site area are as follows:

- Holystone Farm located to the east of the site is mapped from 1858 to the present day. The farm includes a cottage and a number of associated buildings. A small pond is mapped to the northeast of the farm between 1858 and 1966. Further ponds are shown from 1895 to 1938 to the south of the farm along the southeast boundary of the site.
- Seatonburn Wagonway is shown running in a slight southeast-northwest direction in the northern site area. The wagonway is shown on the earliest map from 1858 and is labelled as 'old wagonway' by 1950 and 'dismantled mineral railway' by1966. The line of the former wagonway is now labelled as a track. A well and a signal post were shown along the wagonway to the northwest of Holystone Farm between 1858 and 1897.
- A road is shown in a north-south direction in the northwest of the site. The road was present in 1858 and remains today as the B1317.
- High Farm located in the north-western corner of the site is mapped from 1858 to the present day. The farm includes a number of buildings and a small pond is shown between 1858 and 1928 roughly in the centre of the farm complex. The access road originally led to the west, however with the development of the A19 was re-planned to link with the A1056 to the northwest.
- Hillhead Engine is located in the northwest corner of the site along the line of the former Seatonburn Wagonway. The 'engine' comprises a number of small buildings and is mapped from 1858 to 1938, however it is labelled as disused by 1913.
- A poultry farm appears in the 1974 maps, in the northwest corner of the site adjacent to the former Seatonburn Wagonway. This farm is still present today.
- A depot located in the southwest corner of the site off the corner of B1317 is mapped from 1950 to the present day. A couple of tanks are shown in the corners of the main depot area.
- Highfield well is shown in the southwest of the site, just southwest of the above mentioned depot, in map extracts from 1858 to the present day.
- A large pond was mapped between 1950 and 1974 in the central southern area of the site, either side of the current field drain which forms the southern boundary of much of the site. This area is subsequently labelled as a marsh until 1993.
- Electricity posts are shown on mapping between 1950 and 1984. The linear path of the posts appears to zigzag in a roughly northwest-southeast direction. Although the posts disappear from mapping around 1984, they can still be seen on aerial images of the site.
- Electricity pylons are shown on mapping from 1960. These trend northwest-south east through the centre of the site.

- Although not obvious from the historical maps, the previous TerraConsult report provides details of an engineered containment landfill located in the south-eastern corner of the subject site.

4.1.4 The development of the surrounding area has undergone more extensive change throughout the mapped records; details of which are outlined in the following table:

Map Dates	Approximate Location	Description/comments
Mid 19th Century	Surrounding 250m	Land-use surrounding the site is predominantly agricultural with some coal mining and quarrying activity.
1858-c1950	0-150m West	Killingworth Colliery. By 1895 the colliery is labelled as Killingworth Old Pit. Both an old coal shaft and old air shaft are depicted on the 1919 map. After 1950 the coal shaft is labelled as disused. An 'old wagonway' is also shown along the western boundary of the site.
1858-c1913	350-450m South West	Closinghill Quarry. Disused by 1913 and infilled and developed by 2002.
1858-c1968	300-400m South East	Prosperous Pit with two old coal shafts located around Benton Square.
1858-c1938	20m South	Ridge Pit – old coal pit.
c1895-Present	Immediately East	North East Railway. Later labelled Metro.
c1895-c1966	20m South East	Old coal shaft. Labelled as disused shaft by 1966.
c1895-c1992	250m North	Old coal shaft located to the rear of West Farm. Later labelled as disused shaft.
c1895-c1950	10 & 20m West	Quarries. Two quarries located just north of Killingworth Colliery and by East House.
c1913-c1950	100m South West	Tank.
c1920-c1984	250m North	Burradon Holywell Wagonway. Dismantled and relabelled as a track by 1984.
c1956-Present	50-100m South East	The residential area of Holystone appears with houses, a school and a public house all depicted.
c1966-c1984	50m South	Piggery.
c1969-Present	50-300m South East	Benton Square Industrial Estate. Warehouses, works, factories depots and a builder's yard are all mapped.
c1974-Present	Immediately North	A19.
c1974-c1984	50m South	Depot & builders yard.
c1974-c2002	0-500m West	Dense residential development around Camperdown and Killingworth gradually replaces the agricultural fields.

Map Dates	Approximate Location	Description/comments
c1993-Present	0-300m South West	Dense residential development throughout the Palmersville area.
c2010-Present	10-100m South East	Residential development to the southeast of the site around Palmersville.

NOTE: All locations are approximate; measured from the nearest site boundary.

4.2 Summary

4.2.1 With reference to the available historical maps, much of the site has remained undeveloped to the present day. Notable features across the site include a number of farms, a depot (currently being demolished), former wagonways and a landfill.

4.2.2 Wagonways were formerly in operation on the site and surrounding land, and the Metro now operates along the south-eastern site boundary.

4.2.3 The surrounding land had an early history of agricultural and mining activities, becoming increasingly residential during the 20th century. To the southeast of the site, land-use includes the Benton Square Industrial Estate with warehouses, works and depots.

4.2.4 Much of the site area has remained undeveloped to the present day and has not been subjected to potentially contaminative land uses; therefore the contamination potential for these areas is considered to be Low.

4.2.5 However the following potentially contaminative land uses have been identified within areas of the site itself and the surrounding land and comprise;

- General Made Ground/in-filled ground (i.e. potentially poor quality/contaminated materials)
- Railway sidings and Wagonways (i.e. fuel/oil spillage)
- Farms (i.e. fuel/oil spillage)
- Landfill
- Engine House (i.e. fuel/oil spillage)
- Warehouses (i.e. heating oil storage)
- Engineering works and factories (i.e. chemical/fuel/solvent storage and use)
- Collieries

4.2.6 On the basis of the historical information reviewed, the contamination potential for the previously developed areas of the subject site is considered to be Moderate.

5. Conceptual Site Model

5.1 Introduction

5.1.1 This section summarises the findings of the desk study (including our review and re-appraisal of existing intrusive site investigation information) in the form of a geo-environmental conceptual site model (CSM).

5.1.2 The CSM provides a qualitative evaluation of potentially active "*contaminant linkages*" at the site; these being plausible scenarios whereby a contamination source is connected to a possible receptor by one or more pathways:

i) Potential sources of contamination: these include any actual or potentially contaminating materials and activities, located either on or in the vicinity of the site;
ii) Potential pathways for contamination migration: these comprise the routes or mechanisms by which contaminants may migrate from the source to the receptor including environmental migration pathways and human health exposure pathways; and
iii) Potential receptors of contamination: these include present and/or future land users, ecological systems, water resources and property.

5.2 Contamination Sources

5.2.1 From the information reviewed in this report, few potential sources of contamination associated with the site's previous/historic and current usage have been identified for the majority of the site. This is largely due to the absence of on-site development over much of the land and the site's long standing agricultural use.

5.2.2 Notwithstanding, general Made Ground deposits are likely to be present, associated with the various small scale current and historic developments around the site. Deposits may have been imported to level sites and facilitate construction of buildings; these are likely to comprise materials of unknown provenance, quality and composition.

5.2.3 In addition, an engine house was once located in the northwest corner of the site, wagonways crossed the northern area and more recently a depot was previously located in the southwest of the site; historical maps indicate the presence of tanks in this area. Furthermore a number of farms are currently located onsite and as such there is potential for impacts to soil to have occurred from fuel or oil spillages and fuel or chemical storage at these locations.

5.2.4 The development may be at risk from potential ground gas generation from any extensive Made Ground deposits at the site and locally from the materials deposited in the landfill in the southeast of the site. The TerraConsult report presented a summary of recorded gas monitoring data; elevated concentrations of methane and carbon dioxide were recorded from the landfill site.

5.2.5 The site is in a radon area with less than 1% of homes above the action level; therefore radon gas is not considered a potential contamination source. Furthermore the absence of mine gas beneath the site cannot be fully discounted at this stage.

5.2.6 The most significant off-site sources of potential contamination with the potential to have affected the subject site are:

- Railway Line, located immediately southeast of the site;
- Depot and Builder's Yard, formerly located 50m southwest; and
- Industrial Estate, located 50m southeast of the site.

5.2.7 The depot, builder's yard and industrial estate are unlikely to have affected the subject site due to their respective distances from the site boundaries and the anticipated cohesive superficial geology. However the railway line is located immediately to the southeast of the site and therefore could have the potential to affect the subject site. Notwithstanding, for such sources to have affected the site, cross-boundary migration pathways would have to have been active at some stage.

5.2.8 On the basis of the above, it is feasible that contamination could potentially exist within the site footprint and could include substances such as:

- Heavy metals and metalloids
- Inorganic compounds (sulphates, cyanide)
- Asbestos
- Poly-Aromatic Hydrocarbons
- Petroleum hydrocarbons
- Volatile and Semi-volatile Organic Compounds
- Ground Gases (methane, carbon dioxide etc.)

5.2.9 A Geo-Environmental Constraints Plan highlighting the previous potentially contaminative land uses on the site which could potentially pose constraints on future development (or at least inform future Phase 2 investigations) is presented on drawing KM-03 in Appendix A.

5.3 Pathways

5.3.1 Potential migration pathways are discussed below.

Airborne Migration Pathways

- Under the developed scenario, the area to be covered in some form of hardstanding will be increased; however landscaped areas will be included and as such (without consideration of any mitigation) the particulate inhalation pathway is considered active. Notwithstanding landscaped areas are likely to be grassed and as such dust generation is likely to be minimal.
- During development works, sub-surface soils could be exposed and therefore dust has the potential to be generated. Notwithstanding, typical dust suppression techniques could be employed during construction and events such as these would only result in short-period exposures linked to the development programme.
- Vapour inhalation pathways are potentially active irrespective of site status.

Aqueous Migration Pathways

- Leaching of contaminants in the shallow soils is likely to be negligible in areas of hard-standing (buildings, pavement etc.) where infiltration of rainfall is minimal.
- The site is recorded as being underlain by a Secondary A (bedrock) Aquifer and on this basis the aqueous migration of contamination laterally in deep groundwater could occur.
- The bedrock is anticipated to be overlain by cohesive Glacial Till (Unproductive Strata); as such vertical and lateral aqueous migration pathways in shallow groundwater are considered inactive. As such there is unlikely to be a pathway between shallow/surface-derived contamination and deep groundwater.

Direct Contact Exposure Pathways

- Under the developed scenario, a significant proportion of the site area will be covered in some form of hard-standing (building floor slabs, road pavement, driveways etc); however gardens and landscaped areas will be included and as such (without consideration of any mitigation) direct contact pathways are considered active.
- During the construction phase of the development, soils can become exposed at the surface and hence the direct contact pathways should be considered active for the duration of the development programme and also during any later in-ground maintenance works.
- The proposed development plan will include gardens and as such the consumption of home-grown produce is an active pathway for consideration.

5.3.2 Ground gas migration follows pressure gradients (i.e. from high to low pressure via the path of least resistance). Given the nature of the ground conditions, ground gas migration will be predominantly vertical, migrating from the theoretical source to the surface along the path of least resistance. Ground gas migration pathways are therefore considered active.

5.4 Receptors

5.4.1 With reference to Part 2a of the Environmental Protection Act (1990), the potential receptors to be considered in any contaminated land scenario can be summarised as follows:

Human Health

- The proposed development is for a residential end-use and as such the future residents are the primary receptor for any contamination risk.
- Construction workers/contractors could potentially be exposed to contaminants during the construction process, particularly during the initial groundworks phase. We would however anticipate that the adoption of appropriate health and safety risk assessments and use of suitable personal protective equipment (PPE) will reduce risks to manageable levels.
- Residents of the existing surrounding properties could also be at risk; though for exposure to occur, active cross- boundary migration pathways would be required.

Eco-systems

- There are no sensitive or protected habitats associated with the land upon which the proposed development sits or in the nearby area.

Property (buildings, etc)

- The proposed development will comprise new structures and associated infrastructure; however these should be designed on the basis of a site/development-specific geotechnical investigation which should include an appraisal of relevant risks including historical abandoned coal mine workings and the potential for sulphate attack on buried concrete.

Controlled Water

- All groundwater is Controlled Water; therefore the groundwater beneath the site requires consideration and protection as a potential receptor of any site-derived contamination.
- Surface watercourses are also considered Controlled Water receptors; a drain (primary river) forms much of the southern boundary of the site and two further tertiary rivers encroach onto the northern site area. These are therefore considered to be plausible receptors for any site-derived contamination.

5.5 Preliminary Risk Assessment

5.5.1 Based on the CSM the following table presents the plausible contaminant linkages that apply to this site. An indicative qualitative assessment of the likelihood that a risk could be realised is provided with Table 6.1 constituting the Preliminary Risk Assessment (PRA) as outlined in CLR 11 (DEFRA & EA, 2004).

Summary of the preliminary risk associated with Potential Pollutant Linkages

Potential Receptor	Potential Source	Potential Pathway	Preliminary Risk*
Site Users - Residents	Contaminated soil, perched groundwater and groundwater	Particulate inhalation / dermal contact / ingestion	Low (Locally Moderate)
		Vapour inhalation (indoor and outdoor)	Low (Locally Low-Moderate
	Ground Gas	Migration through structures	Low (Locally Low-Moderate)
Adjoining site users	Contaminated soil	Particulate inhalation (during construction only)	Low
	Contaminated Groundwater	Vapour Inhalation	Low

Potential Receptor	Potential Source	Potential Pathway	Preliminary Risk*
Construction Workers/ Maintenance Workers	Contaminated soil & perched groundwater	Particulate inhalation / dermal contact / ingestion / vapour inhalation.	Low (Locally Moderate)
Property (future building)	Sulphate impacted soil & groundwater	Chemical Attack	Low-Moderate
	Ground Gas	Structural damage due to explosion of combustible gas	Low
Property (future landscaping)	Contaminated Soil	Root uptake	Low (Locally Low-Moderate)
Controlled Water – Groundwater	Contaminated soil and perched groundwater	Leaching and migration of contaminants into the aquifer	Low
Controlled Water – Watercourses	Contaminated soil and perched groundwater	Leaching and migration of contaminants into the watercourses via offsite surface water drainage.	Low

* assuming no mitigation or remedial measures are implemented.

5.6 Discussion

5.6.1 The historical uses of the majority of the site and surrounding area do not allow for the possibility of substantial or wide spread sources of contamination. Nonetheless a few small scale on-site potential sources of contamination do exist.

5.6.2 A review of the PRA above indicates that, in the majority of “Active” SPR linkages, the preliminary risk is considered to be Low, however a number of specific aspects have been assigned an elevated risk (Low to Moderate) and these generally relate to the possible presence of ground contamination in the discrete areas of potential sources as identified above.

5.6.3 Near surface contaminants in these areas could impact upon construction workers during redevelopment ground works activities, however it is envisaged that appropriate health and safety risk assessment and personal protective equipment would provide appropriate mitigation.

5.6.4 A risk (low-moderate) exists from hazardous ground gas in areas of extensive made ground, mine shafts and the landfill until proven otherwise or mitigated through incorporation of appropriate gas protection measures into new buildings.

5.6.5 The environmental risk posed by the site to Controlled Water (groundwater and surface water) would only be significant if substantial, mobile, on-site ground contamination sources are confirmed to exist. The risk to groundwater is not indicated to be significant due to the intervening unproductive superficial strata which might act to eliminate the migration pathway.

5.6.6 Risks to property including chemical attack will be mitigated by design.

6. Conclusion & Recommendations

6.1 Overview

6.1.1 This Phase 1 Geo-Environmental Desk Study Report presents an assessment of the geo-environmental information pertaining to the site based on readily available desktop/published information and any available site investigation data.

6.1.2 The objective of this assessment was to collate and review the available geo-environmental information to determine potential ground contamination risks associated with the Site in its current condition and evaluate potential geo-environmental constraints with regards to its proposed future development.

6.2 Geo-Environmental Risks

6.2.1 From the review of the available site information it is unlikely that the historical land uses of the majority of the site and surrounding area will have generated significant or widespread contamination impacts at the site. Nonetheless a few small scale on-site potential sources of contamination do exist.

6.2.2 The preliminary risk associated with any “active” Source-Pathway-Receptor linkages is in the majority of cases considered to be low, but locally elevated where direct exposure can occur in discrete areas with potential sources of contamination.

6.2.3 Under the development proposals the site will comprise a combination of hardstanding and landscaped areas including private gardens therefore certain exposure pathways will remain active (particularly in the landscaped areas and during development) and therefore may require mitigation by management and design.

6.2.4 A potential risk exists from hazardous ground gas in areas of extensive made ground and the landfill until proven otherwise or is quantified with appropriate recommendations for mitigation measures.

6.2.5 The environmental risk posed by the site to Controlled Water receptors is not anticipated to be significant; however this should be confirmed by appropriate testing and risk assessment during Phase 2 Investigations if substantial, mobile, on-site ground contamination sources are encountered.

6.3 Geotechnical Hazards & Coal Mining Related Risks

6.3.1 Killingworth Moor is in the likely zone of influence from workings in 9no seams of coal in the PMCM at shallow to ~400m depth, and last worked in 1971. The seams/strata subcrop beneath the Glacial Till (anticipated to be circa 5-10m thick) and dip to the southeast and southwest (dip direction being dependent upon the fault block).

6.3.2 The available records from the Coal Authority suggest that the most productive (and therefore exploited) seams were the Moorland, High Main and the Yard seams. These reserves have been extracted via shafts to pillar and stall workings as follows:

- Moorland (via Hill Pit): Worked along the western margin of the site (mostly offsite) at a depth of around 100mbgl.
- High Main (via various pits): Worked along the western margin of the site, across the southeast portion of the site (southeast of the Ninety Fathom Fault) and the north-western tip of the site at known depths of between 60-149mbgl.
- Yard seam (pit/access shaft offsite): Worked across the southeast portion of the site (southeast of the Ninety Fathom Fault) at depths of around 80-120mbgl.

6.3.3 Given the depth of these workings any associated ground movement should have ceased by now; the site is therefore considered to be stable with respect to any subsidence arising due to the recorded deep mining (>60m depth) and the primary concern relates to any potential historic (more primitive) shallow coal workings at or close to the surface.

6.3.4 There are no records of working in coal seams above the Moorland seam within the main fault block and central portion of the site. The geological records indicate that the majority of these higher seams which subcrop beneath the Glacial Till are relatively thin and therefore extraction was likely not feasible/practicable or economically viable on a commercial scale.

6.3.5 Based on the thickness of drift deposits and depth of the coal seams indicated by the available information, it is considered that the potential risk posed to the proposed development by shallow coal workings is low for the majority of the site, however the risk is increased in the vicinity of the subcrops where the coal seams are at their shallowest and may have been worked via more primitive methods (e.g. bell pits).

6.3.6 There are a number of former mine entries recorded by the Coal Authority to be within the site boundaries. 10no of these mine entries (interpreted to have provided access to the High Main seam at relatively shallow depth) may have been partially or fully removed by opencast mining methods; these are clustered in the north eastern corner of the site. There are no treatment details for the remaining entries (including Dyke Pit) and therefore the risks are elevated locally due to the potential for the collapse of abandoned mine shafts.

6.3.7 On the basis of the available information, the development risk associated with coal mining related hazards is generally considered low, however in the absence of detailed intrusive investigations, the potential for unrecorded abandoned shallow mine workings and the existence of recorded/known mine shafts, the risks cannot be fully discounted at this stage.

6.4 Preliminary Geotechnical Appraisal

6.4.1 The site topsoil is indicated to be underlain by cohesive Glacial Till throughout the site with the exception that Alluvium deposits are present along the southern boundary and in a swathe of land with northeast to southwest orientation to the northwest of Holystone Farm.

6.4.2 The Glacial Till Drift deposits are indicated to extend to depths of around 5 to 10mbgl in the site area and are anticipated to be of firm to stiff consistency at relatively shallow depth (i.e. 1 to 2mbgl).

6.4.3 Beneath drift deposits, the site is underlain by Solid undifferentiated strata of the PMCM which are indicated to predominantly comprise mudstones and sandstone with subordinate coal seams.

6.4.4 Shallow spread foundation solution (pads/strips) may be feasible; subject to confirmation that the ground conditions are reasonably competent beneath new building footprints. Depending on the findings of future investigations into to depth to rockhead and the presence of abandoned workings beneath the site, shallow spread foundations may need to be suitably reinforced. Ground-bearing ground floor slabs may also be feasible for the proposed site development, subject to the nature and competence of underlying strata.

6.4.5 Given the cohesive subsoils and in the absence of adequate testing, a low CBR value should be assumed for the design of new road pavement at this stage.

6.4.6 Groundwater may be encountered at shallow depths however due to the low permeability groundwater ingress into open excavations is likely to be slow. Due allowance should therefore be made for dealing with shallow groundwater which could be encountered during ground works/in excavations.

6.4.7 In consideration of the indicated site geology and near-surface ground conditions, it is unlikely that on-site soakaways will be feasible to attenuate surface water drainage and therefore discharge of surface water to the adjacent watercourse at an appropriate/restricted discharge rate (i.e. with suitable storm water storage and attenuation) would be the preferred option.

6.5 Recommendations

6.5.1 Prior to any redevelopment of the site, Phase 2 Intrusive Investigations will be required to establish the nature of the ground conditions and to obtain development-specific geotechnical design parameters. In particular future intrusive investigations will be required to establish the depth to competent bearing strata.

6.5.2 It is recommended during any pre-development surveys to carry out a borehole investigation to determine the presence and depth of any shallow coal seams beneath the site and any evidence of workings within the seams. It should be noted that any intrusive activities which may intersect or disturb coal seams will require the prior written permission of the Coal Authority.

6.5.3 The investigation strategy should also include an “environmental” investigation; designed to interrogate the Phase 1 CSM, establish the status of the identified Source-Pathway-Receptor linkages and thereby reduced uncertainties in the PRA.

6.5.4 Investigation should be undertaken in line with BS5930 (1999) and BS10175 (2011) with the aim of determining the ground conditions, allowing sampling of soils for geotechnical and environmental testing. Such investigations will determine the need for mitigation against aggressive ground, establish the suitability of materials for re-use and characterise 'Waste' for future disposal.

6.5.5 The findings of the Phase II intrusive investigation and subsequent assessments will establish the need (or otherwise) for any mitigation measures necessary for the development to progress including whether land remediation is needed. In such an event, further site investigation maybe appropriate or risk assessment in order to develop a Remediation Strategy may be required. In this respect reference should be made to CLR11 (DEFRA & Environment Agency, 2004) and supporting guidance.

7. References

British Standards Institution (BSI), 1999. Code of Practice for Site Investigations – BS5930:1999.

British Standards Institution (BSI), 2001. Investigation of Potentially Contaminated Sites – Code of Practice. BS 10175 – 2001.

Department for Environment, Food and Rural Affairs (DEFRA) & Environment Agency (EA), 2004. Model Procedures for the Management of Land Contamination. CLR 11.

Appendix A Drawings

Appendix B Photographs

Appendix C GroundSure Report

Appendix D BGS Borehole Records

Appendix E Terraconsult Borehole Logs

Appendix F Coal Authority Report & Mine Abandonment Plans

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