



**REMEDICATION OPTIONS
APPRAISAL AND STRATEGY**

**Former Monckton Coking
Works,
Lund Hill Lane,
Royston,
Barnsley,
South Yorkshire,
S71 4BD**

For

**Monckton Developments
Limited**

July 2020

20.B0010.6.1

Geo² Remediation Limited

Coniston House, Louisa St. Idle. Bradford. BD10 8NE
www.geo2.co.uk Tel 0113 257 5397

Monckton Developments Limited

Quantitative Risk Assessment

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Report ref no. 20/B0010.6.1

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Revision Log

Version	Date	Revision	Approved By
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Monckton Developments Limited

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1.0. Introduction

Geo² Remediation Limited have been commissioned by Monckton Developments Limited to conduct a Quantitative Risk Assessment of Former Monckton Coking Works, Lund Hill Lane, Royston, Barnsley, S71 4BD (the site).

The site comprising a former coal stockyard, colliery and coking plant which at the time of writing the site has ceased trading and has largely been demolished to slab level, in preparation of a proposed redevelopment programme.

This report was commissioned to ensure that the risks identified and quantified in the earlier Quantitative Risk Assessment (QRA ref. 20. B0010.5.1) are appropriately mitigated as part of the proposed redevelopment of the site. This report will comprise the following:

- Remediation Options Appraisal, which will build on the established conceptual site model to determine the most suitable method of treatment taking into consideration the nature of the proposed redevelopment.
- Remediation Strategy: to set out the method in which the remediation should be undertaken, the objectives and goals of the programme and parameters by which success can be judged.

This remediation strategy aims to determine the site condition and level upon completion of remediation works and prior to housebuilders taking possession of the site.

2.0 Site Setting

2.1 Site Location

The site is located on Lund Hill Lane, Royston, to the northeast of Barnsley, South Yorkshire; at a National Grid reference of 437460, 412020, as shown on Figures 1 and 2 in Appendix A.

At the time of writing, most of the site has been reduced to slab, or sub slab level, with few structures remaining associated with the historical workings of the site, either in a state of dereliction or retained for maintenance and operation of utility supplies.

The former engineering workshop, remains on the eastern boundary a portion of the land, beyond the eastern boundary has been redeveloped into offices and car parking for Hargreaves Industrial Services plc.

The site is accessed from two main entrances along the eastern boundary, from Lund Hill Lane, the northernmost entrance allowing access through a weighbridge to the former stockyard and Engineering Workshops, the southern entrance allowing access to the Hargreaves property (which will be considered as offsite in this assessment) and an effluent treatment plant in the far south of the site.

2.2 Site Areas

For convenience many of the historic reports have separated the site into three key areas, divided by the current and historical activities which have taken place. These area designations and names will be adopted herein. The extents of each of these areas is shown on Figure 3, in Appendix A.

2.2.1 Stockyard and Colliery Area

The northernmost portion of the site; formerly occupied by the coke and coal stockyards. This area was the hub of the former colliery operations including numerous buildings and rail tracks.

This area is currently level and largely demolished to slab level, with the exceptions of the Engineers Workshop building and occasional small structures. The former structures in this area were used as workshops, mobile plant refuelling, effluent handling and storage.

This area appears surfaced with a thin layer of black coke dust 'breeze'.

In the northwest corner of the site remain a series of Quench Ponds which appear to remain intact and holding water.

Three mine shafts are understood to be present in this area, records indicate these have been capped.

A portion of the north east of the stockyard area, is surrounded by an earthen bund and is wooded.

The engineering workshop was situated adjacent to a waste storage and collection area. A substation was also indicated to be in this area.

Currently large stockpiles of high silica content brickwork associated with the demolition of structures onsite remain present on the site.

2.2.2 Former Production and By-Products Area

This forms the centre of the site including the Combined Heat and Power (CHP) infrastructure, coking ovens and conveyors. This area includes plant associated with production of tar, benzole and ammonia. With the exception of the main tower of the coking ovens, all infrastructure here has been demolished to slab level.

This area comprises tightly packed concrete obstructions and building footprints, with much evidence of contaminative activities. Investigation encountered elevated concentrations of contaminants widespread around concrete infrastructure in shallow soils and penetrating the underlying bedrock.

2.2.3 Southern Site Section

This area contains the effluent treatment plant, which has yet to be demolished and is predominantly wooded with coarse vegetation and semi-mature trees. Much of this area slopes steeply to the south.

2.2.4 Western Land Parcel

This area lies to the west of the railway lines. This parcel of land is understood to be out with the boundaries of this site. It is understood that this area was formerly linked with a bridge to the main site and historically has been used for deposition of colliery spoil and more recently gas purification, storage and distribution.

This area of the site has been reported separately.

2.3 Site Levels

The ground levels are generally highest in the Process Area / Southern Area (near the footprint of the Combined Heat and Power (CHP) plant) at a height of approx. 72m AOD, the remainder of the site gently falls towards the north, with most of the Stockyard area at approximately 63m AOD. The southern area, slopes steeply from the rear of the CHP plant to a plateau, where the former Biological Treatment Plant remains at a level of 62m AOD.

The western and southern boundaries, slope steeply downwards into the railway cutting and road bridge level (Road level spot height at south of site is 50.2m AOD). In the north, northeast and northwest, the land level has been cut into the hillside where rudimentary retaining walls of tyres have been constructed.

A bund is present in the northeast, and around the site boundary in this area.

2.4 Site Setting

The site is situated in an area characterised by former coal mining activities, at the time of writing little of this infrastructure remains active. Current nearby landuses are summarised on Table 1, below.

North	Agricultural land and commercial facility, approximately 120m to the north. Beyond which lie disused industrial and agricultural land.
East	Lund Hill Lane (B6428), beyond which lies grassed disused industrial land and a timber recovery facility.
South	Lund Hill Lane (B6428), beyond which lies former industrial land now Rabbit Ings Country Park.
West	Railway Cutting, beyond which lies agricultural land and residential properties approx. 120m beyond the site boundary. The Barnsley Canal lies approximately 200m to the west.

Table 1: Surrounding Land Uses

2.5 Sensitive Receptors

Reports have not identified any land use designations, such as SSSIs or similar. Areas of green belt are present in the surrounding land and the site falls within a Nitrate Vulnerable Zone.

2.6 Proposed Development

The Client is looking to redevelop the site as a residential development including circa 400 homes, areas of public open space and roadways.

Due to the current topography of the site, it is understood that areas of the Stockyard and Southern areas are likely to include significant land level rises, to match the surrounding landscape and access routes more closely. Whilst final site levels have yet to be established it is understood that the Stockyard will be elevated from circa 63m AOD to approx. 65-68m AOD, levels in the Production are likely to remain similar to their current levels of 72m and the lowest portion of the Southern Area is likely to increase by 1-2m over its existing level of 62m AOD.

The proposed change in land levels has a significant impact upon the risk assessment undertaken herein.

The development aims to locate historical mine shafts in public open space areas and utilise the topographically lower southern area to incorporate public open space and utility areas. The Southern area will predominantly be used as a green corridor linking to the neighbouring Rabbit Ings Country Park and providing leisure space.

A current site layout plan is incorporated in Figure 2 and a proposed development plan is shown on Figure 3, in Appendix A.

3.0 Summary of Previous Works

This report should be read in conjunction with the following reports:

3.1. Data Review and Gap Analysis, 19/B010.1.2. Geo², 2019

Numerous historic reports have been made available for review providing limited detail with respect to the history, operation and ground condition of the site. The findings of these reports issued between the years of 1994 and 2017 have been incorporated into the Data Review and Gap Analysis report.

This report identified the key contaminants likely and proven to be present in the subsurface, including coal tar, DNAPLs, asbestos, hydrocarbons, cyanides, phenols, heavy metals, high calorific soils, silica bricks as well as numerous geotechnical and structural issues including three capped mine shafts.

This established a Conceptual Site Model and identified the gaps in this interpretation. Establishing an investigation design for subsequent work.

3.2 Site Investigation, 20/B010.4.1, Geo². 2020

Works comprised creating of ninety-eight trial pits (TP1-98), ten window sampled wells (WS20-1 to WS20-10) and eight deeper boreholes (BH19-1 to 4, to 12m and BH19-5 to 8, to 20m).

Investigation covered all areas of the site and encountered volumes of calorific material and cyanides in the stockyard, proved the caps of the mineshafts, absence of infilled deposits and presence of former railway lines.

Contamination included DNAPL, cyanides, organic contaminants and tars as well as substantial volumes of concrete across the production and process area. The south of the site, although relatively free of gasworks infrastructure demonstrates elevated concentrations of cyanide in the groundwater.

The site investigation included a screening of identified contamination against generic assessment criteria and qualitative assessment of plausible pollutant linkages. It should be noted that generic assessment criteria have been used based on a residential end user, these values have been applied as a basic screening method which does not take into consideration the impact of land level changes on exposure pathways.

3.3 Quantitative Risk Assessment, 20.B0010.5.1, Geo². 2020

Undertaken to quantify the risks posed by the relevant pollutant linkages, this report produces a numeric interpretation of the conceptual site model to produce Site Specific Assessment Criteria (SSAC). These values represent maximum safe concentrations of contaminants allowable at the site and also to determine the extends and severity of the areas requiring remediation.

This report encountered a series of unacceptable risks, posed by residual heavily contaminated shallow soils (coal tars, hydrocarbons PAH, phenols and cyanides) and infrastructure, and deeper groundwater; posed to future use of the site as a residential development from shallow soils (in their current location), as well as risks from soils and groundwater contamination to the nearby surface watercourse, Lineside Dyke.

4.0 Identified Hazards

The QRA modelled the linkages identified to determine where any unacceptable risks lie, this is summarised below in Table 2. Potentially significant hazard is indicated by either a tick or cross. Where a potential or significant harm is identified, this linkage will be considered for remediation or mitigation in the following options appraisal.

Potential Source	Potential Pathway	Potential Receptor	Likelihood	Remediation Required
Combustible Shallow Soils in Stockyard area.	Risk in event of fire	Future residential site users.	High likelihood, breeze material is all considered combustible. Medium. Fire may cause harm to human health and significant damage to building and property. High Risk.	✓
Gasworks contamination impact within soils and groundwater including DNAPL associated with relic structures and vapours.	Direct contact, inhalation and ingestion and exposure to harmful vapours from soil and groundwater.	Future residential site users	Likely Subject to level increase, much of the soils material across Production Area is unsuitable. Medium. Should material remain in sub soils this may present a risk to human health. Moderate Risk	✓
	Drainage using site infrastructure.	Lineside Dyke	High likelihood. Concentrations of contaminants peaks in Lineside Dyke linked to site drainage Mild. Dyke is of poor quality and low flow (minimal to no flow during summer). Moderate Risk	✓
	Migration through the underlying bedrock.	Lineside Dyke	Likely. Connection remains unproven however, no barrier to offsite migration. Mild. Dyke is of poor quality and low flow (minimal to no flow during summer). Low / Moderate Risk	✓
Gasworks and Stockyard Contamination impact within soils and groundwater, including metals	Migration through the underlying sandstone.	Secondary A Aquifer Northern Plume	Low Likelihood. Limited evidence of plume formation, only, minor SSAC exceedance observed. Minor. Impact is unlikely to be sufficient to product any meaningful impact to the wider groundwater quality. Very Low Risk	✗
Asbestos in made ground	Direct contact, ingestion and inhalation.	Future residential site users	Low likelihood. Present intermittently within the Production Area and infrequently in the Stockyard area. Mild. JIWG assessment of the risk considered there to be Low. Low Risk	✗

Table 2. Conceptual Site Model Summary

5.0 Remedial Objectives

The Site Investigation and Quantitative Risk Assessment have identified a number of land contamination issues which must be resolved in order to develop the site. In addition to which there are a number of constraints on the site which must be considered as part of the overall remediation and site development programme.

This strategy aims to deliver a development platform to the house builders at which point legacy land remediation issues will have been addressed, leaving final site capping and foundation design to be agreed.

5.1 Key Contaminant Impacts

The key areas of identified unacceptable impact are predominantly situated in the Production Area of the site and associated with Coke Ovens, Benzole Plant, Storage Tanks and Processing works in this area.

These key impact areas are shown on Figure 4 in Appendix A, the site investigation has indicated that the bulk of the contaminant mass is split into three sources.

5.1.1 Primary Source

The principal source area, typified by shallow tarry contamination (both solid and liquid) within and around concrete infrastructure and foundations, including gross tar sumps (full-near TP24) across much of the Production Area. Using historical infrastructure plans Geo² have traced the path of historic contamination. This impact has predominantly used the preferential pathways and natural sumps within the infrastructure to become distributed across the area illustrated on Figure 4, in Appendix A. it is estimated that circa 15,000 to 30,000m³ of NAPL or tarry sludge material is present within these structures, estimated at a volume of approximately 50,000m³.

This impact predominantly remains within the top 1-2mbgl and comprises significantly elevated cyanide (peak values of 7,880mg/kg), metals (a reported peak of 6,340mg/kg chromium), PAH (peak 18,000mg/kg total USEPA 16), hydrocarbons (peak 432,000mg/kg) and phenols (peak of 1,090mg/kg). This material poses a risk to human health (should it remain in shallow soils) and poses a leaching risk to the groundwater allowing for further ongoing contamination of controlled waters.

Geo² consider that the Principal Source Zone comprises the bulk of the contaminant mass at the site.

5.1.2 Secondary Source

In the most significantly impacted areas, the contamination has penetrated vertically beyond the surface infrastructure and entered the made ground and unsaturated zone where it forms substantial contaminant mass. Laterally restricted into the Benzole Plant and Storage Tank Areas of the Production Area of the site and the western boundary of the Stockyard, this impact penetrated to a greater depth. The area of impact comprises made ground and underlying shallow sandstone bedrock, where it is likely that the dual porosity allows for contamination to remain within fractures and fissures.

Due to the manner of sampling and drilling very little sample data is available beyond logging, however its presence can be inferred by the presence of deeper contamination within the groundwater.

5.1.3 Tertiary Source

Groundwater samples have reported significantly elevated concentrations of PAH (11mg/l peak in BH19-05), phenol (peak of 67mg/l in BH19-05) and hydrocarbons reported to be 1,000mg/l in BH19-07. Cyanides and Thiocyanate was reported in excess of target levels protective of Lineside Dyke in BH19-02, BH19-03, BH19-04 and BH19-06. Concentrations of PAH are suggestive of the presence of DNAPL in this area, although this has not been clearly identified in boreholes.

This impact appears to be present within groundwater in the underlying sandstone, where due to the proximity of the Lineside Dyke and railway cutting the local hydraulic regime has been altered to cause this impact to migrate westerly, rather than follow the regional trend to the north. Whilst a clear path for migration has not been demonstrated, it must be assumed that a portion of this impact is contributing to the observed impact in the Lineside Dyke.

The underlying mudstone present across the site and at an approximate depth of 16m below ground level in this area is considered to act to prevent further vertical migration.

Groundwater in the Production Area does not appear to be presenting a risk to the Secondary A aquifer; although sampling from BH305, a deeper well installed historically into an underlying sandstone body (although Geo² consider there to a risk of cross contamination to the well) does indicate a slight exceedance of one hydrocarbon fraction.

5.1.4 Other Hotspots and Diffuse Impacts

Aside from the substantial key contaminant impacts detailed above, numerous isolated or sporadic samples were noted to exceed derived target values.

Where human health values are exceeded (such as metals in TP51, TP61, TP88 and TP95 in the coal stockyard), this should be considered in respect of the final development strategy, where these soils will not be present in the top metre of subsoils, then this material need not be removed or treated.

5.2 High Calorific Soils

A mantle of breeze is present in a horizon up to 0.4m in thickness across the Stockyard area and across a small portion of the Production Area, as indicated on Figure 5, in Appendix A.

This material is a black, coke dust rich substrate and visually readily identifiable. Where this material is considered to be combustible, this would require removal to facilitate redevelopment.

5.3 Pathway Removal

Monitoring has been undertaken from the Lineside Dyke, which demonstrates contamination significantly in excess of the Environmental Quality Standards (EQS). Geo² consider that the majority of this impact is associated with relict drainage infrastructure from the site, associated with the principal contaminant source.

As part of the demolition phase these relic drains and pipes, present both above and below ground should be removed where possible or their connection to the Dyke severed.

5.4 Asbestos in Soil

A Joint Industry Working Group (JIWG) worksheet produced as part of the CAR (Control of Asbestos Regulations) in Soil guidance (2016) assessment of asbestos in made ground considers this to present a low risk to future site users. However, it would be prudent to consider the potential for this material to be present when considering reuse of any material in shallow soils (<1m below finished garden / floor level).

Appropriate acceptance criteria should be adopted for imported or reused material subject to the final positioning of this material. Where materials require reuse onsite an appropriate Materials Management Plan (MMP) should be produced in accordance with the CL:AIRE Definition of Waste Code of Practice (DoW CoP, 2011).

5.5 Silica Bricks

A large stockpile of bricks remains in the Stockyard area associated with the demolition of the Coke Ovens and ancillary structures.

A potential health and safety issue was noted with regards to the high silica content of these bricks, which when broken, cut or crushed, would release silica dust particles. Silica particles are respirable and have the potential to cause long term health issues.

A detailed study of the bricks indicates that these could be suitable for retention on site as part of a future development, subject to its end use. Consideration must be given to the processing and disposal of this material.

5.6 Radon and Ground Gases

Monitoring to date has indicated that the overall site falls into a Characteristic Situation 2 for ground gas risk. It should be noted that the works to date are not sufficient to characterise the site for a residential development and also that the proposed redevelopment and remedial works, detailed herein, are highly likely to change the local ground gas regime and are likely to reduce the gas risk further.

In addition to this the site is located within an area where more than 1% of homes are above the Action Level, as defined by the National Radiological Protection Board.

Appropriate radon mitigation should be adopted in line with BRE 211 in all new homes and dwellings on the site.

6.0 Site Specific Assessment Criteria

Table 3 below shows the remedial targets derived in the QRA, these values will be used for comparison with the results of future soil and groundwater samples.

With respect to groundwater two sets of target levels have been derived, one protective of the Surface Water course, Lineside Dyke and a second, protective of the Secondary A Aquifer. These targets are to be applied to separate areas of the site, depending upon the direction of groundwater flow in that area.

Figure 6, in Appendix A, shows the modelled groundwater flow for the site, with a dotted line representing the topographical break in the water tables. Water to the west and south of the line, which runs approximately northwest to south east across the Production Area, is in the catchment of Lineside Dyke, whilst north and east of the line, flows along the surface of the underlying mudstone to the north and into the catchment of the Secondary A aquifer.

Determinand	Soils			Groundwater	
	To be used to screen suitability of soils material for reuse (not surface soil)	Lineside Dyke Catchment	Secondary A Aquifer Catchment	Lineside Dyke Catchment	Secondary A Aquifer Catchment
		Remedial Targets –Leaching (from L3 Soils) (mg/kg)		Remedial Targets – Groundwater (from L3 groundwater) (mg/l)	
Benzene (or Aromatic C5-C7)	0.42	No Impact	No Impact	No Impact	No Impact
Toluene (or Aromatic C7-C8)	489	173	101,000	1.77	3730
Ethylbenzene	268	NA	NA	NA	NA
Mixed Xylenes (or Aromatic C8-C10)	110	1,490	633,000	2.39	3450
Aromatic C10-C12	290	450	217,000	0.459	0.755
Aromatic C12-C16	545	1,140	889,000	0.584	1.57
Aromatic C16-C21	809	2,630	2,450,000	0.423	0.591
Aromatic C21-C35	1660	2,490,000	No Impact	0.392	0.776
Aliphatic C8-C10	74.7	NA	NA	NA	NA
Aliphatic C10-C12	373	450	No Impact	0.257	3.71
Aliphatic C12-C16	NA	1,140	No Impact	No Impact	No Impact
Benzo (a) pyrene	4.96	No Impact	No Impact	0.000732	0.00148
Naphthalene	40.7	NA	NA	NA	NA
Cyanide	NA	102	680	10.6	10.6
Thiocyanate	NA	102	680	10.6	10.6
Arsenic	37.1	701	1,590,000,000	0.204	0.204
Lead	201	No Impact	No Impact	No Impact	No Impact
Nickel	590	167	No Impact	979	979
Selenium	NA	0.813	419	1.2	1.2
Chromium (total)	910	NA	NA	NA	NA
Phenol	899	4.84	4.84	447,000,000	0.33

Table 3. Remedial Targets

When applying these targets to treated soils, they should be compared to both human health values, but also the appropriate leaching target. This should be selected based on the location of the deposited material. It is anticipated that most of the deposited materials will be positioned



within the Secondary A Aquifer Catchment, and therefore required a lower degree of treatment to be suitable for use.

These derived targets are considered highly stringent and potentially beyond the capability of any feasible cost-effective remediation technology. These will be adopted as ideal targets; however, it should be understood it may be beyond the technical capacity of soil and groundwater treatment technologies to achieve these stringent targets.

7.0 Site Specific Constraints and Objectives

There are a number of significant factors which must be considered as part of the overall remediation design which relate to the Clients objectives for the development and also address other significant geotechnical or structural issues at the site

Key additional factors for consideration are as follows:

- The ideal solution must achieve regulatory approval as part of the planning process to permit the Clients objective, namely the development strategy as established on Figure 3, in Appendix A.
- The cost of works must not be such as to endanger the viability of the project.
- The Client is looking to relevel and remediate the site, prior to development by housebuilders. The remediation works must be completed during the enabling works phase, so as to impose no time or access constraints upon the housebuilders.
- Whilst the site has been mainly demolished to slab level a tower remains around the coke ovens and the Engineering Workshop remains in the east of the site and the Biological Effluent Treatment Plant remains in the southern area. On top of this additional minor structures remain in the stockyard and widespread areas of concrete have been identified across the site. In some areas geotechnical unsuitable materials (tyre wall bunds around the northern and western portions of the Stockyard should be anticipated as requiring offsite disposal.
- Material is to be brought onto the site in order to increase land levels.
- Disposal of material offsite is to be minimised and where possible and cost effective this should be treated or processed for reuse on the property as subsoils (>1m below final land level) in order to aid establishment of the proposed increased land levels.
- The capped mine shafts, proved in the Site Investigation works are to be developed around and to remain in an area of Public Open Space, subject to the final engineering design. Locations of these and other obstructions are shown on Figure 7, in Appendix A.
- There remain infilled former train tunnels beneath the Stockyard Area, if it suggested that there may have been more than one, all running from the southwest of the Stockyard to the north and northeast. These were detected using probe holes and trial trenches and found to be present at 1.5mbgl. Infill was noted to comprise a loose, fine red / brown sandy material and is likely to be geotechnically variable. In areas indicated on Figure 7, in Appendix A. It is likely that other areas of geotechnical variable ground exist or may be uncovered during remedial works.
- Whilst no Japanese Knotweed or invasive species were reported during the investigation historical reports suggest this to be present round the bund in the north eastern area.

8.0 Remedial Solutions Screening

This section lists technologies considered as suitable to treat the bulk of the identified contamination around the USTs and forecourt as listed in CLR 11 plus integrated and emerging techniques. These techniques have been broken down below into broad groups and those options considered unsuitable due to site specific reasons (such as ground stability) discounted from the process.

This approach utilises the Environment Agency Remediation Option Applicability Matrix spreadsheet to target options suitable for this contaminant types. This lists the following techniques as suitable to treat both soil and groundwater; containment systems (such as covers or barriers), biotreatment, chemical oxidation and multi-phase pumped extraction. The complex mix of contaminants on the site means that scope should be given to the deployment of multiple types of treatment method.

The following Sections detail the key contaminant impacts at the site and appraises the viable remediation techniques.

8.1 Primary Source Treatment Options

Primary source area principally comprises concrete hardstanding, with a substantial volume of contaminants bound up within this structure, Geo² consider that an engineering option is the only feasible method of accessing and treating this impact. The works in tandem with the requirement to remove these obstructions as part of the demolition works.

Geo² have traced pipework from these and overlain historic plans with the contamination profile, whilst the gross impact does tie in with the historic land use consideration should be given to the likelihood of fugitive tars within these substructures. Geo² consider that an engineering option is the only feasible method of accessing and treating this impact.

As the works progress known sources of Non-Aqueous Phase Liquid (NAPL) could be removed using specialist pumps and equipment. The generated NAPL could be transferred into bunded storage tanks prior to disposal.

It is estimated that circa 15,000-30,000m³ of NAPL is present in these structures, which would be disposed of off-site. Ideally, this material would be used as a secondary fuel, however, having appraised local facilities the local market would not be able to re-use this and it would be disposed as a waste.

This is the key stage of the remediation approach as this phase of works will be addressing the historic sources of the other materials discussed below and if not treated effectively would result in the potential for an ongoing source.

Where tarry sludges have been encountered these materials would be excavated and segregated for remediation.

The most feasible remediation options for very heavily impacted sludges and tarry wastes are:

- Soil Stabilisation and Solidification,
- Removal to landfill,
- Incineration.

The low volatility and mobility of much of the observed NAPL and its location within and around concrete obstructions makes biological or chemical treatment difficult to apply and control effectively.

The use of Stabilisation and Solidification is relatively common for 'Gasworks' type contaminated soils. The impacted materials are mixed with a series of binders such as Ordinary Portland Cement (OPC), lime, Granular Ground Blast Furnace Slag (GGBFS) etc.

The contamination would then be encapsulated in the resultant monolith this mitigates the risk to groundwater as leachate potential is reduced and human health as vapour is also contained within the monolith. The resultant remediated soils would then be placed beneath a capping layer ideally outside of building footprints and service runs.

Offsite disposal and incineration are prohibitively expensive and unsustainable when applied on a large scale, coupled with the requirement to increase land level this approach becoming increasingly unsustainable for all but the most untreatable materials. If during the excavation works material is encountered that cannot be stabilised i.e. the material cannot be passed through the stabilisation plant, then the options for this material and disposal could be the only option.

8.2 Secondary Source Treatment Options

The Secondary Source comprises subsoils from the unsaturated zone and is mainly located in grossly impacted areas of the former Production area and especially prevalent in the Benzole Plant area. Once the primary source has been removed this material becomes available to treat. Treatment of this material removes a secondary source of groundwater contamination as well as exposing pathways of contaminant transfer to the groundwater, within the bedrock.

The remediation options for this material, which is predominantly granular made ground comprises:

- Soil Stabilisation and Solidification (SS),
- Soil Vapour Extraction,
- Bioremediation,
- Disposal off site to a treatment centre.

Soil Stabilisation and Solidification has been discussed above and is an appropriate treatment option for the material.

Soil Vapour Extraction (SVE) can be applicable to granular soils to treat volatile compounds. The soils would be excavated and placed in a designated treatment area. An array of pipework is then placed beneath and within the soils which in turn are linked to a high air flow vacuum extraction system. The treatment system then pulls high flows of air through the pore space to remove vapour. The vapour is then treated (where required, typically using Granular Activated Carbon filters) prior to discharge to atmosphere. The driver for this system is volatilisation so is only applicable to compounds which have an appropriate Henry's Constant (and is unsuitable for treatment of tarry deposits and PAH as encountered within the Primary Source Area). Also, as the approach relies on air flow, it can only be effectively applied to granular material.

Bioremediation is the stimulation of bacteria to degrade contaminants in more environmentally benign compounds. When applied ex-situ this is undertaken in an aerobic condition. The soils can be treated either in a windrow where the soils are aerated via mechanical means or in a biopile where the soils are aerated in manner similar to ex-situ SVE. The approach can be limited by bio-inhibitors such as toxicity or a lack of terminal electron receptors. As with in-situ bioremediation the indigenous bacteria are often better suited to the site conditions and augmentation required if a viable population is not present. The approach is more effective when temperatures are amenable as bacterial activity for typical consortia is optimum at circa 15-30 degrees Celsius. The reliance on bacteria does however mean that this approach can be slower than Soil Stabilisation but can be appropriate on longer chain compounds than Soil Vacuum Extraction.



Disposal to a treatment centre, as opposed to a landfill, can be appropriate for many compounds as the approaches above would be applied albeit in an offsite environment. As the material is disposed offsite the costs for this approach are higher, for each load of material disposed from site there would be a requirement to import material to replace it, which further increases the cost of this approach as well as reducing the sustainability and efficiency of the strategy.

Whilst chemical treatment is an applicable solution for the treatment of this material, it is considered that as the material can be readily excavated as part of Principal Source removal, ex-situ techniques would be more reliable and cost effective.

Monitored natural attenuation is not considered suitable in addressing the issue as this impact, which may still act as an ongoing source.

8.3 Pathway Removal Options

The overall approach to the remediation works is to remove the source material, however, as the site is excavated pathways both laterally and vertically would be exposed. By identifying and removing the pathways, this significantly reduce the risk to Lineside Dyke and other surface water receptors in addition to the source removal approach.

Pathway removal can take two forms, removal of infrastructure and drainage network connections and also by severing flow paths within the bedrock.

The first approach could easily be incorporated into the Principal Source removal, whilst the second could follow the Secondary Source removal works, which would expose the surface of the Sandstone bedrock. Inspection of the exposed bedrock may allow identification of relevant fracture zones which could then be targeted by grouting to reduce the effectiveness of this flow pathway. The second approach is unlikely to be effective if deployed alone due to the difficulty in demonstrating successful severing of the pathway, however in conjunction with other approaches this provides an additional measure of reducing the perceived risk.

Alternative technologies to treat identified contaminants and pathways include chemical oxidant injection or surfactant flushing have been discounted due to the risks associated with the limited control of the mobilised contamination.

Use of an installed hydraulic barrier, along the boundary of Lineside Dyke would provide comfort that this pathway was severed, however due to the nature of the dual porosity and depth of the sandstone this approach would be costly and may be of variable effectiveness.

8.4 Tertiary Source Treatment Options

The Site Investigation works have identified high elevations of dissolved phase impact in the groundwater and localised globules in the Former Production area, to date, no measurable thickness of NAPL have been identified, albeit the presence of NAPL cannot be discounted. The presence of onsite structures with NAPL makes interrogation of the subsurface without cross contamination difficult, this would be completed following the Primary Source Removal.

The presence of DNAPL, whilst suspected, has not been confirmed. Once the Primary and Secondary sources have been removed Geo² propose to undertake further investigation works in areas where historic sources were present. This would enable delineation wells to be installed to focus on areas of identified gross impact. If recoverable DNAPL is encountered, a mass recovery scheme should be considered to reduce the residual mass present in the aquifer.

Irrespective of the presence or absence of DNAPL, the remediation options for groundwater remediation must be considered as part of the wider remediation strategy. The site contaminant



profile indicates that at shallow depths there is significant gross NAPL impact. This has migrated over time into the aquifer, the residue of which may act as an ongoing source.

8.4.1 DNAPL Treatment Options

This is based on the assumption that localised DNAPL is present albeit not encountered to date. The presence of LNAPL is not expected based on the contamination profile, but if encountered during the NAPL investigation post source removal, the remediation of this is included as part of the Remediation Strategy.

DNAPL, if identified, would be present at circa 16m below existing site levels within fractures and fissures. As outlined above it would be present on a low permeability horizon anticipated to be the underlying mudstone. If identified this is the primary objective of the saturated zone remediation is NAPL (both LNAPL and DNAPL) as this presents a potential residual mass of ongoing dissolution to the dissolved phase.

DNAPL recovery from aquifers is driven by two elements namely the nature of the DNAPL (physical and chemical properties) and the aquifer properties. To date as no measurable, therefore, recoverable DNAPL has been encountered the remediation approach is based on assumed properties.

The remediation options and identified feasible approaches are outlined below.

On similar schemes undertaken by the staff at Geo², DNAPL is expected to be of a viscosity and chemically challenging to typical groundwater abstraction systems. As such, specially DNAPL designed pumps are installed to recover DNAPL. These allow readily recoverable DNAPL to be abstracted and stored on site prior to disposal off site. This simple and robust approach would allow a mass removal approach to be undertaken at the significant depths of potential NAPL impact. This approach has evolved over the last 10-15 years with enhancements and these are outlined below.

The limits to DNAPL recovery are based, typically, on the viscosity of the material to be abstracted. To improve the rates of recovery the following approaches have been used:

8.4.2 DNAPL Flow Path Management

Flow Path Management is based on lowering the hydraulic pressure in the recovery zone and increasing the pressure outside of the recovery zone to provide a greater pressure gradient and improve the flow of the DNAPL to the abstraction well. This approach can work well in a relatively homogenous aquifer where the flow path (DNAPL saturated soils) can be effectively managed and a 'pumpable' i.e. recoverable mass of DNAPL is present. As, to date, there has only been globules of NAPL identified this approach is not applicable.

8.4.3 DNAPL Thermal Treatments

There are a range of thermal approaches to recover DNAPL including Steam Injection, Electrical heating (six phase, resistive etc.) and hot water injection. These approaches are based on improving the viscosity of the DNAPL as temperatures increase as there is, normally, a correlation between temperature and viscosity.

All of these approaches are energy intensive and are reliant on raising the aquifer temperature by a minimum of circa 20 degrees Celsius, although both steam injection and in particular electrical heating can increase by significantly more.

To successfully apply these approaches it is key to heat the DNAPL impacted zone and then control the recovery of the mobilised DNAPL. As stated above, the impacted aquifer is a dual porosity system, this would need the application point to sufficiently intercept the fracture and fissure for example with a steam system the injection point would need to be installed to allow the injection into a relatively narrow fissure at 16m below existing ground level which is impractical. In addition, as water conducts heat relatively efficiently the energy would be dissipated quickly so whilst these approaches are high energy demand on shallow aquifers, where the impact is at depth this would be even more so.

The high energy consumption required to maintain the necessary heat across a large area is considered unsustainable and prohibitive, when taking into considering the variable and potentially limited mass recovery.

8.4.4 Groundwater Treatment Options

The remediation options for groundwater remediation must be considered as part of the wider remediation approach. The site contaminant profile indicates that at shallow depths there is significant gross NAPL impact. This has migrated over time into the aquifer and is acting as an ongoing source.

The first phases of the remediation works should remove the source and excavate all reasonably practical ongoing sources and allowing inspection of pathways hence stopping/minimising ongoing contaminant flux to groundwater. By removing the source of ongoing contaminant impact, residual dissolved phase mass should undergo a process of Natural Attenuation to improve groundwater conditions albeit more active options are considered below.

8.4.5 Physical Groundwater Remediation Options

Physical Remediation approaches remove contaminant mass from the aquifer using a range of approaches typically:

- Steam Injection and off gas recovery,
- Dual Phase Vacuum Extraction (DPVE),
- Air Sparge and Vacuum Extraction,
- Groundwater Abstraction and Treatment
- Injection of additives to alter permeability/contaminant flux

Steam injection with off-gas recovery is an applicable on highly contaminated sites where the injection of steam injected at the lower part of the aquifer volatilises dissolved and adsorbed phase impact, the contaminants are transferred to the vapour phase which is then recovered typically with a DPVE or Soil Vapour Extraction (SVE) system. The generated off gas is then treated prior to discharge to atmosphere.

The use of steam also has an advantage of accelerating biodegradation as bacterial activity would benefit from the introduction of oxygen and their activity increases with the increase in temperature where thermophilic bacteria are present. However, the capture and recovery of the generated volatilised contaminants is critical to prevent re-dissolution. For a unconfined aquifer where the recovery point is laterally close to the injection point this approach is practical. As this site the aquifer is dual porosity, the injected steam could travel via a preferential pathway and discharge some distance from the abstraction well. This is a high cost, high energy approach which has risks that it may be ineffective.

DPVE is a high vacuum system which uses a high vacuum (up to 800mBar) to recover vapour from the subsurface, at the high vacuum and high air flow rates liquids are



entrained as part of the flow which is an excellent approach for treatment of the piezometric smear zone and widely used for LNAPL recovery (see above), however, this approach would have limited use for this site as the contaminant impact is at depth and outside of the effective radius of influence of this technology.

Air Sparge and Vacuum extraction is a similar approach to Steam Injection with the same limitations. As such discounted as inapplicable.

Groundwater abstraction and treatment was widely applied during the 1980s and whilst has significant limitations on many sites can be applicable in niche situations. The system operates by simply abstracting water from the aquifer, passing it through a water treatment plant prior to discharge. The approach is limited as once each pore volume has been removed, it is reliant on dissolution from adsorbed to dissolved phase to enable recovery to surface. In some situations, it can be linked to other systems such as surfactant injection, chemical oxidation oxygen, amendment etc. which improve its performance as these approaches could improve the treatment of the dissolved phase. A multiple stage treatment system of this scale would not represent good value as there would be a need for two to three treatment systems on a large scale.

Whilst the approaches are readily applicable for schemes where the geology is more heterogenous this site's dual porosity nature would result in a more limited impact.

8.4.6 Chemical Groundwater Remediation Options

The typical Chemical Remediation approach is the use of oxidants to cleave the chemical bonds of the contaminants of concern.

The selection of oxidant and delivery mechanism is contaminant, geology and site constraint dependant. Typical oxidants include Hydrogen Peroxide, Sodium and Potassium Permanganate, Sodium Persulphate, Fenton's Reagent and various proprietary oxidants as well as stabilised Fenton's and Persulphate mixes

The oxidant may be delivered using either a direct push method or a conventional borehole array dependant on geology and contaminant distribution.

The Chemical Oxidation process is a powerful remediation technique which has evolved in the UK since 2001 and is proven to work on Gasworks type contaminants. Each oxidant has a limited reaction timescale in the aquifer dependant on the oxidant, for example Hydrogen Peroxide based oxidants which generally are more aggressive and cost effective have an active life span of 8-24 hours.

As the approach is dependent on contact time of oxidant to contaminant the dosed liquids would need to be injected into the appropriate fracture(s). A crude application system would lead to expensive dosed liquids being injected inappropriately, so whilst technically applicable, the practical element of the approach would be challenging. As alluded to, this approach is effectively applied on a wide scale can be expensive and given the delivery challenges has the potential to not offer sufficient benefit versus cost.

8.4.7 Biological Groundwater Treatment Options

Biological remediation approaches rely on predominately indigenous bacteria breaking down the contaminants of concern and can either operate aerobically or anaerobically. In this instance aerobic degradation would be the most rapid means of achieving contaminant destruction.

Natural biodegradation can be enhanced through application of chemical agents to supplement natural levels of oxygen or chemical nutrient. Data from this site suggests that conditions in the aquifer are aerobic, however this could be further supplemented to accelerate the natural degradation rate.

The principal contaminants of concern can degrade aerobically and with the source removed are anticipated to do so under natural conditions, however, to be effective the ongoing sources would need to be removed in the first instance. To introduce oxygen to the subsurface has similar application constraints and cost issues as oxidant or steam injection.

The key constraints to biodegradation are bio-inhibitors (i.e. groundwater concentrations being too toxic), a lack of oxygen for aerobic biodegradation and a lack electron receptors. In certain circumstances the aquifer may need a medium for the bacteria to grow on and occasional the local population may be amended but it is generally more appropriate to rely the indigenous population who would have adopted to the site conditions.

Following source removal, it would be beneficial to determine whether a viable bacteria population is present to confirm that in the long term natural attenuation will occur.

9.0 Detailed Options Appraisal

The screening approach undertaken above has produced a shortlist of two feasible combinations of techniques, each of which will be detailed below and scored to determine the most suitable tool to use.

These approaches aim to provide a robust strategy for minimising risks from the identified sources, but also to have sufficient capacity to deal with variations in volume, encountering unexpected contamination and allowing for tertiary treatment options.

This section addresses only treatment elements of the work pertaining to the identified land contamination and not geotechnical or ancillary elements of the wider remediation works

All licensing requirements associated with these proposals would be organised by the Remediation Contractor.

All of these approaches aim to balance the requirement of the Client and the development with managing the land contamination risk and the principles of sustainable remediation described in the SuRF UK framework.

9.1 Excavation Only Approach

This approach aims to excavate and treat the Primary and Secondary Source areas for reuse onsite. As part of the excavation works, the pathways to the Lineside Dyke will be removed or blocked. Following removal of the Secondary Source all exposed fractures or fissures within the sandstone bedrock will be pressure grouted to reduce infiltration and mobility of any residual deeper impact.

Due to the complexities of recovering contamination from within a dual porosity sandstone, and considering that the principal pathway for contamination to Lineside Dyke is considered to be relic infrastructure and not migration through groundwater, this approach proposes to address the tertiary source by shallow source and pathway removal, preventing further impact to the deeper groundwater and reduce further creation of a tertiary source.

9.1.1 Method

Demolition works will be undertaken at the site to remove all remaining structures, including pipework connections to the Lineside Dyke.

The Primary source will be excavated sequentially, with concrete structures and material found to be visually uncontaminated segregated for processing and reuse on the site. Visually or olfactorily impacted material would be stockpiled for processing and treatment using soil stabilisation techniques to make the material suitable for reuse as subsoils. It is estimated that circa 15,000-30,000m³ of NAPL is present in these structures which would be disposed of off-site.

Soils material found to be highly odourous and granular, but not containing heavy tar and PAH waste (such as the Primary and Secondary sources in the Benzole Plant area) would be more effectively treated by Bioremediated onsite.

As the works progress known sources of NAPL would be removed using specialist pumps and equipment. The generated NAPL would be transferred into bunded storage tanks prior to offsite disposal. Ideally, this material would be used as a secondary fuel, however, having appraised local facilities the local market would not be able to re-use this and it would be disposed as a waste.

Following excavation of the Secondary source for treatment, the bedrock in the area would be examined to determine plausible pathways for contaminant migration. Identified fissures and fractures would be targeted with pressure grouting techniques to sever potential pathways for infiltration into the rock, aiming to alleviate migration within the bedrock.

Following treatment, by stabilisation or bio piling materials would be tested to demonstrate suitability and placed in the prepared benign location, in accordance with the required engineering design. Treated subsoils will be used in locations greater than 1.0m below finished site level allowing for introduction of a clean cap and cover system comprising verified clean fill and topsoil.

9.1.2 Plant

Material designated for stabilisation or bio piling will be excavated and stockpiled in a designated area using excavation and demolition plant.

Material for stabilising will be mixed with an appropriate blend of binding agents, to be determined by the contractor. This mix may either be produced in a designated mixing area or be placed and stabilised in-situ with appropriate mixing plant. Once mixed and placed the soils will become encapsulated, whilst some contamination may remain within the material, leaching testing may demonstrate the effectiveness of the process.

A designated bio-pile area will be specified with a vacuum plant with Granular Activated Carbon (GAC) filters added for treatment of off-gas. The bio-pile will be built with vacuum recovery duct lines to enable recovery of volatile vapours and permit rapid aerobic degradation within the soil. This soils material would need turning during the process to ensure decompaction and thorough air flow. This system would operate 24 hours a day and would require a continuous generator powered electricity feed. The plants operation would be maintained by a staff onsite daily during operation.

Pressure grouting will look to seal fractures and fissures by injecting a lean mix of concrete through a slurry pump down steel rod percussively inserted into fracture zones.



Determining the number and spacing of injection points should be determined once the rock head is exposed in the key area.

Effectiveness would be demonstrated through soil analysis and leachability testing of soils placed. These works would be expected to be completed in 6 to 9 months.

Costs of installation of this approach are relatively low when compared with comparable solutions, with substantial savings achieved over offsite disposal approaches.

Whilst this solution presents a robust strategy which can accommodate variable volumes of contaminated material, the limitations arise associated with uncertainty regarding the effectiveness of the tertiary impact. Whilst this is not anticipated to represent the principal pathway by which contamination of Lineside Dyke is occurring, and the proposed grouting method will reduce the volume of leachate generation, limited uncertainty may remain with respect to the longer term fate of the residual impact at the site boundary.

9.1.3 Infill

The land level raises required as part of the wider site development aim to reuse treated and processed site won materials, depositing this material in benign areas of Public Open Space within the Secondary A Aquifer catchment. Additional infill will be brought to site principally using recycled stone and crush materials and acting as a disposal route for other sites operating at a surplus of inert material.

This material will be imported and tested under appropriate permitting to ensure geotechnical and chemical suitability. A cover system should be used in all developed areas.

9.2 Excavation with Tertiary Treatment

This approach uses the same broad approach as detailed above. However, instead of aiming to isolate any residual tertiary impact within the deeper bedrock, this approach proposes investigation and treatment of this impact.

9.2.1 Method

As part of the unsaturated soil remediation works as detailed above, extensive excavations to remove contaminant impact would be completed. As these works progress vertical pathways will be exposed and should NAPL pathways be identified further boreholes would be installed to determine if NAPL is present.

The aquifer is a dual porosity Sandstone which would suggest that any NAPL present would be encountered within the fractures and fissures rather than the rock mass. To confirm if and where NAPL is present in the first instance a series of cored boreholes would be installed in source areas.

Due to the complexities of the strata it is expected that treatment will not be able to achieve the groundwater targets in the tertiary source zone using any approach within a reasonable timeframe and as such the focus of the Remediation Approach for the saturated zone would be to recover the maximum recoverable mass of contaminant to the point where Monitored Natural Attenuation can occur, with the target values acting as an aspirational objective.

Where encountered, specially DNAPL designed pumps would be installed to recover DNAPL. These allow readily recoverable mobile DNAPL to be abstracted and stored on



site prior to disposal off site. This simple and robust approach would allow a mass removal approach to be undertaken at the significant depths of potential NAPL impact. DNAPL which is not readily recoverable is likely to be of low mobility, recovery of which is likely to be costly and of uncertain effectiveness.

DNAPL recovery pumps would also aim to recover grossly impacted groundwater during these works to reduce the mass of contaminant in the ground. Groundwater recovery volumes are likely to be relatively low with a pumping capacity of approximately 1,000 litres per day. This low volume is undertaken purposely as the key objective would be the steady recovery of any DNAPL source.

Due to the depth of the impact and the dual porosity of the aquifer, enhancement of this pumping solution is unlikely to be effective.

Pumping works should be continued until a DNAPL recovery reaches a state of asymptotic recovery at which point this approach is likely to have achieved its technical limit. It would be anticipated that this would occur within circa 12 months of operation.

Whilst this solution presents a robust strategy which can accommodate variable volumes of contaminated material, the limitations again arise associated with uncertainty regarding the effectiveness of the tertiary impact. As detailed above Whilst this is not anticipated to represent the principal pathway by which contamination of Lineside Dyke is occurring, it is considered unfeasible that all residual impact could be recovered, and is considered unlikely that groundwater remediation targets would be achieved using this, or any other feasible approach.

Costs of installation of this approach are higher than the above approach, associated with moderate ongoing maintenance and waste disposal costs. However, this approach provides an additional degree of environmental improvement and source term reduction.

9.2.2 Plant

In addition to the plant and processes detailed earlier, this would require the installation of a series of air driven bottom (or top for LNAPL) loading borehole pumps targeted to the distinct NAPL horizons.

A central plant house would be required to supply compressed air to each abstraction point. Abstracted NAPL water mix would be quarantined in Oil Water Separators with wastewater treated by Granular Activated Carbon (GAC) for discharge to sewer (under licence) or for storage for offsite disposal.

This plant would be generator powered. The central plant would use computer PLC controls (with high level shutouts, overflows and bunding) to ensure effective operation without full time staffing and would operate 24hrs a day.

All pipework would run above ground and the treatment area would be fenced off.

Recovered NAPLs would be quarantined onsite awaiting offsite disposal along with liquid wastes recovered during the Primary source initially, then using dedicated quarantine vessel.

10.0 Evaluation

In line with the SuRF UK framework (March 2010) an assessment of the remediation options is undertaken qualitatively based on a series of sustainability indicators. These fall into three distinct groups.

- Environmental: Considering the impact to the air, soil, water, ecology, natural resources and wastes and intrusiveness.
- Social: Human health impacts and safety, ethical and equity consideration, neighbourhood impact, community involvement, compliance with policy, uncertainty.
- Economic: Direct cost, indirect cost, employment, project risks and flexibility.

Each of the above indicators has been scored (1-low to 10- high) for each of the following categories based upon balancing remedial objectives, the client's build programme and site-specific constraints. These scores are shown on Table 4-7, below and overleaf.

Environmental	Primary + Secondary Source Removal with Grouting		Primary + Secondary Source Removal with DNAPL Exploration and Pumping	
Impact on the air (climate change)	Treatment by encapsulation using cement generates significant CO ₂ . Treatment onsite reduces regional emissions over offsite disposal. Biological treatment of soils releases VOC and gases, this is reduced through use of vacuum systems and GAC filtration reduces emissions.	6	Treatment by encapsulation using cement generates significant CO ₂ . Treatment onsite reduces regional emissions over offsite disposal. Biological treatment of soils releases VOC and gases, this is reduced through use of vacuum systems and GAC filtration reduces emissions.	6
Impacts on soil	Treatment will improve soil suitability and minimise spread of pollution.	8	Treatment will improve soil suitability and minimise spread of pollution. DNAPL recovery, where necessary may further reduce residual impact.	9
Impacts on water	Treatment will remove impact to Secondary A Aquifer and significantly reduce impact to Lineside Dyke by removing man made pathways and restricting natural flow paths.	6	Treatment will remove impact to Secondary A Aquifer and significantly reduce impact to Lineside Dyke by removing man made pathways and by limiting residual source term where encountered.	7
Impact to ecology	Site is current a barren environment and regional water quality is poor. Proposed redevelopment will retain much green space and improve quality of surface waters.	6	Site is current a barren environment and regional water quality is poor. Proposed redevelopment will retain much green space and improve quality of surface waters.	7
Use of natural resources and waste generation	Remediation is energy intensive, however onsite treatment reduces the carbon footprint of the approach, with minimal waste disposal. Import of fill material will further reduce waste generation from the wider region.	10	Remediation is energy intensive, however onsite treatment reduces the carbon footprint of the approach, with minimal waste disposal. Import of fill material will further reduce waste generation from the wider region.	10
Intrusiveness	As the site is currently a barren landscape surfaces with concrete and black combustible material, the impact of remedial plant is considered to have minimal impact.	10	As the site is currently a barren landscape surfaces with concrete and black combustible material, the impact of remedial plant is considered to have minimal impact.	10
Total		46		49

Table 4 Environmental Indicators

Social	Primary + Secondary Source Removal with Grouting	Primary + Secondary Source Removal with DNAPL Exploration and Pumping
Human health and impact safety	Demolition works are dangerous and must operate in a highly regulated manner to reduce risks. Treatment of contaminated material requires additional controls and permitting. Upon completion of the remediation the risks posed to site users and builders will be significantly reduced.	Demolition works are dangerous and must operate in a highly regulated manner to reduce risks. Treatment of contaminated material requires additional controls and permitting. Upon completion of the remediation the risks posed to site users and builders will be significantly reduced.
Ethical and equity considerations	Treatment will improve ground suitability and minimise spread of pollution and environmental impact.	Treatment will improve ground suitability and minimise spread of pollution. DNAPL recovery, where necessary may further reduce residual impact.
Impact on neighbourhoods and regions	Remediation brings back into use a blighted industrial property, minimising development pressure of green field sites.	Remediation brings back into use a blighted industrial property, minimising development pressure of green field sites.
Community involvement and satisfaction	Remediation will remove a blighted derelict site from the area, removing a potential public health and environmental issue from the neighbourhood.	Remediation will remove a blighted derelict site from the area, removing a potential public health and environmental issue from the neighbourhood.
Compliance with policy objectives and strategies	Remediation will seek planning approval in advance and aim to aid the Council in fulfilling obligations to minimise risk to human health and the environment. Use of SuRF UK framework and environmental impact assessment demonstrates compliance with planning policy and best practice. .	Remediation will seek planning approval in advance and aim to aid the Council in fulfilling obligations to minimise risk to human health and the environment. Use of SuRF UK framework and environmental impact assessment demonstrates compliance with planning policy and best practice. Additional tertiary treatment will achieve greater compliance with EA groundwater protection regulations.
Uncertainty and evidence	The shallow impact across the site has been well characterised by extensive investigation works. Deeper impacts are less clearly understood. However preventive measures are incorporated.	As the site is currently a barren landscape surfaces with concrete and black combustible material, the impact of remedial plant is considered to have minimal impact.
Total	42	47

Table 5 Social Indicators

Economic	Primary + Secondary Source Removal with Grouting	Primary + Secondary Source Removal with DNAPL Exploration and Pumping
Direct economic benefit	Remediation as part of a package of redevelopment works promises to provide direct economic benefit through property sales. 8	Remediation as part of a package of redevelopment works promises to provide direct economic benefit through property sales. 6
Indirect benefit	Generation of a new housing development will bring residents to the area and benefit local shops and infrastructure. 6	Generation of a new housing development will bring residents to the area and benefit local shops and infrastructure. 6
Employment and capital gain	Development of the site will not contribute directly to employment beyond the redevelopment programme. Investment in the site through development and sale of property will produce capital gain in the area. 8	Development of the site will not contribute directly to employment beyond the redevelopment programme. Investment in the site through development and sale of property will produce capital gain in the area. 8
Economic Gearing	Undertaking works now will minimise cost of having to undertaken them later as part of any future redevelopment. 5	Undertaking works now will minimise cost of having to undertaken them later as part of any future redevelopment. 5
Life span and project risks	Proposal offers high confidence in minimising human health risks as part of redevelopment. Use of encapsulation -has proven longevity. Project risks associated with tertiary impact; however, design seeks to mitigate this. 6	Proposal offers high confidence in minimising human health risks as part of redevelopment. Use of encapsulation -has proven longevity. Project risks associated with tertiary impact; however, design provides additional confidence in resolution. 8
Flexibility	The primary and secondary source removal phases are flexible in scope to accommodate additional treatment volumes within reason. 8	The primary and secondary source removal phases are flexible in scope to accommodate additional treatment volumes within reason. Additional characterisation and DNAPL pumping facility provide additional flexibility. 10
Total	41	43

Table 6 Economic Indicators

Table 7 indicates qualitatively that the most appropriate feasible solution is excavation and treatment of Primary and Secondary Impacts along with characterisation and pumping of any mobile DNAPL phase, this technology will be selected for deployment on the site.

	Primary + Secondary Source Removal with Grouting	Primary + Secondary Source Removal with DNAPL Exploration and Pumping
Environmental	46	49
Social	42	47
Economic	41	43
Total	129	139

Table 7 Options Evaluation

11.0 Remediation Strategy

To ensure the successful implementation of the site redevelopment the remainder of this document will form a remediation strategy document for the proposed remediation programme. This will serve as a road map ensuring that necessary steps can be taken in an appropriate and timely fashion to ensure mitigation of all potential land contamination hazards.

As with all remediation schemes the Remediation Strategy may alter in detail of volume and treatment as more information becomes available. It is expected that an Remediation Implementation Plan would be developed prior to remediation mobilisation and that this would be updated in detail albeit in accordance with the objectives and validation requirements of this Remediation Strategy.

11.1 Pre-Remediation Works

11.1.1 Removal of Calorific Soils

High calorific soils are present across the Stockyard and portion of the Production Area of the site. These materials represent a potential geotechnical and structural issue should these remain onsite

It is understood that this material is current being removed for use as a fuel by the operators currently present onsite. It is understood that this material will be entirely removed upon commencement of these remediation works.

Should this material, encountered as a thin granular layer of black coke dust, be encountered this should be assumed to be potentially combustible. This should be removed from site for offsite disposal either as a fuel feed stock (under appropriate waste exemption) or be disposed of as a waste in line with Waste Management legislation.

11.1.2 Stockpiles

Currently numerous stockpiled of material understood to be stockpiled inert soils are located in the north of the stockyard area, it is understood that these will be removed by the current operator in advance of site works. Should this material remain in situ, this should be sampled to enable determining of its suitability for use as fill onsite.

11.1.3. Mobile Phone Mast

Currently in the south of the production area a mobile phone communications mast and generator are located, if this remains on site then additional investigation works would be undertaken and, potentially, a physical barrier placed to isolate this area..

11.1.4 Utility Connections

Geo² understand that all utility connections to the site have been disconnected. The contractor should satisfy themselves of appropriate disconnection.

11.1.5 Borehole Decommissioning

It is likely that most, if not all, boreholes onsite will be destroyed during remediation works or as part of site releveling.

To prevent these acting as pathways for migration wells should be decommissioned with an appropriate backfill in line with the EA guidance, 'Decommissioning Redundant Boreholes and Wells'.

11.1.6 Invasive Species

Historical investigations from 2015 suggested the presence of Japanese knotweed within the bund structures in the northeast of the site. Whilst this was not observed during Geo² works in March 2020, its presence cannot be ruled out.

Prior to works the area of the bund should be inspected for evidence of knotweed and appropriate advice sought in the event that such material should be identified.

11.2 Demolition

11.2.1 Remaining Structures

Numerous structures remain present on the site, as illustrated on Figure 7 in Appendix A, and including the following:

- **Stockyard Area:** Brick built engineering workshop in the east, concrete quench pond structures in the northwest, a vacant brick-built structure in the centre of the Stockyard, numerous brick sheds and concrete storage bays located across the area. All concrete slab bases in the Stockyard area should be grubbed up as part of this process.
- **Production Area:** Limited steel and prefabricated structures remain in the eastern portion of this area. This site is surfaced extensively with concrete and remnants of structures, much of which bears clear visual evidence of tar contamination. Extensive excavation in this area should be undertaken as part of later remediation stages once treatment infrastructure is established. Additionally, in the south of this area the floor slab of the former Combined Heat and Power Plant (CHP) remain, this area is free from gross impact, however concrete in this area is understood to be substantial and heavily reinforced.
- **Southern Area:** In the southern area the Biological Effluent Plant remains in situ, this comprises a series of large concrete pool structures, areas of fencing and access roads. All materials should be grubbed up in this area.

11.2.2 Asbestos within Structures

Prior to demolition of relevant onsite structures, an appropriate asbestos survey should be undertaken. In the event that asbestos is present this should be removed from site and disposed of by appropriately licenced contractors to a suitable facility. Following asbestos removal buildings should be issued with certificates of cleanliness to verify successful removal.

11.2.3 Site Won Demolition Rubble

Recovered concrete and brick structures, free from evidence of gross contamination should be retained for processing to permit reuse on site.

Material reuse is a central principle in achieving the sustainable redevelopment of this site, appropriate permitting or exemptions and an application should be sought in order to demonstrate suitability for use and to avoid this material becoming a waste product.

11.2.4 Removal of Bund Structures

Bunds of earth and tyres remain along the northern, north western and eastern boundaries of the Stockyard area. Tyres (and any other unexpected litter or untreatable wastes) should be removed for offsite disposal. Bunds should be removed and processed for reuse onsite, or reduction to 1m below the final site levels.

11.3 Silica Bricks

A stockpile of silica brick bricks remains onsite in the area of the former Coke Ovens. Studies undertaken on these materials indicate that this is suitable for reuse onsite as a fill material. Assessment undertaken on this material by HBR (2016) indicated that this is suitable for 'crushing using a conventional construction crusher to provide a graded material for reuse'. This report highlights the health risks associated with exposure to silica dust, which was found to be prevalent within this material.

The contractor should ensure that suitable methods of processing this material, such as 'using water sprayers and misters to dampen the bricks whilst moving and crushing...to reduce the production of dusts. (HBR 2016). Potential exposure to silica dusts should be considered in the contractor's health and safety working plan for the remediation.

This material once processed is considered suitable for use as general subsoil fill (<1m below final site level).

11.4 Geotechnical Variable Areas

Areas of variable ground were observed in the Stockyard area associated with historic infrastructure, a buried train line and also capped mine shafts (see Figure 7, in Appendix A). Whilst this material appears limited in extent, consideration should be given to geotechnical variability within material.

Mine shaft caps have been proven at the following locations:

- Shaft 1: SE 37505 12187. N412187, E 437503; beneath the fence line of the Engineering Workshop in the east of the Stockyard. Cap level 62mAOD.
- Shaft 2. SE 37431 12221. N412217, E437432, in the centre of the Stockyard. Cap level 608mAOD.
- Shaft 3. SE 37430 12159. N412154, E437430, in the south of the Stockyard. Cap level 61.6mAOD.

To ensure confidence in these materials, this should be excavated for processing for reuse onsite. Testing of materials undertaken in the site investigation and QRA report demonstrates they are suitable for use as general subsoil on the site (<1m below final site level) without treatment.

Mine shaft capping has not been tested and these remain of concern to the development, location of an area of Public Open Space (POS) in this area aims to reduce the potential for geotechnical or ground gas issues within nearby resident properties.

11.5 Establishment of Treatment Areas

Treatment works onsite require the establishment of designated stockpiling, treatment and placement areas. This is currently subject to liaison between demolition and remediation contractors and subject to treatment licence conditions.



11.6 Primary Source Removal

This approach will target the Production Area, where the bulk of the residual contaminant source used the preferential pathways and natural sumps within the infrastructure to become distributed across the area illustrated on Figure 4, in Appendix A. It is estimated that circa 15,000 to 30,000m³ of NAPL or tarry sludge material is present within these structures, estimated at a volume of approximately soil and rock volume of 50,000m³, some of the excavated material would be suitable for direct replacement, impacted soils would be tested and put into treatment streams dependant on level of impact and physical characteristics

Where encountered as a pumpable fluid, such as within identified sumps (near TP24, close to the Coke Ovens), or in other basement of foundation sumps, this should be removed using specialist pumps and equipment. The generated NAPL would be transferred into bunded storage tanks prior to disposal offsite as a waste.

Concrete and soils material excavated by machine should be removed to the designated stockpile or treatment area. Engineering supervision should be present at all times during these works to aid segregation of materials into five classifications:

- **Contaminated:** Material displaying visual or olfactory evidence of gasworks type contamination. This material is likely to contain tars, tarry residue, cyanides and concrete. This material should be stockpiled for stabilisation
- **Contaminated High VOC:** Material granular and loose in nature, (i.e. Made Ground) displaying strongly elevated olfactory evidence of VOCs. This material should be free from evidence of tarry waste. This stream should be segregated for aerobic treatment by bio piling. Anticipated to be encountered predominantly in the Benzole Plant area (Secondary Source area).
- **Uncontaminated:** Material visually free from evidence of contamination, suitable for processing for reuse as general subsoil (<1m below final site level) without treatment.
- **Unsuitable Contaminated:** Material which cannot be treated by the stabilisation plant, such as material which cannot be passed through the stabilisation plant (tar saturated bulk reinforced concrete). This material may be considered untreatable and require offsite disposal.
- **Ancillary Wastes:** This may include tyres, green waste, or other general litter and items excavated which do not comply with the above classifications. This material should be segregated and stockpiled to allow classification and offsite disposal.

In most areas of designated contamination excavation of the Primary Source will reveal underlying bedrock which serve as the vertical limit for excavation. In areas with deeper superficial deposits (or natural ground), visual inspection and verification testing of the underlying deposits should be used to determine whether this material should be addressed as a Secondary Source or allowed to remain onsite.

The excavation should target all areas of the former Production Area, although gross impact is anticipated within the areas indicated on Figure 4, in Appendix A.

11.7 Secondary Source Removal

Predominantly located around the Benzole Plant and former tanks area, this material is located beneath the concrete former site level and associated foundation and structures. This material comprises mainly made ground deposits predominantly highly contaminated granular subsoils.



As detailed above, excavation should be supervised to aid segregation of this material is anticipated to fall into the Contaminated, Uncontaminated and Contaminated High VOC bracket.

The lateral extent of this excavation may be screened by visual, olfactory and VOC monitoring (using a photo-ionisation detector) and verified using soil analysis.

The vertical extend of excavation in this area is likely to be competent rockhead of the underlying sandstone at a depth of 2.0-3.0mbgl.

When exposed the rockhead surface should be assessed for evidence of vertical migration fractures and fissures. Where encountered these should be located (x,y,z survey) to enable targeting with exploratory drilling.

11.8 Stabilisation Operation

11.8.1 Stabilisation Mix

The contractor must be able to produce a suitable stabilisation binder mix capable of encapsulating the target contaminants (listed on Table 3) and achieving suitable geotechnical properties as specified by the Clients engineer.

The binder mix must be verified by leachate testing following deposition against appropriate leachability SSAC as listed on Table 3 (subject to location of deposition).

Binders mix designs typically comprise Ordinary Portland Cement (OPC), lime, Granular Ground Blast Furnace Slag (GGBFS), Pulverised Fuel Ash (PFA) or granular made ground in varying proportions.

11.8.2 Stabilisation Process

Stabilisation will comprise the screening and segregation of materials to break the structure of the soil and to reduce the size of material to suitable treatable dimensions. The specification for this material will be dependent upon the selected machinery used in the treatment process and to be specified by the contractor to ensure suitable geotechnical performance of the resulting stabilised material.

Material will be mixed with the binding agent (and potentially water) using a specialised mixer, this could either be done in the selected placement area or be undertaken ex situ for transport into the deposition area immediately upon treatment of the material. Once treated the material will increase in strength over a period of weeks as the binding agents encapsulate the contaminants. The length of the curing time is subject to the mix design.

11.8.3 Stabilisation Performance

Samples will be obtained at a frequency of one sample per 250m³. Samples will be obtained by using composite sampling techniques, by which a single sample is obtained by collecting equivalent volumes of material from positions across the stockpile.

11.9 Bio-remediation Operation

11.9.1 Bio-remediation Process

The bioremediation process aims to treat contaminated soils by encouraging natural biodegradation to occur within the soils material. This process is achieved through the following mechanisms:



- Through the breaking down of the soil structure to encourage air flow through the material.
- Through application of a vacuum, supplying a source of O₂ to the bacteria and recovering volatilised contaminants from the soils.

The three key phases of the treatment process are summarised below:

1. Screening of accepted materials to break down soil structure, remove oversized (greater than 150mm) and untreatable materials (concrete, tarry waste or slurry).
2. Bio-piling of the soils to encourage rapid natural biodegradation.
3. Monitoring, sampling and decompaction of the bioremediated soils to ensure successful treatment.

11.9.2 Biopile Construction

The soils are anticipated to have a high odour releasing potential, therefore mechanical aeration (windrows) would not be anticipated as the primary mechanism for introducing oxygen to the soils. To reduce the odour potential it is proposed to use a Bio-Pile system which pulls air through the soils but critically the generated off gas can be captured and treated. In addition, if the encountered material is more amenable to a Soil Vacuum Extraction approach i.e. reliant on volatilisation rather than biodegradation then the infrastructure is in place for either approach.

Bio-piles should contain material of a uniform nature and contaminant type and loading to ensure an equal treatment rate within the bio-pile. This will reduce the potential for variable treatment rates within the material and prevent hotspots of insufficiently treated material remaining within a larger predominantly suitable stockpile.

The bio-piles will be formed by excavator with a ditching bucket following transfer of materials from the stockpile.

Odorous soils awaiting treatment would also be covered manually by suitable impermeable tarpaulin cover to optimise moisture retention and minimise run off and odour.

Bio-piles should be positioned overlying the vacuum recovery pipework, lain in gravel beds along the floor off the treatment area at a distance of 2m apart and at least 3m away from the periphery of the bio-pile to prevent atmospheric shortcutting.

There is no maximum bio-pile width and it would be anticipated that bio-piles will vary in size dependant upon the source and nature of materials accepted. Geo² would consider that additional efficiencies may be achieved in terms temperature insulation for wider stockpiles. Stockpiles should not exceed 3m in height.

11.9.3 Biopile Treatment

The biopile treatment plant should comprise a suitable vacuum system capable of extracting a suitable volume of pore volumes of air through the soil material, using the vacuum recovery pipework. Sizing and specification of this plant is the responsibility of the contractor. The plant should ensure that emissions can be controlled from waste air

streams (GAC use would be anticipated to control vapour) and also from fugitive emissions from uncovered bio-piles.

Bio-pile treatment would be anticipated to take between 8-16 weeks, depending upon contaminant type and loading (should tarry waste enter the treatment process, this will prove very difficult to aerobically degrade on this timescale).

The bio-pile is expected to require periodic decompaction, estimated to be every 4-6 weeks. Decompaction will entail the excavation of the entire pile using a ditching bucket, care should be taken close to the base of the bio-pile to avoid damage to the gravel surrounded soil vapour lines running along the base of the bio-pile.

Covering of bio-piles should be considered for odourous or heavily contaminated materials in order to reduce nuisance odours or to insulate the bio-pile.

11.9.4 Verification of Biopile Treatment

Ongoing performance monitoring may be achieved by monitoring offgas, use of soil thermometers and soil testing against SSAC.

The bio-pile treatment process is validated as complete by obtaining soil samples to demonstrate that the processed material complies with the SSAC as displayed in Table 3. Treatment material achieving this status should be classified as general subsoil suitable for use at depths of <1m below final land level.

Samples will be obtained at a frequency of one sample per 250m³. Samples will be obtained by using composite sampling techniques, by which a single sample is obtained by collecting equivalent volumes of material from positions across the stockpile.

11.10 DNAPL Exploration Drilling

Following completion of the Secondary Source Removal, the underlying bedrock will have been exposed and evidence of fissures and fractures located. The potential for underlying DNAPL to be characterised should be assessed using coring techniques to recover undisturbed core samples of sandstone, aiming to target the top of the underlying mudstone (a depth of approximately 16m below rockhead in the target area). Boreholes must be installed to target this key horizon, whilst still allowing for assessment of any previously unidentified LNAPL.

Borehole monitoring and core log characterisation should be assessed for evidence of DNAPL within the water column. Groundwater sampling (passive, discrete or low flow), use of interface probes NAPL recovery pumps should be considered as a means of assessing direct lines of DNAPLP evidence.

Should sufficient evidence be gathered to determine the presence of DNAPLs an assessment should be made of its recoverability, through pump testing and analysis. This information may allow further characterisation of contaminant fate transport within the sandstone aquifer.

Drilling would be expected in two phases, a first targeted assessment of upto 4 boreholes to assess presence of absence of DNAPLs, with further boreholes at a frequency to be determined subject to the results of NAPL characterisation. All boreholes should be capable of being used for pumped recovery.

11.11 NAPL and Water Recovery Plant

11.11.1 NAPL Pumping

Should NAPL be encountered and proven as recoverable, or requiring removal, then this strategy proposes to reduce the contaminant mass within the tertiary source, thereby reducing the ongoing impact in the dissolved phase.

Specially designed air driven (or equivalent suitable) bottom (or top should LNAPL be encountered) loading pumps are installed to recover DNAPL. These allow readily recoverable DNAPL to be abstracted and stored on site prior to disposal off site. This simple and robust approach would allow a mass removal approach to be undertaken at the significant depths of potential NAPL impact. Subject to performance testing this approach should aim as a minimum to recover measurable, pumpable DNAPL where encountered within boreholes.

Based on experience, flow and recoverable volumes of liquid are likely to be low due to the viscosity of the NAPL. Slow operation allow NAPL rebound within boreholes, thereby maximising source reduction, over that achieved by dissolve phase pumping.

11.11.2 Storage and Treatment of Recovered NAPL

Recovered product should be separated into NAPL and water with resulting water either treated for disposal under licence onsite or for offsite disposal. NAPL should be quarantined for offsite disposal under relevant waste management licencing.

11.11.3 Operational Objectives

Removal of all DNAPL is considered likely to be unfeasible, similarly this approach will not be sufficient to achieve the SSAC proposed in Table 3. This approach aims to reduce the source volume as part of a combined approach (including Primary and Secondary Source removal as well as pathway severing) to reduce risk to Lineside Dyke.

Pumping should be undertaken until asymptotic recovery is observed, in the form of a plateauing of recovery following an observed reduction and diminishing returns at which point this approach is likely to have achieved its technical limit. It would be anticipated that this would occur within circa 12 months of operation.

11.12 Site Filling Works

11.12.1 Site Fill Types

Site filling works are proposed to increase site levels, whilst final levels have yet to be crystallised in the design, Geo² understand that this includes lifting the Stockyard from circa 63m AOD to approx. 65-68m AOD, levels in the Production are likely to remain similar to their current levels of 72m and the lowest portion of the Southern Area is likely to increase by 1-2m over its existing level of 62m AOD.

The contractor must ensure that final agreed site levels are achieved by placed soils.

The fill to be used onsite to establish final site levels will fall into the following categories:

- **General Subsoil:** Comprising recovered uncontaminated soils, recycled site won hardcore, treated biopiled soils and imported crush. All material must meet the criteria displayed in Table 3 for leaching to groundwater (subject to the location of this material). Provided this falls outside of the top 1m of soil, this does not need to achieve the Human health SSAC listed. This may be used in any area of the site.
- **Stabilised Material:** Comprising encapsulated materials, this should only be deposited in the area of Public Open Space (POS) as shown on Figure 3. It is anticipated that a void space of approximately 10,000-12,000m³ is available in the areas around the mine shaft caps. A further void volume of approximately 5,000m³ has been identified in the Southern Area of POS.
- **Shallow Soils:** Should be suitable for use in the top 1m of soils and therefore should comply with the SSAC protective of human health listed in Table 3. For compounds not listed in Table 3, C4SL, LQM and EIC derived GAC should be adopted to screen this material.

- **Topsoil:** Topsoils should be imported from a verified source and either tested to ensure compliance with the above criteria or identified as meeting PAS accreditation standards.

11.12.2 Cover System

The specification of the cover system falls outside of the remit of this remediation design and will be the responsibility of the house builders, looking to develop out the property.

It is indicated that the top 1m of soils should provide a cover system acting as a barrier between future site users and the general subsoils.

12.0 Validation

12.1 Watching Brief

It is recommended that a watching brief be undertaken by contractors during the demolition and remediation works and also during subsequent development phases (outside the scope of this report) to ensure any previously unidentified contamination impacts may be appropriately addressed. Contractors should be briefed on areas of expected contamination in advance.

If any significant unexpected contamination is uncovered during the redevelopment, measures to be enacted are detailed in the contractors Watching Brief Method Statement, in Appendix B. The purpose of the Watching Brief is to ensure such material is appropriately characterised and suitable measures are enacted to ensure no potential current or future hazards are created by this material.

12.2 Validation of Excavated Soils

In order to demonstrate that key sources have been satisfactorily removed, validation samples should be obtained to demonstrate that no remaining contamination is present which exceeds the appropriate Site Specific Assessment Criteria (Table 3) or relevant GAC criteria as derived by EA, LQM/CIEH, EIC and DEFRA based on the proposed commercial end use of the site. Samples should be obtained from:

- The sides and base (where appropriate, and not bedrock) of any excavation considered to be potentially contaminated, with a frequency of one sample per 250m² of excavation, from the perimeter.
- Areas of previously unidentified contamination in order to characterise this material.

The samples should be sent to a laboratory for analysis for compounds including the following:

- Fractionation and speciation of hydrocarbons including analysis for benzene, toluene, ethylbenzene and xylenes (BTEX) and MTBE compounds.
- Heavy metals and Sulphate by IRIS emission spectroscopy;
- Cyanide by colorimetric determination using Automated Flow Injection Analyser;
- Volatile and semi volatile components (including PAHs and Phenols), by GC/MS; and
- Asbestos by microscopy.

The results of the validation sampling should be sufficient to demonstrate the satisfactory removal of this impact (and free from asbestos) when compared with selected SSAC values shown in Table 3.

12.3 Verification of Imported or Reused Materials

Where any material is imported to site to backfill any excavations, to adjust site levels or establish areas of landscaping the following factors should be considered where material importing is required.

This would be necessary to satisfy the Regulatory Authorities that the above measures have been successfully implemented and this needs to be independently confirmed, in accordance with the guidance supplied in the document produced by the Yorkshire and Lincolnshire Pollution Advisory Group (YALPAG): "Guidance on the Verification Requirements for Cover Systems".

12.3.1 Sampling Criteria

Imported topsoil must be able to demonstrate suitability for use; this should include information demonstrating the source of the materials origin and suitable chemical analysis. Sampling of imported material should be undertaken on a minimum frequency of 3 samples, or 1 per 250m³ for greenfield/manufactured sourced materials, or 6 samples with 1 sample per 100m³ for brownfield sourced materials (whichever is greater).

Where site won material is selected for reuse onsite it must be ensured that this material is also suitable for its desired usage and tested as per brownfield sampling.

Imported crushed stone should be sampled on a frequency of 1 per 1,000m³ (or a minimum of 3 samples).

12.3.2 Laboratory Analysis

Soils analysis should include the following:

- **Break layer:** CLEA metals suite, including speciated PAH and asbestos.
- **Topsoil:** CLEA metals suite, including speciated PAH and asbestos. Including TPH-CWG and additional relevant analysis (if deemed appropriate) when materials are imported from a brownfield source, or PAS certification.
- **Subsoils:** TPH- CWG, VOC and SVOC suites (inc. US EPA PAH 16) for compounds listed in Table 3, heavy metals, cyanides.

12.3.3 Verification of Fill

All deposited material should be capable of compaction to achieve a suitable geotechnical standard to support the proposed development, to be confirmed by the Clients engineer. Appropriate testing must be undertaken at a frequency to be specified by the engineer to demonstrate that this has been achieved.

13.0 Ground Gas and Radon

Monitoring of ground gases reported in the Site Investigation report has indicated that the overall site falls into a Characteristic Situation 2 for ground gas risk.

This assessment is insufficient to characterise the ground gas risk adequately for a residential development in accordance with Ciria C665 guidance, a further six visits over three months should be undertaken.

The remediation detailed herein will significantly alter the ground gas regime, with the introduction of permeable fill, the removal of contaminant sources, likely to reduce the level of risk at the site. As such the data collected to date, should be considered as a worst-case assessment.

Following completion of the levelling works across a sufficient proportion of the site, a further three months of monitoring should be undertaken. As boreholes used in earlier phases are likely to have been destroyed, further window sample wells should be installed across the site to provide a suitable coverage to permit the completion of the ground gas monitoring.

A ground gas risk assessment should be produced to inform upon appropriate foundation design requirement in accordance with Ciria C735 and BS8485 +A1 guidance.

In addition to this the site is located within an area where more than 1% of homes are above the Action Level, as defined by the National Radiological Protection Board.

Appropriate radon mitigation should be adopted in line with BRE 211 in all new homes and dwellings on the site.

On the basis of existing data, it is therefore considered likely that all new homes should be fitted with a vapour barrier, resistant to ground gases and radon.

14.0 Additional Considerations

14.1 Geotechnical and Aggressive Ground Conditions

This report does not address concerns pertaining towards aggressive ground conditions or geotechnical suitability, all of which must be agreed with the Clients engineer in order to ensure suitability of the final design.

14.2 Potable Water Pipe Installation

To ensure any new water pipes installed will meet the installation criteria of the water companies any water pipes to be installed running through made ground materials should be laid in clean lined trenches. All water pipes should comprise barrier pipe rather than standard MDPE.

14.3 Health and Safety Considerations

It would be required that appropriate risk assessments and method statements are put in place prior to each aspect of the works. Liaison with the Client and other subcontractors onsite should be held in advance of ensure safe working conditions for all staff and the environment.

14.4 Security

The site must be appropriately fenced off to prevent trespass and unauthorised access. Consideration must be given to securing open excavations and risks from ponding water.

14.5 Dusts

To minimise risks from dusts (potentially containing asbestos fibres) damping down or covering of stockpiles may be considered necessary. Movement of contamination off site on vehicle wheels shall be minimised by cleaning of vehicle wheels and/or use of a road sweeper, as required.

14.6 Welfare

Washing facilities and a clean mess room from which work boots and overalls are excluded. Provision must be allowed to permit adequate hygiene to be maintained and to ensure provision of appropriate PPE.

14.7 Utility Provision

The contractor must arrange all necessary power, drainage and water supply connections in order to facilitate works.

14.8 Lineside Dyke

During remediation works, quarterly samples should be obtained from designated sample points upstream and downstream of the site. These should be tested for hydrocarbons, PAH, Phenols, heavy metals and cyanides.

15.0 Waste Management Plan

15.1 Untreatable Soils

Material considered to be untreated, as defined earlier, should be quarantined for offsite disposal, under appropriate waste management legislation.

All treatable soils and site won demolition materials is to be retained for reuse onsite wherever possible.

15.2 Recovered NAPLs

NAPLs recovered during Primary Source removal, DNAPL recovery phases should be quarantined in bunded tanks or drums (as appropriate), should be quarantined for disposal at a appropriately permitted facility using an suitable licensed waste carrier in accordance with waste management legislation.

15.3 Asbestos

It is understood that should remaining buildings be found to contain asbestos this will be removed by specialist contractors in advance of this remediation. Should materials be encountered considered to be ACMs, these should be characterised and dealt with be appropriately trained persons.

Sampling of shallow soils has not encountered limited evidence of asbestos fibres, as detailed in the QRA report, these are considered to present a low risk to future use of the site, however the potential for this material to be present sporadically and infrequently within all made ground across the site must be considered as part of the Construction Phase Health and Safety Plan.

Whilst no asbestos is anticipated during these works, Geo² cannot rule out that asbestos may be encountered during site works. Should contractors become aware of potentiality asbestos containing materials, expert assistance should be sought to characterise and remove this material.

15.4 General and Ancillary Wastes

The contractor must make provision for offsite disposal of general ancillary wastes including general construction waste, tyres, general waste and green waste recovered as part of demolition and levelling works.

16.0 Licencing

To ensure materials scheduled for reuse on site cannot be considered as a 'waste' a Materials Management Plan, should be issued in advance of the start of works in accordance with the CL:AIRE Definition of Waste Code of Practice (v2 March 2011).

Importation of soils may need to be undertaken under a separate Environmental Permit, or Hub and Cluster system.

Remediation processed will require deployment of an Environment Permit.to enable these treatment works to proceed.

Discharge of wastewater, if necessary, may require a trade effluent discharge consent from the sewerage undertaker.

Should abstracted volumes of groundwater exceed 20m³/day a Section 32 permit to undertake aquifer testing and groundwater remediation will be required from the EA.

It will be the responsibility of the contractor to ensure that all necessary steps are taken to source and adhere to the relevant permits.

17.0 Verification Plan

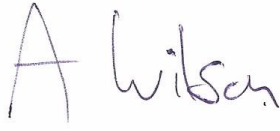
The validation sampling methodology and findings, detailing the remedial works undertaken, will be presented in a report following completion of the remediation.

The aim of the report will be to demonstrate that the measures proposed in this Remediation Statement have been undertaken and to demonstrate the degree of success achieved. To ensure the verification report can be completed the following information should be requested from suppliers or retained for inclusion:

No	Item	Info required
1	Validation of Principal, Secondary Source Removal	Provide details to demonstrate that all identified impacted materials have been successfully removed Including sampling analysis, site plans and photographs.
2	Pathway Removal	Provide evidence in support of the pathway removal between the site and Lineside Dyke.
3	DNAPL Drilling and Recovery	Borehole logs and soils and groundwater test data, results of and ancillary test works and interpretative reporting on DNAPL recoverability where encountered. Where deployed provide evidence of recovery, performance monitoring and cessation of pumping agreed with the regulators.
4	Stabilisation	Demonstration of the mix deployed, and volumes treated and final deposition. Performance testing to demonstrate suitability of the material.
5	Biopiling	Demonstration of the volumes biopiled, monitoring and performance testing and verification sampling.
6	Waste Removal from Site	Waste Transfer Notes / Consignment Notes for material offsite disposal. Detail regarding source locations of wastes.
7	Asbestos	Ensure a pre demolition and any necessary subsequent asbestos certification can be provided associated with the remaining structures onsite.
8	Ground Gas Assessment	An appropriate assessment must be completed to comply with Ciria and BS guidance to enable appropriate foundation design.
9	Licencing	Evidence must be retained of the use of and adherence Environmental Permit licence conditions and any additional permits, exemptions used in the treatment works.
10	Imported or Reused Materials	Sample analysis should be provided to demonstrate the quality of imported soils for both geotechnical and contamination. Delivery notes should be made available to demonstrate the volume of imported materials.
11	Watching Brief	Was any unexpected contamination encountered? Have any unexpected structures been identified on-site? What remedial activities have been undertaken as a result? If so, evidence should be provided to demonstrate it is classification, it's volume and how it was treated.
12	Materials Management Plan	Demonstrate the provision of an MMP, with details of a relevant QP signature and of CL:AIRE submission. Demonstrate that material reused on site has met suitability criteria detailed herein.
13	Land Levels	Demonstrate through topographical levelling that the remediated site has achieved the necessary site levels.

Table 10: Details for Verification Report

This report was prepared by



Adam Wilson

29.07.2020

Date

This report was reviewed by



Gary Chapman

29.07.2020

Date

18.0 Limitations

Geo²s' conclusions, recommendations and opinions are based on information gathered at the time of the investigation from a variety of third party sources and from observations made during site reconnaissance and ground conditions encountered during the field work and on the results of laboratory and field tests performed during the investigation. However, there may be conditions at the site that have not been taken into account, such as unpredictable soil strata and water conditions between or below intrusive locations. It should also be noted that groundwater levels may vary due to seasonal or other effects and may at times differ to those measured during the investigation.

A portion of this report is based solely upon information provided by third parties. The information has not been independently verified by Geo². Whilst this report and the opinions given in it are accurate to the best knowledge of Geo², Geo² cannot guarantee the completeness or accuracy of any descriptions, opinions or conclusions based solely upon information that has not been independently verified.

The recommendations contained within this report represent our professional opinions. These opinions were arrived at in accordance with currently accepted industry practices and hydrological and engineering practices at this time. As such they are not a guarantee that the site is free of hazardous materials or conditions.

Geo² prepared this report for our Client; any third parties using this report do so entirely at their risk. Geo² makes no warranty or representation whatsoever, express or implied, with respect to the use by a third party of any information contained in this report or its suitability for any purpose. Geo² assumes no responsibility for any costs, claims, damages or expenses (including any consequential damages) resulting from the use of this report or any information contained in this report by a third party.

19.0 References

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Department of the Environment

Industry Profile-

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March 2010

Appendix A

Figures



Ref: Ordnance Survey

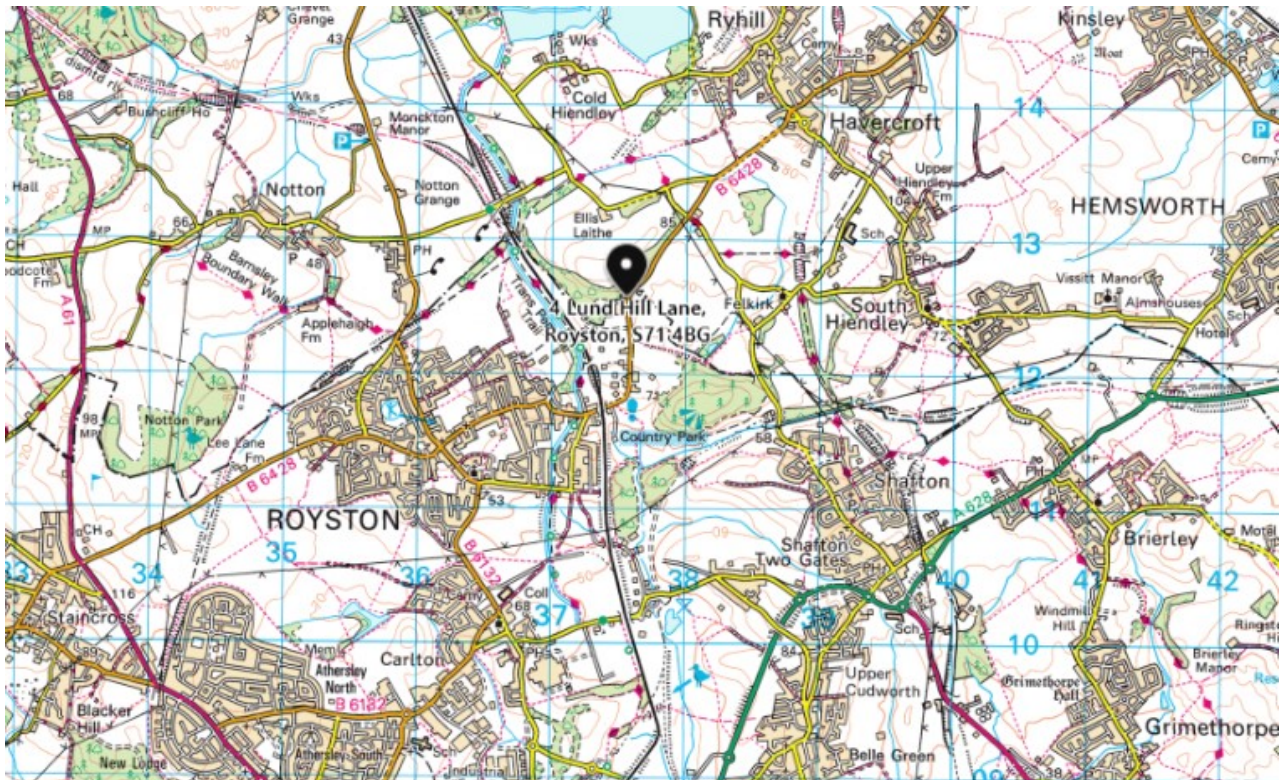


Figure 1 Site Location -
Former Monckton Coke and Colliery Works, Lund Hill Lane, Royston,
Barnsley, South Yorkshire, S71 4BD.

Geo2 Remediation Limited, The Coniston, Louisa Street, Idle, West Yorkshire, BD10 8NE

Tel: (0113) 2575397

www.geo2.co.uk

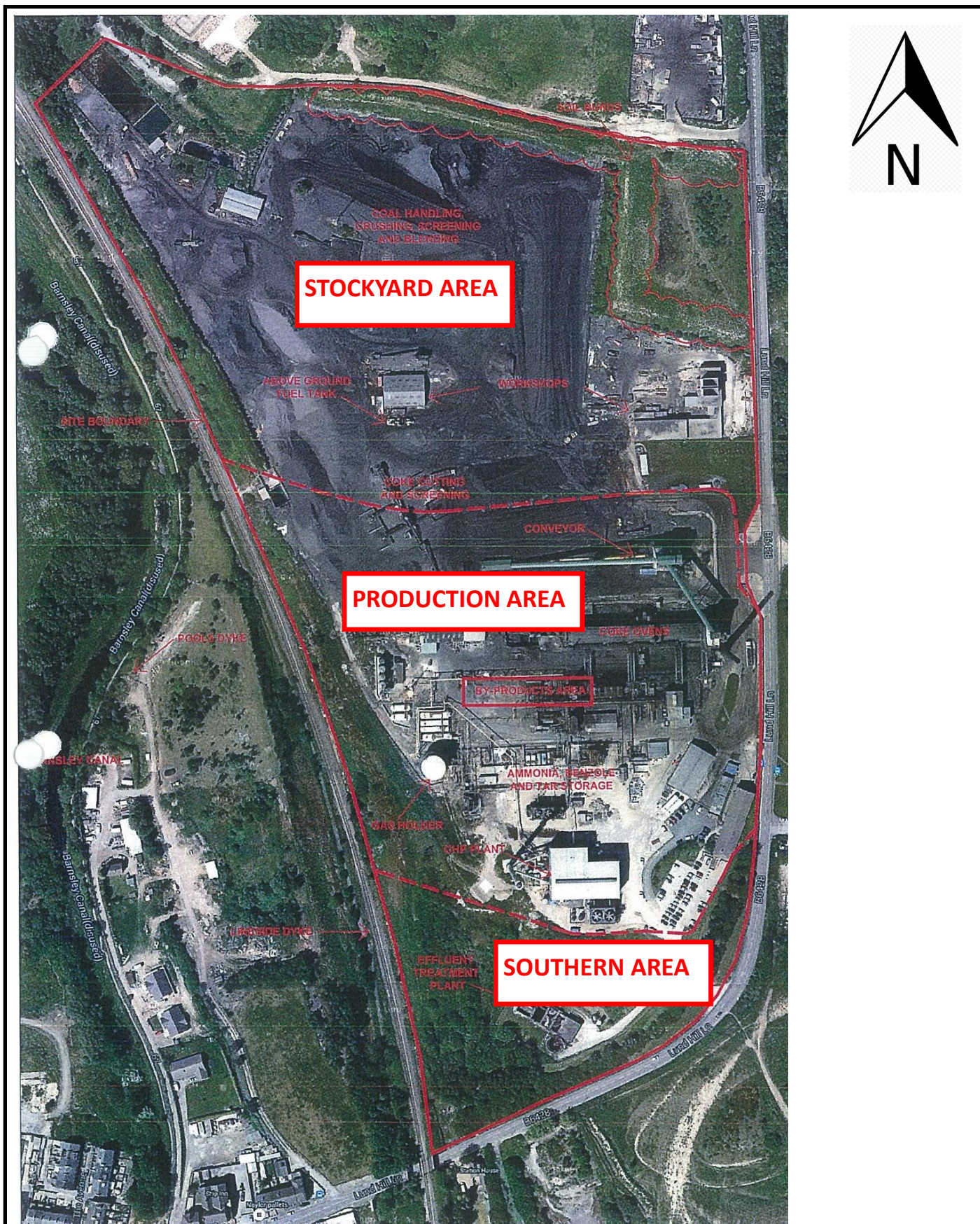


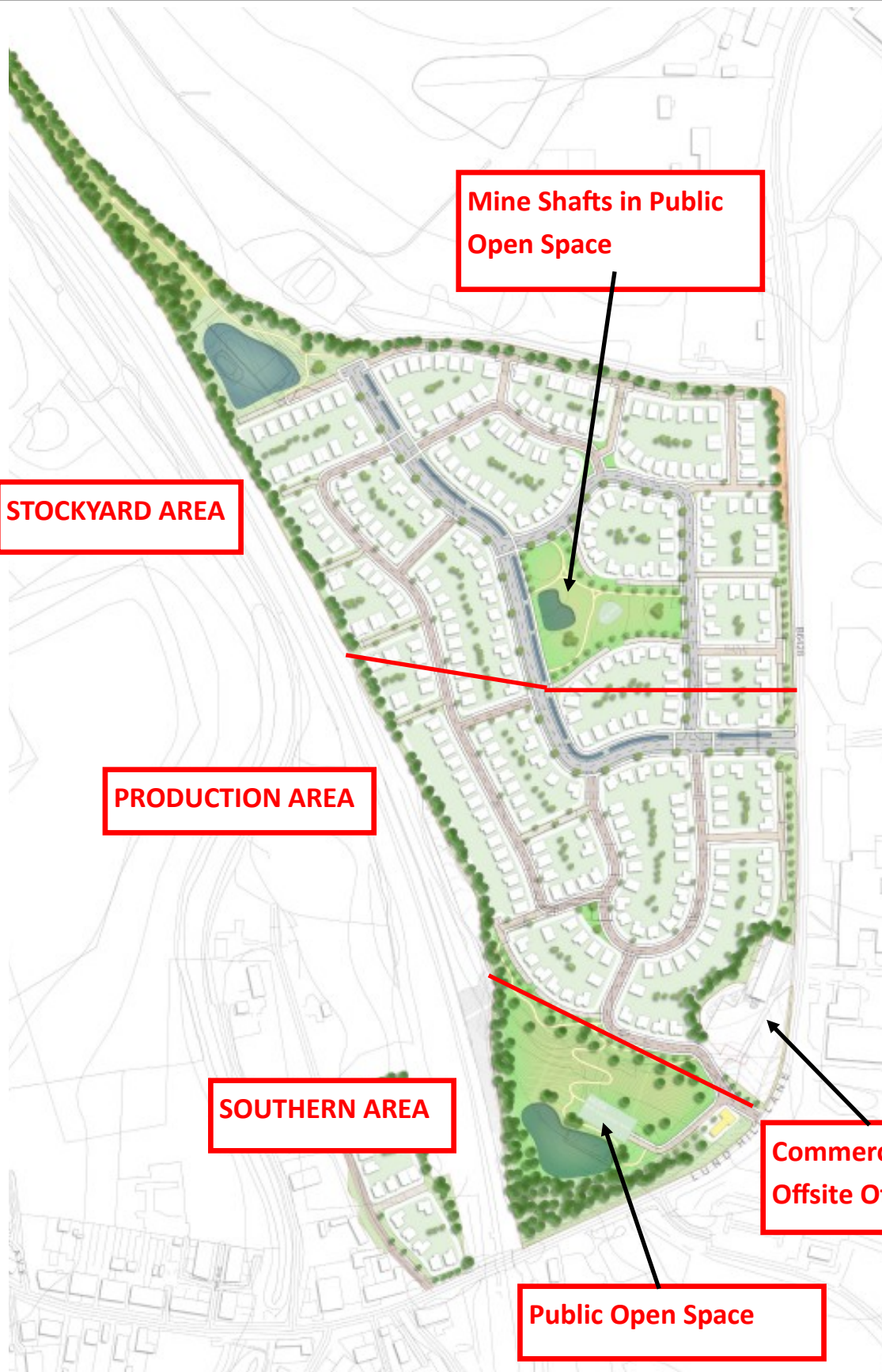
Figure 2— Aerial Photo and Site Layout

Drawn from Patrick Parsons 2015

Geo² Remediation Limited, The Coniston, Louisa Street, Idle, West Yorkshire, BD10 8NE

Tel: (0113) 2575397

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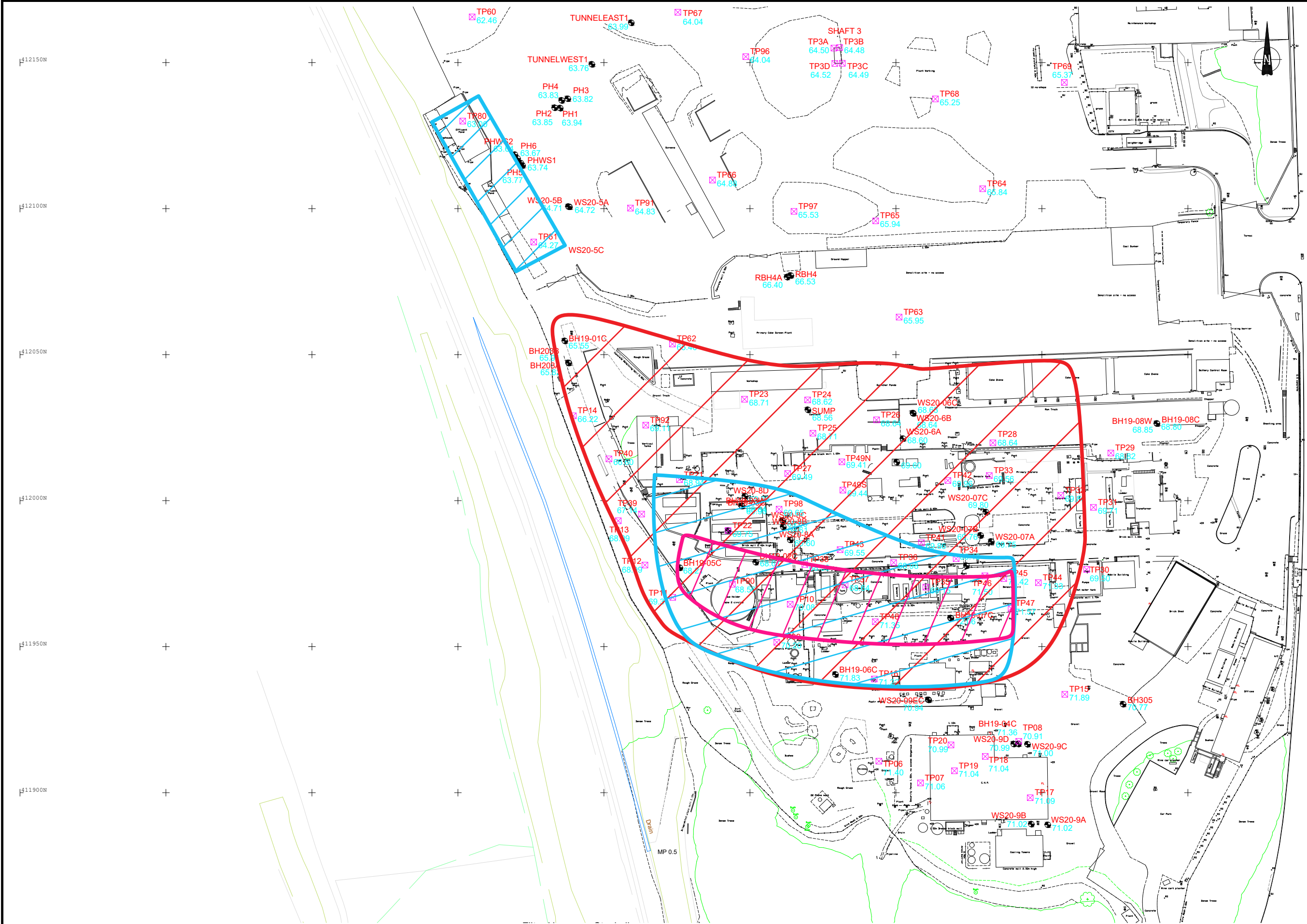
Figure 3 — Proposed Site Development Masterplan

Provided by Pegasus Group

Geo² Remediation Limited, The Coniston, Louisa Street, Idle, West Yorkshire, BD10 8NE

Tel: (0113) 2575397

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LEGEND

- Exploration Hole
- Trial Pit
- Principal Source
- Secondary Source
- Tertiary Source

Figure 4
Key Areas
of Impact.

Sheet Layout:

Geo2

Geo2 Remediation Limited
11 The Mending Rooms, Sunny Bank Mills, Town St,
Farsley, Leeds, LS28 5UJ.

Client

-

Site Location

Monckton Coke Site

-

Surveyed by	Drawn by	Approved by
-	A.B.	-
Drawing No.	0720-GEO2-7955	Revision
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 2 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Approximate Location of Coal Breeze > 0.1m

Figure 5a

Coal Breeze

Sheet Layout:

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Client

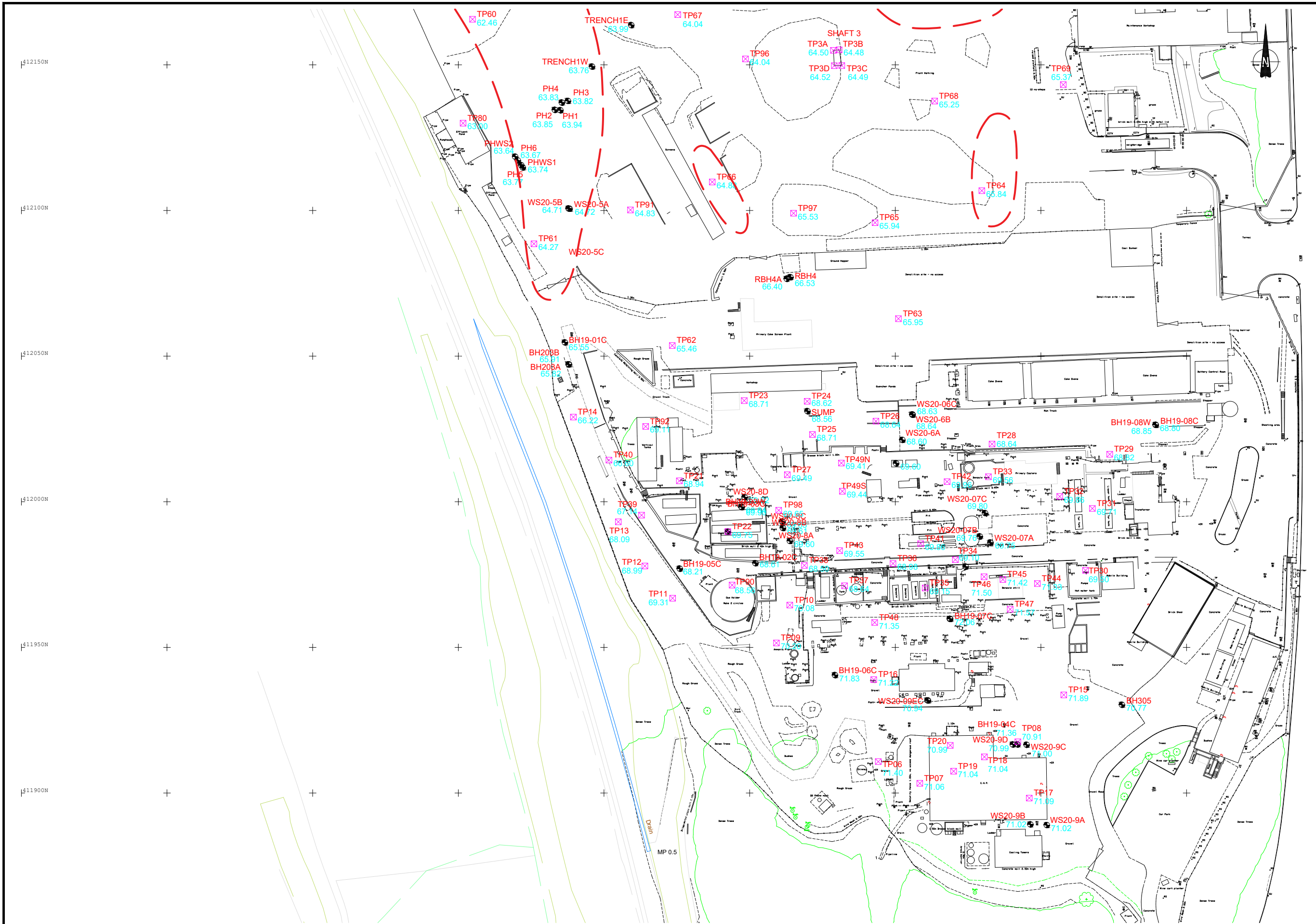
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Site Location

Monckton Coke Site

-

Surveyed by	Drawn by	Approved by
-	A.B.	-
Drawing No.	0720-GEO2-7955	Revision
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 1 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Approximate Location of Coal Breeze > 0.1m

Figure 5b
Coal Breeze

Sheet Layout:

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Farsley, Leeds, LS28 5UJ.

Client: -

Site Location:
Monckton Coke Site

Surveyed by: -	Drawn by: A.B.	Approved by: -
Drawing No. 0720-GEO2-7955	Revision: -	
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 2 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Hydrocarbons
- Metals
- Inferred DNAPL
- Cyanide

Figure 6a
Significant
Groundwater
Impact.

Sheet Layout:

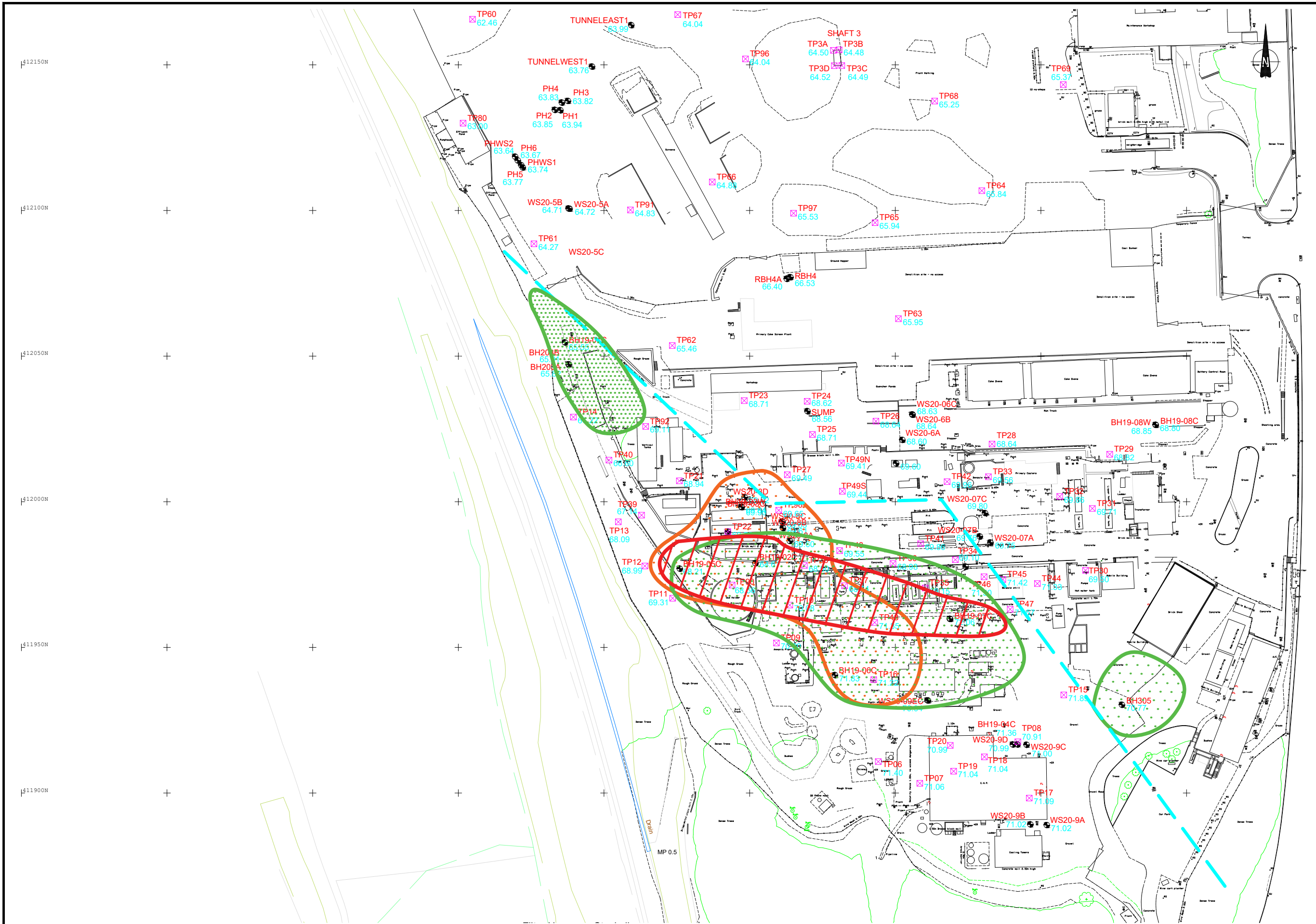


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Farsley, Leeds, LS28 5UJ.

Client -

Site Location
Monckton Coke Site

Surveyed by	Drawn by A.B.	Approved by
Drawing No. 0720-GEO2-7955	Revision	
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 1 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Hydrocarbons
- Metals
- Inferred DNAPL
- Cyanide

Figure 6b
Significant
Groundwater
Impact.

Sheet Layout:

Geo2

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11 The Mending Rooms, Sunny Bank Mills, Town St,
Farsley, Leeds, LS28 5UJ.

Client

Monckton Coke Site

Surveyed by	Drawn by	Approved by
	A.B.	
Drawing No.	0720-GEO2-7955	Revision
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 2 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Hydrocarbons
- Metals
- Inferred DNAPL
- Cyanide

Figure 6c
Significant
Groundwater
Impact.

Sheet Layout:

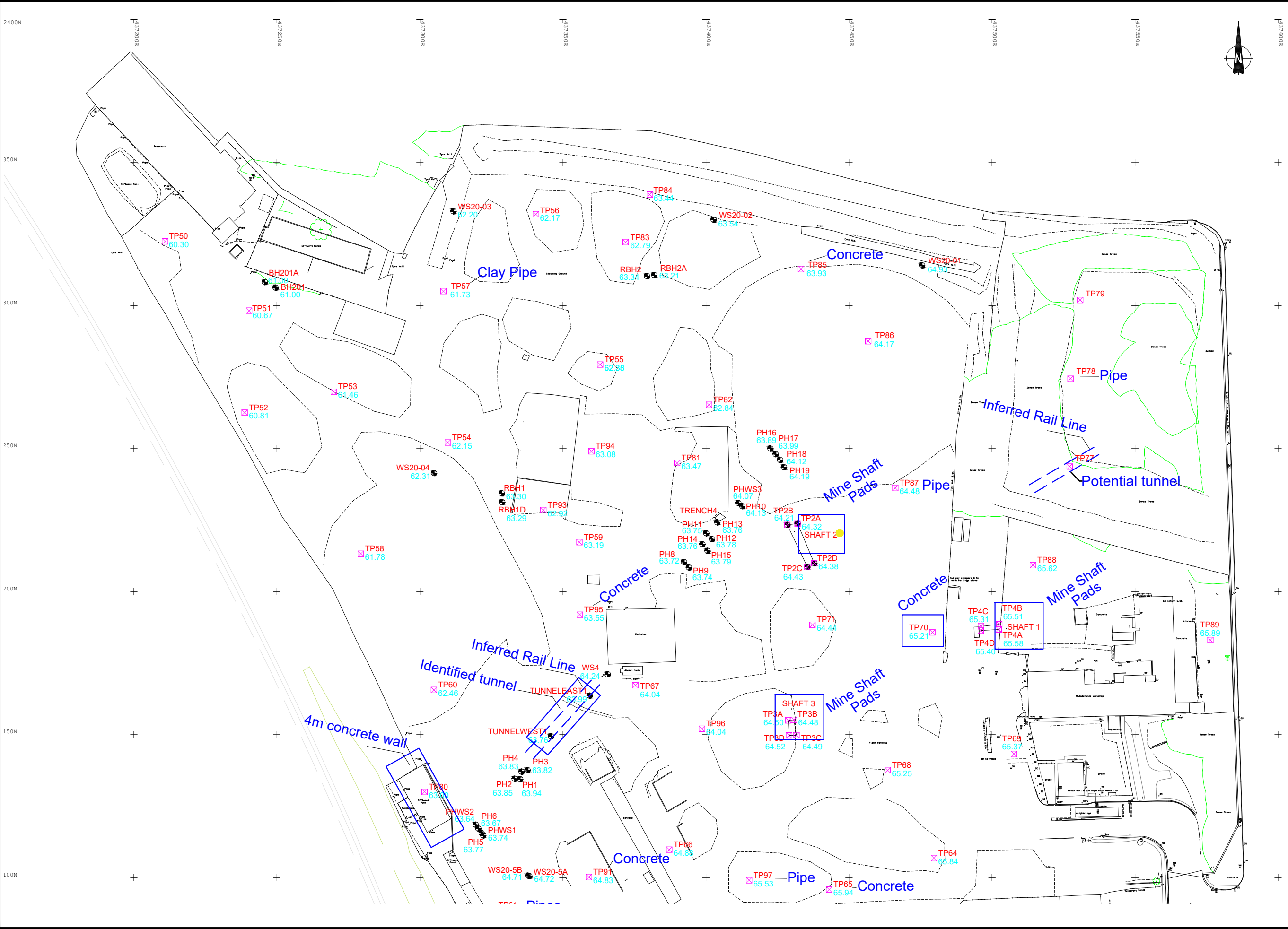
Geo2

Geo2 Remediation Limited
 11 The Mending Rooms, Sunny Bank Mills, Town St,
 Farsley, Leeds, LS28 5UJ.

Client: -

Site Location:
Monckton Coke Site

Surveyed by: -	Drawn by: A.B.	Approved by: -
Drawing No. 0720-GEO2-7955	Revision: -	
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 3 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Obstruction

Figure 7a
Obstruction
Plan

Sheet Layout:

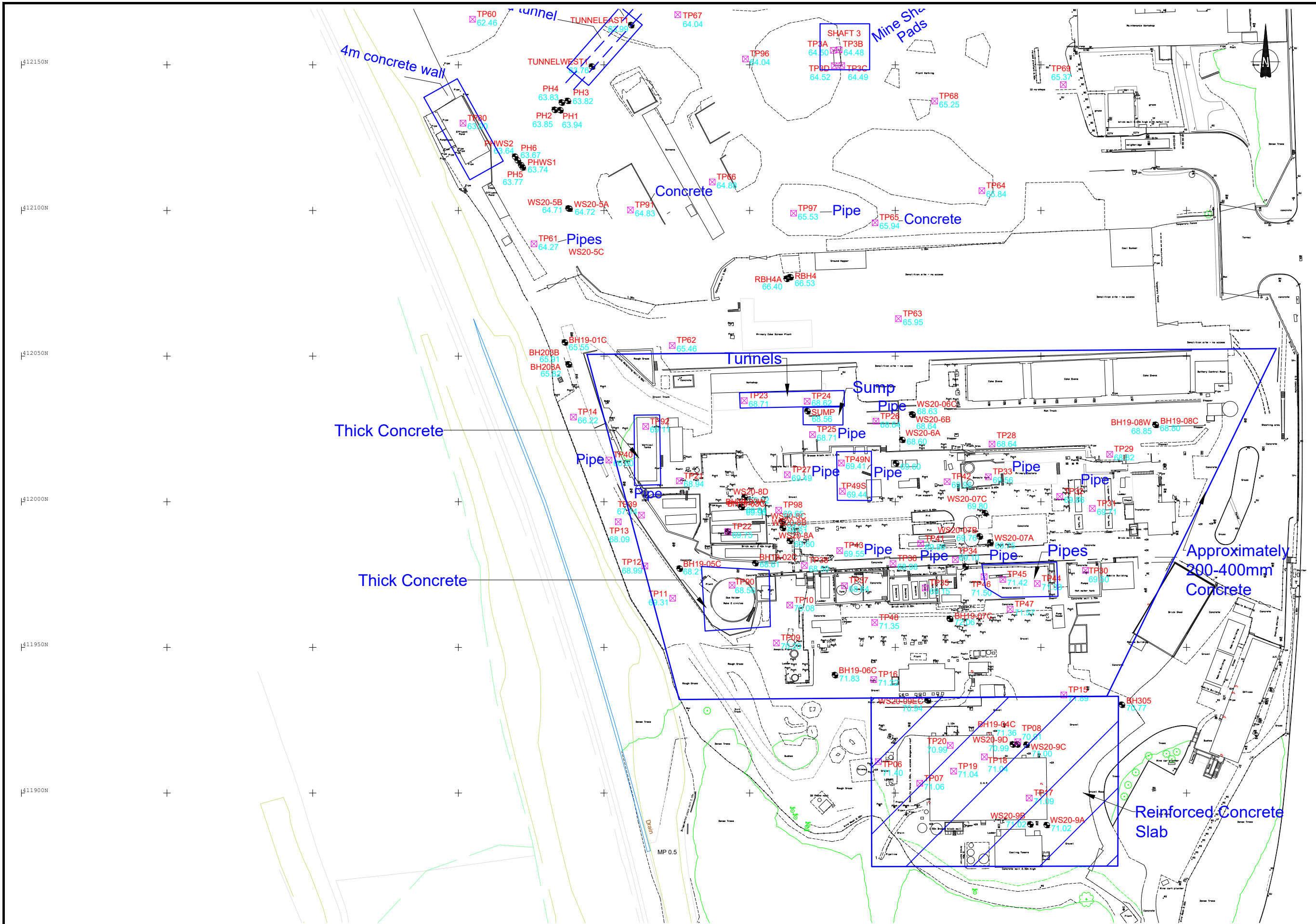
Geo2

Geo2 Remediation Limited
11 The Mending Rooms, Sunny Bank Mills, Town St,
Farsley, Leeds, LS28 5UJ.

Client: -

Site Location:
Monckton Coke Site

Surveyed by: -	Drawn by: A.B.	Approved by: -
Drawing No. 0720-GEO2-7955	Revision: -	
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 1 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Obstruction

Figure 7b
Obstruction
Plan

Sheet Layout:

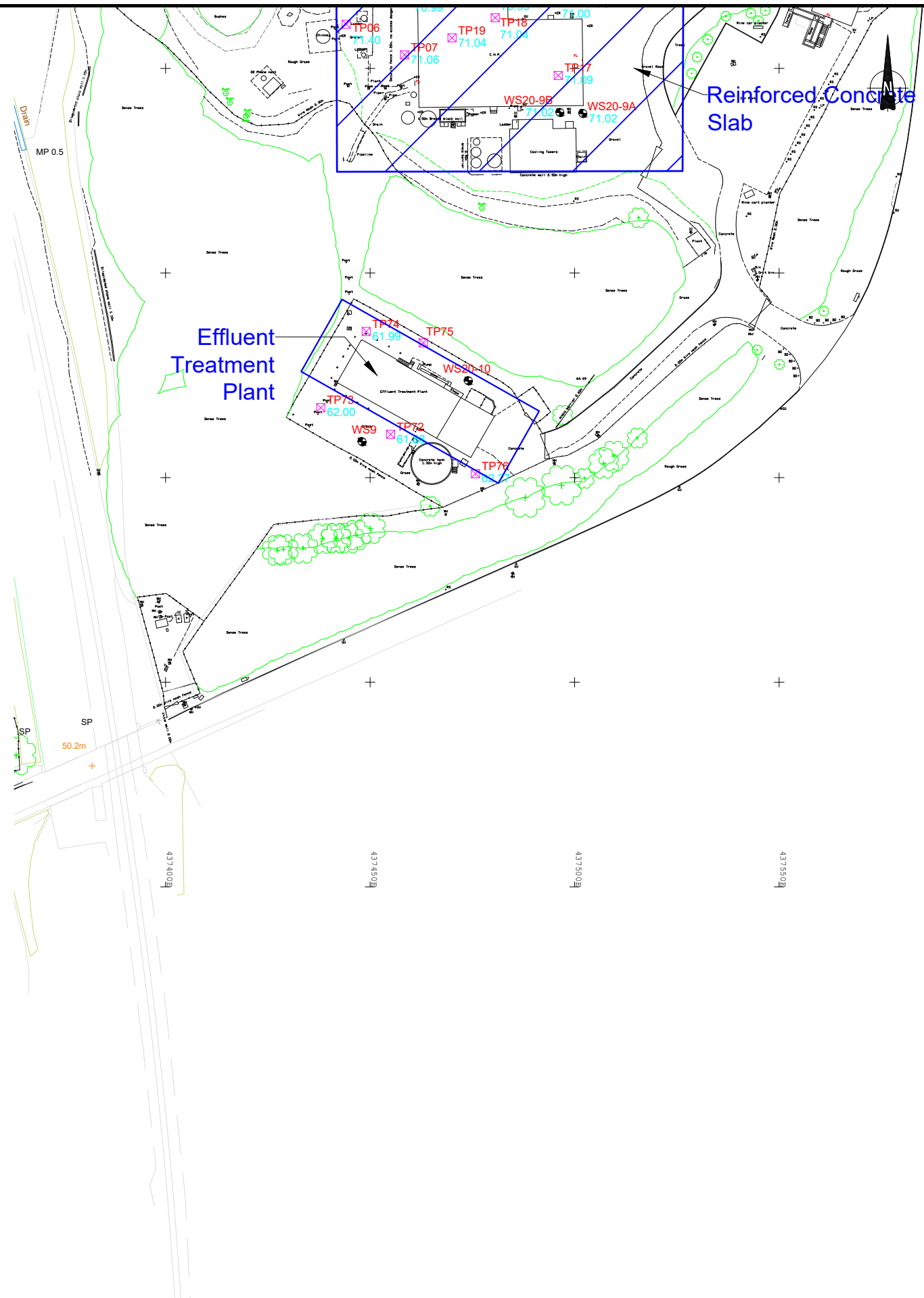
Geo2

Geo2 Remediation Limited
11 The Mending Rooms, Sunny Bank Mills, Town St,
Farsley, Leeds, LS28 5UJ.

Client: -

Site Location:
Monckton Coke Site

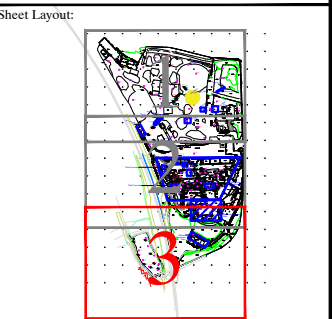
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Drawing No. 0720-GEO2-7955	Revision: -	
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 2 of 3



LEGEND

- Exploration Hole
- Trial Pit
- Obstruction

Figure 7c
Obstruction
Plan



Geo2 Remediation Limited
11 The Mending Rooms, Sunny Bank Mills, Town St,
Farsley, Leeds, LS28 5UJ.

Client -

Site Location
Monckton Coke Site
-
-

Surveyed by -	Drawn by A.B.	Approved by -
Drawing No. 0720-GEO2-7955	Revision -	
Scale 1:1250@ A3	Date 15-07-20	Sheet No. 3 of 3

Appendix B

Watching Brief Method Statement



Geo2 Remediation Ltd
Coniston House,
Louisa St. Idle
Bradford
BD10 8NE

Phone 0113 257 5397
Email info@geo2.co.uk
Web www.geo2.co.uk

Generic Watching Brief Method Statement

This method statement aims to establish a structure by which site works / development contractors will be able to effectively meet the requirements of a watching brief. A watching brief is frequently proposed as part of planning conditions imposed onto any brownfield site, or a site potentially affected by contaminants. This methodology proposed a strategy which allows the site workers to effectively undertake these works themselves without the need for a full time environmental specialist.

Requirements of a Nominated Competent Person (CP)

The party undertaking the site works will nominate a Competent Person (CP) who will be responsible for providing a watching brief over all excavation, soil handling works associated with construction and for ensuring site workers conform to appropriate PPE requirements at all times. The CP will be on-site during all enabling, and construction works.

The CP will be briefed by Geo² on environmental management during or in advance of the groundworks at an on-site meeting to be held prior to the commencement of works. This would typically address the following issues;

- A review of any existing site information with regard to areas of potential contamination both identified and unidentified,
- Types of contamination which may be encountered and also potential for unexpected contamination, and means of identification,
- Potential risks associated with contaminants, with regard to health and safety concerns of construction workers,
- Potential for waste disposal issues,
- Ensuring that the CP is confident and capable of undertaking the practical responsibilities identified,
- Any additional site specific concerns or factors which may prove relevant to works, such as any visual monitoring / inspection requirements (e.g. daily observations of adjacent streams etc).

The CP would be required to maintain records of any issues, as detailed above, which would be encountered during the programme of works. Records should detail the time and date, nature of any incident, or detail of potentially contaminated soils encountered, location of this material, where possible extent and the actions undertaken to ensure this was appropriately classified. These would

be required to be submitted to the client and Geo² to ensure that an appropriate validation report could be compiled to enable the planning conditions to be lifted. Records should be available onsite at all times for inspection as required.

The CP is also responsible for contacting Geo² in the event of encountering situations requiring environmental management. A Geo² contact will be ascribed to each site, so suitable site specific advice will be available over the phone as necessary. Site visits can be arranged at short notice to assist with any potentially significant issues.

Unexpected Contamination

Unexpected contamination may comprise impacted sub-soil, or structures such as underground storage tanks (UST), subsurface features, pipes, sumps or chambers with associated contamination observed beneath the site during the redevelopment works.

Where apparently contaminated sub-soils (or waters) are encountered, the permanent nominated CP should be contacted for assessment.

As a guide, apparently contaminated sub-soils or waters may comprise visually impacted and strongly odorous material. Encountered odours could be petrol, diesel, solvents or oil-like. Should materials of this description, or other description following a site specific briefing, be encountered and this material be considered to be unidentified, Geo² should be contacted. In such circumstances, the affected area should be isolated and work in the area stopped, pending the Geo² consultant visit to sample or assess the soil. The area should remain isolated whilst the samples are analysed at an appropriate laboratory, if considered necessary.

Based on the results and in comparison with adopted screening criteria, Geo² will determine whether the identified materials present a significant environmental risk. Should the soil need to be removed in line with the proposed development programme, or as a result of a risk based analysis, validation samples will be collected from the edge of the excavation by a Geo² site engineer.

All waste should be appropriately isolated and stored to prevent spreading contamination across the site. Waste should then be classified and disposed of in accordance with the applicable waste management regulations under full duty of care documentation. Potential exists for hazardous waste to be present, and this should also be dealt with in accordance with the relevant legislation.

Should unidentified underground features be encountered, such as tanks or fuel delivery lines, that require removal in line with the proposed development, they should be appropriately decommissioned. Decommissioning should comprise pumping and removal of waste water and any sediment in accordance with the applicable waste management regulations under full duty of care documentation. Water and sediment waste may need to be sampled and analysed to determine whether it needs to be disposed of as hazardous.

Should any structure encountered remain in situ, Geo² should be contacted to ensure that any potential impact that may be associated with this feature can be appropriately addressed, if necessary. This process may entail additional sampling works, which would require the identified area to be isolated until Geo² site staff are able to attend site.

Following removal of any such structure, the CP should inspect the excavations for apparently impacted materials. Should apparently contaminated material be identified beneath or adjacent to

the structure, Geo² should be contacted to undertake further sampling and analysis. All results will be included in the Validation Report.

The relevant planning authorities will be notified should any unexpected contamination be identified and any remedial actions that are required as a result of encountered materials will be agreed prior to the work being carried out.

Sampling Procedure

All samples obtained by Geo² will be stored in appropriate vessels for the required analysis and stored in controlled conditions prior to submission to an appropriately accredited laboratory. All samples will be obtained in line with standard industry guidance.

Validation Report

This typically forms the final part of any contaminated land planning condition and allows the client or local authority certainty that any contaminated land encountered during works has been appropriately addressed and the condition of remaining soils (and groundwater if applicable) is understood. This may be compiled by Geo² (typically in the event of unexpected contamination being encountered) or by the Client (this may take the form of a brief letter, stating the completed nature of the site and a brief description of conditions encountered).

Geo² Contact

A Geo² contact will be prescribed to the site upon implementation of the watching brief. If there are any other queries Geo² can be contacted on the office number at 0113 257 5397

