Caulmert Limited

Engineering, Environmental & Planning Consultancy Services

Knottingley Waste to Resource Facility

FCC Recycling (UK) Limited

Environmental Permit Variation Application

Site Condition Report

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Site Condition Report

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1.0 INTRODUCTION

1.1.1 FCC Recycling (UK) Limited (hereafter referred to as 'the Operator') have appointed Caulmert Limited to prepare a bespoke environmental permit variation application for permit reference EPR/JP3547JL, to allow a number of additional operational activities at the Knottingley Waste to Resource Facility on Weeland Road, Knottingley, West Yorkshire (hereafter referred to as 'the Site').

1.1.2 The Environment Agency guidance on Site Condition Reports (Horizontal Guidance note H5[1]) sets out the requirements to prepare and maintain a SCR for facilities that are regulated under the Environmental Permitting Regulations[2] over the operational lifetime of the facility.

1.1.3 This report includes information in Sections 1-3 of the H5 template.

1.1.4 Further information including details of the methodology and assessment of a Stage 1 to 3 set out within EC Commission Guidance on baseline reporting (2014/C 136/03) dated 6th May 2014, which is in accordance with Schedule 7 (paragraph 5 [m]) of the Environmental Permitting Regulation 2016 / Article 22 of Industrial Emissions Directive (IED) is presented in the report entitled "Knottingley Waste to Resource Facility, FCC Recycling (UK) Limited, Environmental Permit Variation Application, Site Condition Report" prepared by Caulmert Limited for FCC Recycling (UK) Limited, reference 5827-CAU-XX-XX-RP-V-0304, dated December 2025. A copy of this report is presented at Annex A.

[1] Environment Agency Site condition report – guidance and templates, LIT 8001 Version 3.0 April 2013 and Site Condition Report template, V2.0 4 August 2008
[2] The Environmental Permitting (England and Wales) Regulations 2016

2.0 SECTIONS 1 TO 3 FOR THE SITE CONDITION REPORT TEMPLATE

1.0 SITE DETAILS	
Name of the applicant	FCC Recycling (UK) Limited
Activity address	Weeland Road, Knottingley, West Yorkshire, WF11 8DZ
National grid reference	SE 51227 23757 (site entrance)

Document reference and dates for Site Condition Report at permit application and surrender	Caulmert Limited. Knottingley Waste to Resource Facility, FCC Recycling (UK) Limited, Environmental Permit Variation Application, Site Condition Report, reference 5827-CAU-XX-XX-RP-V-0304, dated December 2025 A copy of this report is presented at Annex A

Document references for site plans (including location and boundaries)	See Figure 1 report reference 5827-CAU-XX-XX-RP-V-0304 at Annex A

Note:
In Part A of the application form you must give us details of the site's location and provide us with a site plan. We need a detailed site plan (or plans) showing:

- Site location, the area covered by the site condition report, and the location and nature of the activities and/or waste facilities on the site.
- Locations of receptors, sources of emissions/releases, and monitoring points.
- Site drainage.
- Site surfacing.

If this information is not shown on the site plan required by Part A of the application form then you should submit the additional plan or plans with this site condition report.

2.0 Condition of the land at permit issue

Environmental setting including:

- geology
- hydrogeology
- surface waters

Geology

The geology at the Site has been investigated previously and information is recorded in a number of site investigations and desk study reports, a summary of the geology and ground conditions is presented in the Conceptual Site Model (CSM) in Appendix 1 (report reference 5827-CAU-XX-XX-RP-V-0304, dated December 2025).

The ground conditions and geology are summarised in Table below:

Summary of site geology

Stratum	Description	Typical Thickness (m)
Made Ground	A mixture of loose and cohesive materials, with areas of soft dark grey/ black slightly sandy gravelly clay with occasional concrete and brick cobbles and areas of brown /red clayey gravel of brick and concrete with frequent brick cobbles and other occasional man-made products.	0.05 to 3.8m
Recent Fluvial Deposits	Variable in presence, generally comprising a soft, grey, slightly gravelly sandy clay. Identified to be occasionally absent within areas of deeper made ground.	0.1 to 3.5m
Vale of York Drift Deposits (Breighton Sand Formation)	*Alluvial Clay* - stiff laminated grey/brown firm to stiff laminated orange brown sandy clay. *Middle Deposits* – Generally comprising grey, clayey, medium to coarse sand with occasional gravels of flint which becomes slightly clayey, silty fine sand with depth. *Middle Clay* – Firm thinly laminated red/brown slightly sandy clay. However, this unit was notably absent in areas of the site.	0.2 to 3.8m 0.3 to 6.4m 0 to 2 m 1.3 to 8.4m

	Deep deposits – typically comprise grey coloured, gravelly sands and sands and gravels with occasional cobbles retrieved towards the base of these deposits.	
Roxby Formation	Generally comprising a stiff to very stiff red clay with frequent gravel of flint. Becomes stiff silty grey clay with depth. Gypsum rock fragments recorded more frequent towards the base.	Approx 7.4m (base not recorded)

Hydrogeology

The hydrogeological regime at the Site has been investigated through site investigations and groundwater monitoring programmes.

There are three discrete groundwater units at the Site referred to as 'Shallow' 'Middle' and Deep'. These units are distinct and considered to be generally separated by confining layers of clay and cohesive deposits (aquitards) within the stratified geology.

Shallow groundwater has been recorded within Made Ground, resting within former tar distillation structures and also present in shallow granular soils. This shallow groundwater is understood to be discontinuous in its extent and perching is likely to be influenced by the presence of remnant below ground structures such as tar wells. Previous monitoring, dewatering and trial pumping (pump tests) of this groundwater unit has confirmed the highly discontinuous nature of the groundwater. Based on information available, the majority of shallow groundwater recorded is located within the CEMEX and former tar distillation site and is analogous with areas of deeper Made Ground and former structures associated with the former tar distillery.

The groundwater flow direction within the Middle Deposits is generally easterly to north-easterly. In most of the Site, the hydrogeological assessment completed as part of the remediation proposals in 2011 concluded that groundwater flow direction is likely to be influenced by the watercourse to the north and may flow parallel to the River Aire and the canal. In the east of the Site, there may be an element of hydraulic continuity between the groundwater in the Middle Deposits and groundwater in the Deeper Deposits and the River Aire. Although overall groundwater flow direction in the Middle Deposits is likely to be toward the north-east and to continue off-site and may be in hydraulic continuity with the groundwater in the Deep Deposits. In areas where the Middle Clay is absent, there may be hydraulic continuity between groundwater in the Middle and Deep Deposits.

	The groundwater flow direction within the Deep Deposits is generally parallel to the River Aire (towards the east), within the central and southern areas of the Site, with a distinct northerly component of groundwater flow toward the River Aire. The depth of the groundwater in the Deep Deposits and based on the findings of the pump tests indicate that the groundwater this unit is likely to be in hydraulic continuity with the River Aire in this area. The superficial geology of the site consists of a combination of Alluvium (clay, silt, sand, and gravel) designated as an unproductive aquifer, as well as Breighton Sand Formation (sand), classified as a Secondary B aquifer. The bedrock geology Roxby Formation underlying the Site is designated a Secondary B aquifer comprising mudstone and siltstone. **Surface Waters** The River Aire is located adjacent to the northern boundary of the Site. The Aire and Calder Navigation Canal is connected the River Aire 10m to the north of the site and located 80m south of the site. There are also three ponds associated with the Willow Garth Nature Reserve located north east of the site, the closest of which is located 130m north-northeast, the others are located 161m and 328m northeast, respectively.
Pollution history including: • pollution incidents that may have affected land • historical land-uses and associated contaminants • any visual/olfactory evidence of existing contamination • evidence of damage to pollution prevention measures	**Pollution History** The site as a whole has an extensive history of tar distillation and associated activities dating back to the 1870's. The site was originally established as the Aire Tar Works which later expanded into the Stainsby and Lyon and Robinson Brothers Tar Works. These companies later merged with further entities to form Midland Yorkshire Holdings Limited (MYHL) in the 1960s. Croda International acquired MYHL in 1975 and the site has generally remained in Croda's ownership and more recently Tradebe, with areas of the site leased to third parties, including CEMEX. The approximate eastern three quarters of the Knottingley site was purchased by FCC from Tradebe in 2022. Tar distillation processes have dominated the Site's history since the 19th Century, with crude coal tar imported by barge to site from local gas works and coking works. The tar was offloaded at a wharf on the Knottingley to Goole Canal adjacent to the site at Bank Dole Cut. Bulk tar was stored in below ground tar wells (of which ten have been identified to exist on site). The tar wells were brick lined and extended to depths of approximately 3.5m to 4.0m bgl. From there, the primary operation within the Croda land ownership comprised

	the distillation of coal tar to produce a range of finished products including bitumen, tars, creosotes, pitches, coatings and sealants. The operations comprised a significant above and below ground infrastructure associated with the manufacture and storage of tar related products. At one stage, coal tar distillation occupied the majority of the Site, however since the 1980s, these activities diversified to include aggregates coating (undertaken by CEMEX) and solvent recovery (undertaken by Tradebe). The development and operations at the Site may have resulted in the potential for contaminant sources associated with the former coal tar distillation activities.
Evidence of historic contamination, for example, historical site investigation, assessment, remediation and verification reports (where available)	**Soil Contamination** Based on a review of previous investigation and site assessment reports, soil contamination is generally restricted to Made Ground in proximity to bulk storage and historical process facilities. Hydrocarbon contamination associated with tar processing products has been identified within shallow soils and was observed at surface across the former tar storage and processing areas, including present in the form of saturated soils and tar residues. Coal tar-based hydrocarbons are the primary contaminants of concern identified at the site, including: • Naphthalene • Benzene • Xylene • C6-8 Aliphatic Hydrocarbons • C10-12 Aromatic Hydrocarbons • C12-C16 Aromatic Hydrocarbons • C16-21 Aromatic Hydrocarbons Assessment of the constituent components of the coal tar contaminants suggest that the coal tar is generally characteristic of a low temperature coal tar derived from coking works and former gas works which are understood to have supplied the site with raw coal tar.

	In addition to the primary contaminants, polycyclic aromatic hydrocarbon (PAH) and phenolic compounds are likely to be present within contaminated soils and groundwater at the site. **Non Aqueous Phase Liquids (NAPL)** NAPL has been recorded within the Shallow Deposits, Middle Deposits and to a much lesser extent Deep Deposits, the majority of which is recorded within the Middle Deposits. NAPL within the Middle Deposits has been characterised to comprise a mixture of a more buoyant 'creosote' type product, with a density slightly greater than water and a more dense tar that has been recorded as settled thicknesses toward the base of more permeable water-bearing strata. It is understood that the mobile NAPL is not measured directly during monitoring works and the extent is inferred from field observations, dissolved phase concentrations in groundwater and the baseline recovery of NAPL determined during the remediation trials. The mobile NAPL is considered more susceptible to lateral migration driven by groundwater flow. It is understood that NAPL migration has occurred within the Middle Deposits, with NAPL recorded at exploratory hole locations away from the principal source areas (i.e. former tar wells). NAPL has previously been recorded in three isolated locations within the Deep Deposits, including a location on the Bank Dole promontory to the north of the canal. **Groundwater Contamination** Assessment of the groundwater quality recorded dissolved phase contamination (coal tar related hydrocarbons) associated with the historical contamination principally within samples from the groundwater from the Middle Deposits. The concentrations of contaminants are elevated, frequently recorded above the theoretical solubility limit. The distribution of dissolved phase contaminants generally correlates with the NAPL impacted areas with lower concentrations in dissolved phase recorded in groundwater from outside of these NAPL impacted areas. The exception to this occurrence is phenol, which has been recorded in the southern area of the Site, outside of the NAPL impacted areas. Phenol is significantly more soluble that many other organic compounds. Dissolved phase contamination has been recorded within the groundwater in the former tar distillation site, on the northern boundary of the FCC operated area and also to the north of the Bank Dole Cut Canal. Dissolved phase contamination has also been identified within the groundwater in the Deep Deposits, albeit at significantly lower concentrations compared to concentrations recorded in the groundwater from the Middle

Deposits. Contamination has been recorded in the groundwater in the northern area of the site, down-hydraulic gradient of the inferred area of contamination and where the Middle Clay deposits are absent, suggesting that there may be hydraulic continuity between the groundwater bodies and the dissolved phase contamination could be migrating from the groundwater in the Middle Deposits to the Deep Deposits.

Considering this situation with regard to the CSM and groundwater regime, the Deep Deposits are considered to be the critical groundwater receptor for the historical contamination.

Shallow LNAPL Contamination (adjacent, former CEMEX Site)

A minor area of shallow light NAPL was identified on the former CEMEX site (see Appendix 1), which is located to the west of the Site currently with the FFC ownership boundary. The characterisation of this contamination was different to the hydrocarbon contamination recorded elsewhere on the Site with the following differences:

- The TPH carbon banding fractions recorded within the product are generally within the aliphatic C12-21 range, with a lower proportion of aromatic hydrocarbons that has been characterised in product from elsewhere on the site;
- The product is relatively unweathered, is lighter in density than water, and is present only in the shallow deposits; and
- The contamination appears to be laterally hydraulically isolated.

This shallow light NAPL contamination is understood to be from historical use of gas oil fuel in the aggregates coating activities within this area.

Remediation Actions

The Remedial Action Plan for the site was set out by WSP in 2013. The remediation plan focussed on the removal of NAPL from the Made Ground and shallow groundwater across the affected area of the site. The strategy was to divide the Site into 9 separate remediation cells (7.5 of these cells are located in the current area owned by FCC), comprising a total of 268 remediation (treatment and recovery) wells. WSP also recommended that quarterly monitoring of quality of the surface water in the River Aire and deep groundwater was undertaken to assess natural attenuation activity of residual hydrocarbon contaminant mass occurring along the groundwater migration pathway from the shallow source areas to the River Aire.

Remediation of the LNAPL contamination to the west of the site at the former CEMEX site has been operated as a separate activity, which comprises a number of sumps installed within the shallow soils to intercept the

	shallow groundwater to facilitate abstraction of LNAPL and contaminated groundwater, which is transferred to a treatment plant. A 2023 groundwater monitoring report concluded that the concentrations of contaminants and natural attenuation parameters recorded in groundwater are comparable to those modelled in the risk assessment completed in 2011. Groundwater monitoring data indicates that sulphate reduction and methanogenic processes are occurring within the groundwater hydrocarbon plume, and consequently there is biodegradation of petroleum hydrocarbons in deep groundwater occurring under reducing (anaerobic) conditions. It is reported that the biodegradation activity is reducing the flux of petroleum hydrocarbon from groundwater reaching the River Aire, although contamination is still reaching groundwater at the riverbank area based on groundwater analytical data. The groundwater monitoring report indicated that water quality in the River Aire is considered not to be adversely affected by the contamination at the Site.
Baseline soil and groundwater reference data	The baseline soil and groundwater reference data is presented and summarised in the report entitled "Former Tar Distillery, Knottingley, Updated Conceptual Site Model" prepared by WSP for Croda Distillates Limited, report reference Ref: 2824.003 dated December 2011. A copy of this report is presented at Appendix 1 of the Site Condition Report entitled "Knottingley Waste to Resource Facility, FCC Recycling (UK) Limited, Environmental Permit Variation Application, Site Condition Report" prepared by Caulmert Limited for FCC Recycling (UK) Limited, report reference 5827-CAU-XX-XX-RP-V-0304, dated December 2025. The site has been the subject of remediation works. The remediation activities have now been completed and approved by the Environment Agency for activities in eight of the nine cells. The one remaining cell, under active remediation is located in the in the FCC permitted area.
Supporting information	• Source information identifying environmental setting and pollution incidents • Historical Ordnance Survey plans • Site reconnaissance • Historical investigation / assessment / remediation / verification reports • Baseline soil and groundwater reference data

3.0 Permitted activities

Permitted activities

The current permitted activities are presented in Table S1.1.1, as listed in the Environmental Permit ref. EPR/JP3547JL. Activities at the site include the bulk handling and transfer of both hazardous and non-hazardous waste, distillation-based solvent recovery, the creation of Secondary Liquid Fuel (involving the utilisation of heat and steam from boilers), together with the storage and management of waste materials and raw substances. Furthermore, the site conducts surface water and process water treatment through a biological aerobic treatment plant. These activities are summarised in Table below

Current Permitted Activities.

Activity Listed in the EPR/ JP3547JL and Schedule 1 of the EP Regulations	Description of Specified Activity
Section 5.3 A(1)(a)(v): Recovering by distillation of any oil or organic solvent.	Operation of kettle, reboiler heat exchanger, distillation column and vent condenser, feed, and production tanks.
Section 5.3A(1)(a)(iii): Disposal or recovery of hazardous waste with a capacity exceeding 10 tonnes per day involving blending or mixing prior to submission to any of the other activities listed in 5.3 or 5.1.	Formulation of Secondary Liquid Fuel by blending process residues with waste materials.
Section 5.6A(1)(a): Temporary storage of hazardous waste with a total capacity exceeding 50 tonnes pending a 5.1, 5.2 or 5.3 activity.	Storage of wastes prior to treatment or transfer off-site.
Section 5.3A(1)(a)(iv): Disposal or recovery of hazardous waste with a capacity exceeding 10 tonnes per day involving repackaging prior to submission to any of the other activities listed in 5.3 or 5.1.	Bulking up of waste materials within Waste Transfer Building.

Non-permitted activities undertaken

Document references for:	**Site plan**
• plan showing activity layout; and • environmental risk assessment.	

	Environmental risk assessment Details regarding the environmental risk assessment is presented in the report Caulmert Limited. Knottingley Waste to Resource Facility, FCC Recycling (UK) Limited, Environmental Permit Variation Application, Site Condition Report, reference 5827-CAU-XX-XX-RP-V-0304, dated December 2025 The Industrial Emissions Directive (IED) requires assessment to be carried out for all hazardous substances used, produced or released within the installation. Hazardous substances (Article 3(18) and Article 22(2), first subparagraph) are those substances or mixtures defined within Article 3 of Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulation) which, as a result of their hazardousness, mobility, persistence and biodegradability (as well as other characteristics), are capable of contaminating soil or groundwater and are used, produced and/or released by the installation. The 'baseline report' referred to in the IED requires an assessment of the "…possibility of soil and groundwater contamination at the site of the installation…" (Article 22(2), first subparagraph). An environmental risk assessment (Stage 3 – Assessment of site-specific pollution possibility) is therefore based on the hazardous substances used, produced or released within the installation, and relates to those under the permitted activities, and not historical land use (i.e associated with the processing of coal tar). This is presented at Table 4 in the Site Condition report (December 2025) and replicated below.

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Treatment substances					
Leachate (ammoniacal nitrogen)	Moderate to High	Yes	4100 m3 total	All leachate effluent will be stored in tanks which will be self-bunded or within bunded areas on impermeable concrete in accordance with good practice. Tanks are self-contained having capacity to hold in excess of 110% of the tanks content. Control measures are in place on site in the unlikely event of spillage, failure or overfill.	No The site specific control measures are considered adequate
Aqueous and inorganic wastes, solids and sludge	Very High	Yes	2200 m3 total	All inorganic wastes will be stored in tanks on site which will be self-bunded or within bunded areas on impermeable concrete in accordance with good practice guidance. Tanks are self-contained having capacity to hold in excess of 110% of the tanks content. Incompatible materials will be segregated. Storage bays will be segregated and sloped appropriately to ensure any spilt liquid is contained within the bay and cleaned accordingly.	No The site specific control measures are considered adequate
Raw materials					
Acids	High	Yes		All chemical containers will be bunded, with 110% capacity. Sulphuric acid is stored in an acid resistant tank. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Bases (Alkaline Substances)	Moderate to High	Yes		All chemical containers will be bunded and tanks shall be above ground with secondary containment of materials that are appropriate to the chemical nature of the materials being stored. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Hydrocarbons	High	Yes		All chemical containers will be bunded and tanks shall be above ground with secondary containment of materials that are appropriate to the chemical nature of the materials being stored. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Temporarily stored wastes					
Chlorinated Solvents	High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Chlorinated aromatics	Moderate	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and treated/disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Chlorinated alkanes	Moderate to high	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and treated/disposed of appropriately.	No The site specific control measures are considered adequate
Phenolic	Moderate to high	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Chlorophenoxy Herbicides, Pesticides/Insecticides /Fungicides/Triazines and Herbicide-like Structures (Meroprop)	Moderate	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Polychlorinated biphenyls and dioxins	High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Nitroaromatics	High potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Monoaromatic (benzene)	High Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Polycyclic aromatic hydrocarbons (benzo(a) pyrene)	High Potential in Soil / Low Groundwater Contamination Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Halogenated alcohols and ethers	High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Phenyls and anilines	Moderate to High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Fluorinated compounds (PFAS)	Very High Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Metals and metalloids	High Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Note:

In Part B of the application form you must tell us about the activities that you will undertake at the site. You must also give us an environmental risk assessment. This risk assessment must be based on our guidance (*Environmental Risk Assessment - EPR H1*) or use an equivalent approach.

It is essential that you identify in your environmental risk assessment all the substances used and produced that could pollute the soil or groundwater if there were an accident, or if measures to protect land fail.

These include substances that would be classified as ‘dangerous’ under the Control of Major Accident Hazards (COMAH) regulations and also raw materials, fuels, intermediates, products, wastes and effluents.

If your submitted environmental risk assessment does not adequately address the risks to soil and groundwater, we may need to request further information from you or even refuse your permit application

ANNEX A

Knottingley Waste to Resource Facility, FCC Recycling (UK) Limited, Environmental Permit Variation Application, Site Condition Report" prepared by Caulmert Limited for FCC Recycling (UK) Limited, reference 5827-CAU-XX-XX-RP-V-0304, dated December 2025

Caulmert Limited

Engineering, Environmental & Planning
Consultancy Services

Knottingley Waste to Resource Facility

FCC Recycling (UK) Limited

Environmental Permit Variation Application

ANNEX A

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Caulmert
engineering environmental planning

APPROVAL RECORD

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ANNEX A

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1.0 Introduction

1.1 Background

1.1.1 FCC Recycling (UK) Limited (hereafter referred to as 'the Operator') have appointed Caulmert Limited to prepare a bespoke environmental permit variation application for permit reference EPR/JP3547JL, to allow a number of additional operational activities at the Knottingley Waste to Resource Facility on Weeland Road, Knottingley, West Yorkshire (hereafter referred to as 'the Site').

1.1.2 FCC Recycling (UK) Limited currently operates the Knottingley Waste to Resource Facility which is dedicated to the storage, transfer, treatment, and recovery of industrial wastes. The Site is located on the eastern edge of Knottingley occupying a site that was historically associated with chemical processing, primarily the storage and processing of coal tar and related products dating back to the 1870's. The Site is located within an area that was previously a larger facility occupied by coal tar processing activities (including land located to the east and west) which is currently occupied by a mix of industrial and low-grade agricultural land. The Bank Dole Cut and Lock (part of Aire and Calder Navigation canal) and the River Aire lies to the north, and the A645 road to the south. Approximately 300m to the west, beyond the canal, lies an industrial area which includes a glassworks beyond which are residential areas.

1.1.3 This updated Site Condition Report (SCR) describes and records the condition of the land and groundwater at the Site based on the information available. An initial SCR was prepared as part of the original permit application (by the previous owners) associated with the previous permitted activities at the Site, however the initial SCR could not be currently located. This updated SCR has been prepared to include the additional proposed activities at the Site to support the permit variation application.

1.2 Template for Site Condition Reports

1.2.1 The Environment Agency guidance on Site Condition Reports (Horizontal Guidance note H5[1]) sets out the requirements to prepare and maintain a SCR for facilities that are regulated under the Environmental Permitting Regulations[2] over the operational lifetime of the facility.

1.2.1 Although the H5 guidance includes a template for a SCR, the template is limited in its suitability for the presentation of information. However, the H5 guidance has been considered in the preparation of this report. The template is divided into sections to be completed at different life stages of the regulated facility:

[1] Environment Agency Site condition report – guidance and templates, LIT 8001 Version 3.0 April 2013 and Site Condition Report template, V2.0 4 August 2008
[2] The Environmental Permitting (England and Wales) Regulations 2016

Sections 1-3 to be completed and submitted with applications for new facilities: The report information should include a description of the condition of the land at permit issue and a description of permitted activities at the site.

Sections 4-7 to be maintained during the life of the site: The report information should include a description of any changes to the activities and any changes to the use or production of dangerous substances[3] at the facility. It should also include records of inspections for all pollution prevention measures, pollution incidents that may have had an impact on land, and environmental monitoring.

Sections 8-10 to be completed and submitted with surrender applications: The report information should include a description of site decommissioning and removal of pollution risk and, where relevant, reference data and details of any remediation. Finally, the report information should include a 'statement of site condition' that is based on the information provided in the previous sections of the report.

1.2.2 This updated SCR addresses section 1-3 and section 4-5 which includes information regarding new activities in order to support the permit variation application.

[3] Based on the H5 Guidance, these include substances that would be classified as 'dangerous' under the Control of Major Accident Hazards (COMAH) regulations which include raw materials, fuels, intermediates, products, wastes and effluents.

2.0 SITE DETAILS

2.1 Operator & Site Details

2.1.1 The details of the Operator and the Site address are presented in Table 1:

Table 1 – Site Operator and Address

Name of Operator	FCC Recycling (UK) Ltd
Activity Address	Weeland Road Knottingley West Yorkshire WF11 8DZ
National Grid Reference	SE 51279 23861 (centre of permitted site)

2.2 Site Location and Surrounding Land Use

2.2.1 The Site is located in Knottingley, West Yorkshire. It is centred on National Grid Reference SE 51279 23861 and postcode WF11 8DZ. The main site entrance is accessed from Weeland Road on the southern boundary.

2.2.2 The Site is in a semi-rural setting on the edge of industrial and residential locations. The residential areas of Knottingley are primarily situated southwest of the Site. The closest residential areas to the Site are along Weeland Road, The Croft, Springfields Avenue, and Broomhill Avenue. Fernley Green Industrial Estate encompasses the area immediately west of the Site boundary and extends northwest. Willow Garth Nature Reserve extends immediately northeast. Approximately 1 km of open countryside abuts the northern and southern boundaries of the Site. To the north, the Site is bordered by the Bank Dole Cut and Lock (a section of the Aire and Calder Navigation Canal), as well as the River Aire. The A645 road is to the south of the Site.

2.2.3 The Site location (shown within the red line boundary) is displayed in **Figure 1** below:

Figure 1 – Site Location (permit boundary in Red).

2.3 Site Plans

2.3.1 In the H5 guidance, the following is stated about site plans:

*"**Note**: In Part A of the application form you must give us details of the site's location and provide us with a site plan. We need a detailed site plan (or plans) showing:*

- *Site location, the area covered by the site condition report, and the location and nature of the activities and/or waste facilities on the site.*
- *Locations of receptors, sources of emissions/releases, and monitoring points.*
- *Site drainage.*
- *Site surfacing.*

If this information is not shown on the site plan required by Part A of the application form, then you should submit the additional plan or plans with this site condition report".

2.3.2 The relevant Site plans showing details of the Site, and its surroundings are listed below and presented in this report:

Drawing number	Drawing title
5827-CAU-XX-XX-DR-V-1800	Sensitive Receptors Plan
5827-CAU-XX-XX-DR-V-1804	Permit Boundary Plan
Figure 1 of this report (above)	Site Location

2.4 Site History

2.4.1 The site as a whole has an extensive history of tar distillation and associated activities dating back to the 1870's. The site was originally established as the Aire Tar Works which later expanded into the Stainsby and Lyon and Robinson Brothers Tar Works. These companies later merged with further entities to form Midland Yorkshire Holdings Limited (MYHL) in the 1960s. Croda International acquired MYHL in 1975 and the site has generally remained in Croda's ownership and more recently Tradebe, with areas of the site leased to third parties, including CEMEX. The approximate eastern three quarters of the Knottingley site was purchased by FCC from Tradebe in 2022.

2.4.2 Tar distillation processes have dominated the Site's history since the 19th Century, with crude coal tar imported by barge to site from local gas works and coking works. The tar was offloaded at a wharf on the Knottingley to Goole Canal adjacent to the site at Bank Dole Cut. Bulk tar was stored in below ground tar wells (of which ten have been identified to exist on site). The tar wells were brick lined and extended to depths of approximately 3.5m to 4.0m bgl. From there, the primary operation within the Croda land ownership comprised the distillation of coal tar to produce a range of finished products including bitumen, tars, creosotes, pitches, coatings and sealants. The operations comprised a significant above and below ground infrastructure associated with the manufacture and storage of tar related products.

2.4.3 At one stage, coal tar distillation occupied the majority of the Site, however since the 1980s, these activities diversified to include aggregates coating (undertaken by CEMEX) and solvent recovery (undertaken by Tradebe).

2.4.4 The development and operations at the Site may have resulted in the potential for contaminant sources associated with the former coal tar distillation activities.

3.0 CONDITION OF LAND AT PERMIT ISSUE

3.1 Overview

3.1.1 The updated SCR considers the condition of the land at the time of this permit variation, reviewing the geology, hydrogeology and surface waters of the Site and area.

3.2 Geology

3.2.1 The geology at the Site has been investigated previously and information is recorded in a number of site investigations and desk study reports, a summary of the geology and ground conditions is presented in the Conceptual Site Model (CSM) in Appendix 1. The CSM presented in Appendix 1 was prepared in 2011, however, it is considered that the geological and groundwater assessments present in the CSM are still relevant.

3.2.2 The ground conditions and geology are summarised in Table 2 below:

Table 2. Summary of site geology

Stratum	Description	Typical Thickness (m)
Made Ground	A mixture of loose and cohesive materials, with areas of soft dark grey/ black slightly sandy gravelly clay with occasional concrete and brick cobbles and areas of brown /red clayey gravel of brick and concrete with frequent brick cobbles and other occasional man-made products.	0.05 to 3.8m
Recent Fluvial Deposits	Variable in presence, generally comprising a soft, grey, slightly gravelly sandy clay. Identified to be occasionally absent within areas of deeper made ground.	0.1 to 3.5m
Vale of York Drift Deposits (Breighton Sand Formation)	*Alluvial Clay* - stiff laminated grey/brown firm to stiff laminated orange brown sandy clay. *Middle Deposits* – Generally comprising grey, clayey, medium to coarse sand with occasional gravels of flint which becomes slightly clayey, silty fine sand with depth. *Middle Clay* – Firm thinly laminated red/brown slightly sandy clay. However, this unit was notably absent in areas of the site. *Deep deposits* – typically comprise grey coloured, gravelly sands and sands and gravels with occasional cobbles retrieved towards the base of these deposits.	0.2 to 3.8m 0.3 to 6.4m 0 to 2 m 1.3 to 8.4m

Stratum	Description	Typical Thickness (m)
Roxby Formation	Generally comprising a stiff to very stiff red clay with frequent gravel of flint. Becomes stiff silty grey clay with depth. Gypsum rock fragments recorded more frequent towards the base.	Approx 7.4m (base not recorded)

3.3 Hydrogeology

3.3.1 The hydrogeological regime at the Site has been investigated through site investigations and groundwater monitoring programmes and a summary is presented in the CSM presented in Appendix 1. A summary of the hydrogeological regime is presented below.

3.3.2 There are three discrete groundwater units at the Site referred to as 'Shallow' 'Middle' and Deep'. These units are distinct and considered to be generally separated by confining layers of clay and cohesive deposits (aquitards) within the stratified geology.

3.3.3 Shallow groundwater has been recorded within Made Ground, resting within former tar distillation structures and also present in shallow granular soils. This shallow groundwater is understood to be discontinuous in its extent and perching is likely to be influenced by the presence of remnant below ground structures such as tar wells. Previous monitoring, dewatering and trial pumping (pump tests) of this groundwater unit has confirmed the highly discontinuous nature of the groundwater. Based on information available, the majority of shallow groundwater recorded is located within the CEMEX and former tar distillation site and is analogous with areas of deeper Made Ground and former structures associated with the former tar distillery.

3.3.4 The groundwater flow direction within the Middle Deposits is generally easterly to north-easterly. In most of the Site, the hydrogeological assessment completed as part of the remediation proposals in 2011 concluded that groundwater flow direction is likely to be influenced by the watercourse to the north and may flow parallel to the River Aire and the canal. In the east of the Site, there may be an element of hydraulic continuity between the groundwater in the Middle Deposits and groundwater in the Deeper Deposits and the River Aire. Although overall groundwater flow direction in the Middle Deposits is likely to be toward the north-east and to continue off-site and may be in hydraulic continuity with the groundwater in the Deep Deposits. In areas where the Middle Clay is absent, there may be hydraulic continuity between groundwater in the Middle and Deep Deposits.

3.3.5 The groundwater flow direction within the Deep Deposits is generally parallel to the River Aire (towards the east), within the central and southern areas of the Site, with a distinct northerly component of groundwater flow toward the River Aire. The depth of the groundwater in the Deep Deposits and based on the findings of the pump tests indicate that the groundwater this unit is likely to be in hydraulic continuity with the River Aire in this area.

3.3.6 The superficial geology of the site consists of a combination of Alluvium (clay, silt, sand, and gravel) designated as an unproductive aquifer, as well as Breighton Sand Formation (sand), classified as a secondary B aquifer. The bedrock geology Roxby Formation underlying the Site is designated a Secondary B aquifer comprising mudstone and siltstone.

3.4 Surface Waters

3.4.1 The River Aire is located adjacent to the northern boundary of the Site. The Aire and Calder Navigation Canal is connected the River Aire 10m to the North of the site and located 80m south of the site. There are also three ponds associated with the Willow Garth Nature Reserve located north east of the site, the closest of which is located 130m north-northeast, the others are located 161m and 328m northeast, respectively.

3.5 Pollution History

3.5.1 The historical land use of the Site includes chemical processing, primarily the storage and processing of coal tar and related products dating back to the 1870's. The site history is summarised in section 1.4. Soil and groundwater contamination has been recorded across the areas of the former tar distillation facilities.

3.5.2 A summary of contamination of the ground conditions and remediation actions are presented below.

Soil Contamination

3.5.3 Based on a review of previous investigation and site assessment reports, soil contamination is generally restricted to Made Ground in proximity to bulk storage and historical process facilities. Hydrocarbon contamination associated with tar processing products has been identified within shallow soils and was observed at surface across the former tar storage and processing areas, including present in the form of saturated soils and tar residues.

3.5.4 Coal tar-based hydrocarbons are the primary contaminants of concern identified at the site, including:

- Naphthalene
- Benzene
- Xylene
- C6-8 Aliphatic Hydrocarbons
- C10-12 Aromatic Hydrocarbons
- C12-C16 Aromatic Hydrocarbons
- C16-21 Aromatic Hydrocarbons

3.5.5 Assessment of the constituent components of the coal tar contaminants suggest that the coal tar is generally characteristic of a low temperature coal tar derived from coking works and former gas works which are understood to have supplied the site with raw coal tar.

3.5.6 In addition to the primary contaminants, polycyclic aromatic hydrocarbon (PAH) and phenolic compounds are likely to be present within contaminated soils and groundwater at the site.

Non Aqueous Phase Liquids (NAPL)

3.5.7 NAPL has been recorded within the Shallow Deposits, Middle Deposits and to a much lesser extent Deep Deposits, the majority of which is recorded within the Middle Deposits. NAPL within the Middle Deposits has been characterised to comprise a mixture of a more buoyant 'creosote' type product, with a density slightly greater than water and a more dense tar that has been recorded as settled thicknesses toward the base of more permeable water-bearing strata. It is understood that the mobile NAPL is not measured directly during monitoring works and the extent is inferred from field observations, dissolved phase concentrations in groundwater and the baseline recovery of NAPL determined during the remediation trials.

3.5.8 The mobile NAPL is considered more susceptible to lateral migration driven by groundwater flow. It is understood that NAPL migration has occurred within the Middle Deposits, with NAPL recorded at exploratory hole locations away from the principal source areas (i.e. former tar wells).

3.5.9 NAPL has previously been recorded in three isolated locations within the Deep Deposits, including a location on the Bank Dole promontory to the north of the canal.

Groundwater Contamination

3.5.10 Assessment of the groundwater quality recorded dissolved phase contamination (coal tar related hydrocarbons) associated with the historical contamination principally within samples from the groundwater from the Middle Deposits. The concentrations of contaminants are elevated, frequently recorded above the theoretical solubility limit. The distribution of dissolved phase contaminants generally correlates with the NAPL impacted areas with lower concentrations in dissolved phase recorded in groundwater from outside of these NAPL impacted areas. The exception to this occurrence is phenol, which has been recorded in the southern area of the Site, outside of the NAPL impacted areas. Phenol is significantly more soluble that many other organic compounds. Dissolved phase contamination has been recorded within the groundwater in the former tar distillation site, on the northern boundary of the FCC operated area and also to the north of the Bank Dole Cut Canal.

3.5.11 Dissolved phase contamination has also been identified within the groundwater in the Deep Deposits, albeit at significantly lower concentrations compared to concentrations recorded in the groundwater from the Middle Deposits. Contamination has been recorded in the groundwater in the northern area of the site, down-hydraulic gradient of the inferred area of contamination and where the Middle Clay deposits are absent, suggesting that there may be hydraulic continuity between the groundwater bodies and the dissolved phase contamination could be migrating from the groundwater in the Middle Deposits to the Deep Deposits.

3.5.12 Considering this situation with regard to the CSM and groundwater regime, the Deep Deposits are considered to be the critical groundwater receptor for the historical contamination.

Shallow LNAPL Contamination (adjacent, former CEMEX Site)

3.5.13 A minor area of shallow light NAPL was identified on the former CEMEX site (see Appendix 1), which is located to the west of the Site currently with the FFC ownership boundary. The characterisation of this contamination was different to the hydrocarbon contamination recorded elsewhere on the Site with the following differences:

- The TPH carbon banding fractions recorded within the product are generally within the aliphatic C12-21 range, with a lower proportion of aromatic hydrocarbons that has been characterised in product from elsewhere on the site;
- The product is relatively unweathered, is lighter in density than water, and is present only in the shallow deposits; and
- The contamination appears to be laterally hydraulically isolated.

3.5.14 This shallow light NAPL contamination is understood to be from historical use of gas oil fuel in the aggregates coating activities within this area.

Remediation Actions

3.5.15 The Remedial Action Plan for the site was set out by WSP in 2013, of which a copy is presented in Appendix 2. The remediation plan focussed on the removal of NAPL from the Made Ground and shallow groundwater across the affected area of the site. The strategy was to divide the Site into 9 separate remediation cells (7.5 of these cells are located in the current area owned by FCC), comprising a total of 268 remediation (treatment and recovery) wells. WSP also recommended that quarterly monitoring of quality of the surface water in the River Aire and deep groundwater was undertaken to assess natural attenuation activity of residual hydrocarbon contaminant mass occurring along the groundwater migration pathway from the shallow source areas to the River Aire.

3.5.16 Remediation of the LNAPL contamination to the west of the site at the former CEMEX site has been operated as a separate activity, which comprises a number of sumps installed within the shallow soils to intercept the shallow groundwater to facilitate abstraction of LNAPL and contaminated groundwater, which is transferred to a treatment plant.

3.5.17 A 2023 groundwater monitoring report (presented at Appendix 3) concluded that the concentrations of contaminants and natural attenuation parameters recorded in groundwater are comparable to those modelled in the risk assessment completed in 2011. Groundwater monitoring data indicates that sulphate reduction and methanogenic processes are occurring within the groundwater hydrocarbon plume, and consequently there is biodegradation of petroleum hydrocarbons in deep groundwater occurring under reducing (anaerobic) conditions. It is reported that the biodegradation activity is reducing the flux of petroleum hydrocarbon from groundwater reaching the River Aire, although contamination is still reaching groundwater at the riverbank area based on groundwater analytical data. The groundwater monitoring report indicated that water quality in the River Aire is considered not to be adversely affected by the contamination at the Site.

3.5.18 Remediation activities have now been completed and approved by the Environment Agency for activities in eight of the nine cells. The one remaining cell, under active remediation is located in the in the FCC permitted area.

4.0 PROPOSED CHANGES TO THE PERMITTED ACTVITIES

4.1 Current Permitted Activities

4.1.1 Knottingley Waste to Resource Facility is managed by FCC Recycling (UK) Limited. The facility comprises the storage, transfer, treatment, and recovery primarily of industrial wastes.

4.1.2 The current permitted activities are presented in Table S1.1.1, as listed in the Environmental Permit ref. EPR/JP3547JL. Activities at the site include the bulk handling and transfer of both hazardous and non-hazardous waste, distillation-based solvent recovery, the creation of Secondary Liquid Fuel (involving the utilisation of heat and steam from boilers), together with the storage and management of waste materials and raw substances. Furthermore, the site conducts surface water and process water treatment through a biological aerobic treatment plant. These activities are summarised in Table 3.

Table 3: Current Permitted Activities.

Activity Listed in the EPR/ JP3547JL and Schedule 1 of the EP Regulations	Description of Specified Activity
Section 5.3 A(1)(a)(v): Recovering by distillation of any oil or organic solvent.	Operation of kettle, reboiler heat exchanger, distillation column and vent condenser, feed, and production tanks.
Section 5.3A(1)(a)(iii): Disposal or recovery of hazardous waste with a capacity exceeding 10 tonnes per day involving blending or mixing prior to submission to any of the other activities listed in 5.3 or 5.1.	Formulation of Secondary Liquid Fuel by blending process residues with waste materials.
Section 5.6A(1)(a): Temporary storage of hazardous waste with a total capacity exceeding 50 tonnes pending a 5.1, 5.2 or 5.3 activity.	Storage of wastes prior to treatment or transfer off-site.
Section 5.3A(1)(a)(iv): Disposal or recovery of hazardous waste with a capacity exceeding 10 tonnes per day involving repackaging prior to submission to any of the other activities listed in 5.3 or 5.1.	Bulking up of waste materials within Waste Transfer Building.

4.2 Proposed changes to the Permitted Activities

4.2.1 It is proposed to remove the distillation of solvents activities and the activity/waste list for Tank S13 from the Permit, although to retain two boilers (Boilers 4 and 5) of the previously three permitted boilers using gas and Secondary Liquid Fuels (SLF) as fuel. Currently the two remaining boilers (Boilers 4 and 5 in Boiler House 1 and 2 respectively) and associated storage tanks are mothballed with no formal timetable for recommissioning.

4.2.2 It is proposed to retain the following activities on the Permit although to amend as follows:

- **Waste Transfer Station -** the storage and transfer of hazardous and non-hazardous wastes, including where appropriate repackaging, size reduction and decanting. To amend the waste list in the permit to add additional waste codes for storage and transfer and to allow these activities to take place on the site as a whole.

- **Associated raw materials/reagents will be stored** and used on site.

- **Discharge of treated effluents** (i.e., site surface water and process water in the aerobic treatment plant) **to sewer** is already permitted but needs updating to reflect the changes that pertains the existing biological treatment plant which is mothballed and will not recommence. However, the Operator has repurposed the infrastructure as a **surface water collection tank**.

- **The use of existing gas or liquid-fuelled boilers** which is to be reduced to two (i.e., Boiler 4 with rated thermal input of 6.6MWth and Boiler 5 with rated thermal input of 9.0MWth) with tag numbers B01-ZP-01 and B01-ZP-02 and their corresponding boiler stack emission points - EP08 and EP12 (currently A12 and A13 in the existing permit ref. EPR/JP3547JL) within the Boiler Complex, indicated on the Sampling and Emission Point Plan (ref. 5827-CAU-XX-XX-DR-V-1805) will be retained to provide steam to the proposed dryer, the ammonia recovery unit and the metals recovery facility as directly associated activities (DAA).

4.2.3 It is proposed to undertake the following **new** activities on site:

- **Refuse Derived Fuel (RDF) Preparation** - processing of non-hazardous industrial wastes into RDF fuel for Energy from Waste (EfW) facilities including shredding and storage.
- **Packaged Waste Processing –** including sorting, washing, shredding, drum crushing and storing of drums.
- **Leachate and Aqueous Wastes Treatment -** the physico chemical and biological treatment of landfill leachate and similar aqueous wastes in a biological treatment plant and reverse osmosis plant, with effluents discharged to sewer or surface water as appropriate. The process will include stripping of ammonia from wastes and the recovery of ammonia as an aqueous solution.
- **Physico-chemical Treatment of Aqueous & Inorganic Wastes, Solids and Sludges -** the physico-chemical treatment of solid and liquid wastes so as to facilitate recovery or disposal, the drying of solid and sludge wastes so as to facilitate recovery or disposal; including mixing, blending, separating, washing, filtering, precipitating out, filter pressing, drying, storing.
- **Metals and Inorganic Salts Recovery** – pH adjustment, precipitation reactions, separation of precipitated solids and storage for recovery of the precipitated solids; with the remaining liquid effluent either being treated on site or being removed.
- **Temporary Storage of Hazardous and Non-Hazardous containerised/palletised wastes.**
- **Discharge of effluent to surface water** (river) from leachate and aqueous wastes treatment.
- **Discharge of site surface water run-off to surface water** (river).

4.2.4 The proposed activities for the temporary storage of hazardous and non-hazardous containerised/palletised wastes, includes a wide range of wastes. The waste which will be temporarily stored included waste form the 20 separate chapters in the European Waste Catalogue (EWC) code, which include industry specific waste together with some generic wastes. EWC code Chapters 01 to 12 and 17 to 20 refer specifically to industry process waste and municipal waste, Chapters 13 and 14referes to oil wastes and wastes of liquid fuels, waste organic solvents, refrigerants and propellants. The waste for temporary storage will not be processed on the facility, they will arrive at the facility is appropriate containers, stored and handled with relevant mitigation and control measures prior to being moved off site to other waste management facilities.

5.0 MEASURES TAKEN TO PROTECT LAND, ENGINEERED SITE MANAGEMENT AND DRAINAGE

5.1 Waste Types to be stored and treated

5.1.1 Waste types at the site to be stored and treated consist of non-hazardous and hazardous wastes, are divided into 3 main categories:

- Leachate and aqueous wastes treatment
- Aqueous and inorganic wastes, solids and sludges
- Refuse Derived Fuel (RDF) Preparation

Leachate and Aqueous Wastes

5.1.2 The Operator proposes to add new activities to the permit, which will involve Leachate and Aqueous Waste Treatment through physico-chemical and biological treatment of imported landfill leachate and similar aqueous wastes in a biological treatment plant and BAT-proof reverse osmosis plants, with effluent discharged to sewer or surface water where appropriate. It will also include the stripping of ammonia from wastes and the recovery of ammonia as an aqueous solution.

5.1.3 The total storage in the Leachate and Aqueous Wastewater treatment area will be up to 4100m^3 within 13 tanks, including 50m^3 storage for packaged reagents and a further 25m^3 of biomass residues skips. These will be appropriately contained within fully bunded segregated storage areas.

5.1.4 All tanks or a combination of tanks in this area shall be self-bunded or within bunded areas on impermeable concrete, designed in line with the CIRIA 'Containment systems for the prevention of pollution: Secondary, tertiary and other measures for industrial and commercial premises' (C736;2014) and relevant HSE standards for storing chemicals. See **Appendix 5** of the report ref. 5827-CAU-XX-XX-RP-V-0308 for details on secondary containment calculations for the applicable tank capacity and bund associated with the relevant buildings.

5.1.5 Further details on the treatment processes and storage of materials for leachate and aqueous wastes at the Site are set out in the following document 'Process Description and BAT Review for the Physico-chemical and Biological Treatment of Leachate and Aqueous Wastes (Report ref. 5827-CAU-XX-XX-RP-V-0307).

Aqueous and inorganic wastes, solids and sludge

5.1.6 The Operator proposes to carry out a series of physical and physico-chemical treatment activities to facilitate recovery and disposal activities under the following headings:

- The physical aspect will include the inspection, storage, and processing (e.g., dismantling and sorting, separation, bulking or shredding) of hazardous and non-hazardous materials for recovery or off-site disposal;

- Physico-chemical treatment of Aqueous and Inorganic Wastes which will include physico-chemical treatment of solid and liquid wastes to facilitate recovery or disposal;

- Physico-chemical treatment of Solids and Sludges involving drying of solid and sludge wastes to facilitate recovery or disposal;

- Metals and Inorganic Salts Recovery;

5.1.7 The physico-chemical treatment processes will incorporate mixing, blending, separating, washing, filtering, chemical treatment (including pH adjustment, reduction-oxidation reactions, precipitation reactions, absorption, adsorption), solids separation (filtering, decanting), drying and storage for recovery or disposal.

5.1.8 The metals and inorganic salts recovery will comprise pH adjustment, precipitation reactions, separation of precipitated solids, washing and storage for recovery of the precipitated solids, with the remaining liquid effluent either being treated on site or taken off-site for further treatment.

5.1.9 Total storage in the Physico-chemical Treatment and Recovery area for wastes will be up to 2200m^3 within 30 tanks, including 200 m^3 storage for packaged wastes and reagents within fully bunded segregated storage areas or skips.

5.1.10 The area for Metal and Inorganic Salts recovery will have up to 500m^3 storage for wastes and effluents within 8 tanks, including additional storage of 200m^3 for packaged wastes, reagents and residues in skips.

5.1.11 Further details on the treatment processes and storage of materials for aqueous and inorganic wastes, solids and sludges at the Site are set out in the following document 'Process Description and BAT Review for the Physical and Physico-chemical Treatment of Aqueous & Inorganic Wastes, Solids and Sludges' (Report ref. 5827-CAU-XX-XX-RP-V-0308).

Refuse Derived Fuel (RDF) Preparation

5.1.12 It is proposed to add new activities to the permit for the Site which involve Refuse Derived Fuel (RDF) preparation. The Refuse Derived Fuel (RDF) Preparation will involve the processing of non-hazardous industrial wastes into RDF fuel for Energy from Waste (EfW) facilities or landfill, including shredding and storage.

5.1.13 The processing of non-hazardous wastes to produce RDF will include shredding of non-hazardous wastes from on-site wastes and incoming waste streams, including crushing of drums and shredding of packaging wastes, and the sorting and removal of materials that are suitable for other recovery or reuse purposes.

5.1.14 Further details on the treatment processes and storage of materials for Refuse Derived Fuel preparation and packaged waste processing at the Site are set out in the following document

'Process Description and BAT Review for RDF preparation (Report ref. 5827-CAU-XX-XX-RP-V-0306).

5.2 Waste Storage

5.2.1 Waste storage (including temporary storage of hazardous and non-hazardous containerised/palletised wastes) will be provided in appropriate areas, segregating incompatible materials to make sure only compatible materials are stored near each other. Waste deemed not acceptable to be placed near other waste will be stored within a quarantine area pending removal from site.

5.2.2 Where waste storage is in the open, the Operator will adequately store the wastes within either packaging or larger containers suitable for the contents.

5.2.3 Additional storage for wastes, reagents and residues in skips will be provided in bunded areas with appropriate segregation.

5.2.4 Additionally, the site will have two main waste storage areas that will be used to store different waste types that are accepted on-site. These areas will be fully bunded.

5.2.5 Some of these areas will be further split into bays/sections to provide adequate storage for materials that may be stored temporarily (which may range between <1 working day to <6 months). Storage bays will be individually segregated and designed to slope backwards, ensuring that any spilt liquid is contained within the bay and will be cleaned accordingly, and incompatible material will not contact each other.

5.2.6 The non-hazardous inspection and repackaging area will be separately bunded and used for the inspection and repacking or bulking of non-hazardous waste materials. In contrast, the handling, bulking, repackaging and storing of hazardous waste will be fully bunded and separated from other waste streams to ensure proper segregation of activities and stored materials. Packaged wastes, which may be hazardous, stored in the open will be in suitable UN-approved containers designed for such content. The site Operator will store packaged waste at a maximum of 2m height.

5.3 Site Engineering and Drainage

5.3.1 All tanks or a combination of tanks shall be self-bunded or within bunded areas on impermeable concrete, designed in line with the CIRIA 'Containment systems for the prevention of pollution: Secondary, tertiary and other measures for industrial and commercial premises' (C736;2014) and relevant HSE standards for storing chemicals.

5.3.2 The bunded areas will have sumps for collecting rainwater and contaminated liquid from spillages/leaks and disposed of appropriately (see IMS-4-04.19.02-KETP for procedure on Sump integrity check). The bunds will be inspected regularly (inspection detail are presented in IMS-4.02.04.02-BM procedure for Daily Site Checks that includes bund inspection). All surface water collected in bunds will pass through the treatment facility.

5.3.3 Surface water from site roads and non-waste areas will discharge to the existing treatment plant and river as currently permitted. Any water collecting within the bunded waste areas (not only tanks) will pass through the aqueous treatment plant, hence establishing a clear distinction of segregating uncontaminated wastewater streams from wastewater streams that require treatment.

5.3.4 See **Appendix 6** of the report ref. 5827-CAU-XX-XX-RP-V-0308 for details about the site's drainage plan.

5.4 Site Management

5.4.1 The site operates under an ISO 14001 accredited environmental management system (EMS). Audits of the performance of key plants, and all maintenance will be carried out in compliance with the standard requirements and reviewed at the required frequency by senior management to demonstrate engagement with the management system and to drive continual improvement in the Site's overall environmental performance.

5.4.2 The Site's management system is audited externally as part of the ISO 9001 and ISO 14001 accreditation. It also operates and is audited against ISO 45001 and ISO 50001.

5.5 Relevant Substances Assessment

5.5.1 The Industrial Emissions Directive (IED) requires assessment to be carried out for all hazardous substances used, produced or released within the installation. The EC guidance document (2014/C 136/03) is a comprehensive guide for the production of a baseline report as required by Article 22(2) of the IED. However, the Environment Agency H5 guidance refers to 'dangerous substances' (as defined under COMAH Regulations).

5.5.2 Hazardous substances (Article 3(18) and Article 22(2), first subparagraph) are those substances or mixtures defined within Article 3 of Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulation) which, as a result of their hazardousness, mobility, persistence and biodegradability (as well as other characteristics), are capable of contaminating soil or groundwater and are used, produced and/or released by the installation.

5.5.3 The 'baseline report' referred to in the IED requires an assessment of the *"…possibility of soil and groundwater contamination at the site of the installation…"* (Article 22(2), first subparagraph). The Water Framework Directive (2000/60/EC) and Groundwater Daughter Directive (2006/118/EC) (GDD) require the prevention of the input of hazardous substances into groundwater subject to various exemptions. The respective UK environment agencies are responsible for considering whether a potential pollutant should be determined to be a hazardous substance or a non-hazardous pollutant. The approach used in assessing substances updates that set out in the old Groundwater Directive (80/68/EEC). The Joint Agencies Groundwater Directive Advisory Group (JAGDAG) reviews assessments made by the agencies and has compiled a list of hazardous substances.

5.5.4 The hazardous substances assessment comprises a 1 to 3 stage assessment procedure.

Stage 1 – Identify Substances used at the Installation

5.5.5 Stage 1 requires the identification of substances used, produced or released at the installation. The installation will accept a range of hazardous and non-hazardous wastes from a wide range European Waste Catalogue (EWC) code descriptions. Although there will be a wide range of both organic and inorganic substances present within the waste and raw materials at the site, a substantial amount of these waste will be packaged waste that will be stored and transfer wastes, rather than processed waste.

5.5.6 The waste arsing for the site treatment activities and raw materials include the following:

- Leachate (ammoniacal nitrogen, chloride, metals)Aqueous and inorganic wastes, solids and sludge (including metals)
- Non-hazardous wastes for Refuse-derived fuel (RDF) preparation (substances in RDF are mainly cellulose, hemicellulose, lignin, polyethylene, polypropylene, and polyethylene terephthalate)
- Raw materials for treatments undertaken on site include the following based on physio-chemical properties:

    - Acids
      Sulphuric acid
      Citric acid (membrane acidic cleaner)
      Acetic acid
      Phosphoric acid
      Oxalic acid

    - Bases (Alkaline Substances)
      Caustic Soda (sodium hydroxide)
      Alkaline cleaner (likely contains sodium or potassium hydroxide)
      Sodium carbonate
      Hydrated lime (calcium hydroxide)

    - Salts
      Ferric chloride ($FeCl_3$) / Ferrous chloride ($FeCl_2$)
      Ferrous sulphate ($FeSO_4$)
      Sodium sulphate (Na_2SO_4)
      Sodium bisulphate ($NaHSO_4$)
      Sodium oxalate ($Na_2C_2O_4$)

    - Organic Solvents / Hydrocarbons
      Paraffin
      Kerosene

    - Adsorbents / Ion Exchangers
      Activated carbon
      Ion exchanged clays

- Flocculants / Coagulants
  Flocculant (typically synthetic polymers or alum-based)

5.5.7 Waste arising from the temporary storage of hazardous and non-hazardous containerised/palletised wastes includes waste arising from the 20 separate EWC codes and consequently a wide range of substances will be managed at the facility. These key groups of substances based on physico-chemical properties that will be temporarily stored as containerised/palletised wastes and may contain certain hazardous substances (including the following:

- Chlorinated Solvents (e.g. example trichloroethane, carbon tetrachloride)
- Chlorinated aromatics (e.g. chlorobenzenes) and chlorinated alkanes
- Phenolic (e.g. chlorophenols)
- Chlorophenoxy Herbicides, Pesticides/Insecticides/Fungicides/ Triazines and Herbicide-like Structures
- Polychlorinated biphenyls and dioxins
- Nitroaromatics
- Monoaromatic (e.g. benzene)
- Polycyclic aromatics (e.g. benzo(a) pyrene)
- Halogenated alcohols and ethers
- Phenyls and anilines
- Fluorinated compounds (e.g. Per- and Polyfluoroalkyl Substances, PFAS)
- Metals and metalloids (e.g. lead, mercury, chromium VI)

5.5.8 The substances identified above are substances which could be present in the waste types based on the EWC codes, although where present are likely to be part of combined waste types rather than a separate substance.

Stage 2 – Identify Substances which are Relevant Hazardous Substances or substances with pollution potential

5.5.9 Based on the waste and raw materials to be stored, managed and processed on the facility, there will be a range of relevant hazardous substances. It is not possible to identify all the relevant hazardous substances that could be present. The key substances identified in Stage 1 of the assessment therefore include groups of substances, based on physico-chemical properties have similar behaviours and therefore risks in the environment and hence the same

or similar pollution mitigation and controls measures are applied. Most of these substances and groups of substances are primarily associated with the temporary storage of hazardous and non-hazardous containerised/palletised wastes.

5.5.10 The substances (and groups of substances based on physico-chemical properties) used and stored (including temporary storage) at the Installation that are identified in Stage 1 have been further assessed considering the chemical and physical properties to determine whether the substance have the potential to cause potential pollution of soil and groundwater or are 'Relevant hazardous substance'. These substances (and groups of substances based on physico-chemical properties) are presented in a table at Appendix 4 and include information on the classification, physical state, solubility, toxicity, mobility, persistence, soil and groundwater pollution potential and assessed to determine if the substances (and groups of substances based on physico-chemical properties) are considered 'relevant hazardous substance' or substances with pollution potential. Given that the waste may contain a wide range of hazardous substances, the properties presented in the table presented at Appendix 4 are based on using a 'surrogate' substance for the individual groups of the substances.

5.6 Stage 3 – Assessment of site-specific pollution possibility

5.6.1 Stage 3 assessment of the site-specific pollution possibility for the relevant substances identified in Stage 2.

5.6.2 A substance may be considered to be of concern where:

- The substance is a Relevant Hazardous Substance;
- The substance is highly toxic and persistent and if released, even in small quantities, could result in a pollution risk and;
- The substance is relatively benign, although the quantity managed is such that the effect of a catastrophic leak could result in a pollution risk:
- Numerous small, seemingly insignificant drips or leaks have occurred over a long period of time and may have resulted in an accumulation of the substance in the environment;
- There is insufficient information on which to determine the potential risks.

5.6.3 A substance may be considered *not* to be of concern where:

- The substance is highly toxic and persistent but used/stored in such small quantities that it could never enter the environment (even on a cumulative basis) at levels which could result in a pollution risk;
- The substance is highly toxic and a pollution risk if released, however the operator has sufficient measures in place to ensure it could never be released;

- Large quantities of a non-hazardous substance are used, but even if there were a catastrophic leak it could not result in a pollution risk or the site being in an unsatisfactory state.

5.6.4 The substances (and groups of substances based on physico-chemical properties) used and stored (including temporary storage) at the Installation that are identified in Stage 2 as a relevant Hazardous Substances or substances with pollution potential (i.e. relevant substance) are assessed further in Table 4.

5.6.5 The site-specific pollution control measures have been considered for those substances identified as relevant substances in Stage 2 and summarised in Table 4.

Table 4. Assessment of site-specific pollution possibility

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Treatment substances					
Leachate (ammoniacal nitrogen)	Moderate to High	Yes	4100 m3 total	All leachate effluent will be stored in tanks which will be self-bunded or within bunded areas on impermeable concrete in accordance with good practice. Tanks are self-contained having capacity to hold in excess of 110% of the tanks content. Control measures are in place on site in the unlikely event of spillage, failure or overfill.	No The site specific control measures are considered adequate
Aqueous and inorganic wastes, solids and sludge	Very High	Yes	2200 m3 total	All inorganic wastes will be stored in tanks on site which will be self-bunded or within bunded areas on impermeable concrete in accordance with good practice guidance. Tanks are self-contained having capacity to hold in excess of 110% of the tanks content. Incompatible materials will be segregated. Storage bays will be segregated and sloped appropriately to ensure any spilt liquid is contained within the bay and cleaned accordingly.	No The site specific control measures are considered adequate
Raw materials					
Acids	High	Yes		All chemical containers will be bunded, with 110% capacity. Sulphuric acid is stored in an acid resistant tank. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Bases (Alkaline Substances)	Moderate to High	Yes		All chemical containers will be bunded and tanks shall be above ground with secondary containment of materials that are appropriate to the chemical nature of the materials being stored. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Hydrocarbons	High	Yes		All chemical containers will be bunded and tanks shall be above ground with secondary containment of materials that are appropriate to the chemical nature of the materials being stored. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Temporarily stored wastes					
Chlorinated Solvents	High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Chlorinated aromatics	Moderate	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and treated/disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Chlorinated alkanes	Moderate to high	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and treated/disposed of appropriately.	No The site specific control measures are considered adequate
Phenolic	Moderate to high	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Chlorophenoxy Herbicides, Pesticides/Insecticides /Fungicides/Triazines and Herbicide-like Structures (Meroprop)	Moderate	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Polychlorinated biphenyls and dioxins	High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Nitroaromatics	High potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Monoaromatic (benzene)	High Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Polycyclic aromatic hydrocarbons (benzo(a) pyrene)	High Potential in Soil / Low Groundwater Contamination Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Halogenated alcohols and ethers	High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Phenyls and anilines	Moderate to High	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

Substance (inc based on physico-chemical properties)	Soil and groundwater pollution potential /possibility	Relevant substance	Quantity	Pollution Prevent measures	Pollution risk
Fluorinated compounds (PFAS)	Very High Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate
Metals and metalloids	High Potential	Yes		The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste. Wastes (containers, packaged waste) shall be stored appropriately on bunded area and concrete surface. Materials will be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.	No The site specific control measures are considered adequate

6.0 STATEMENT OF SITE CONDITION

6.1.1 Knottingley Wate to Resource Facility operated by FCC Recycling (UK) Limited is dedicated to the storage, transfer, treatment, and recovery of industrial wastes. The Site is located on the eastern edge of Knottingley occupying a site historically associated with chemical processing, primarily the storage and processing of coal tar and related products dating back to the 1870's.

6.1.2 These historical uses have resulted in significant soil and groundwater contamination, consisting of tar -based hydrocarbons, across the areas of the former tar distillation facilities. Remediation actions have been undertaken and are currently ongoing at the Site which focusses on the removal of NAPL from the Made Ground and shallow groundwater across the affected areas. Groundwater monitoring data has been reviewed regularly and a 2023 report indicated that biodegradation of hydrocarbons is occurring within the groundwater plume.

6.1.3 The currently permitted activities comprise bulk handling and transfer of both hazardous and non-hazardous waste, distillation-based solvent recovery, the creation of Secondary Liquid Fuel (involving the utilisation of heat and steam from boilers), together with the storage and management of waste materials and raw substances. Furthermore, the Site conducts surface water and process water treatment through a biological aerobic treatment plant.

6.1.4 It is considered that chemical substances in the raw materials wastes that are likely to be stored and managed on site as part of the waste management activities could potentially be present in the underlying ground and groundwater from historical activities on Site and the surrounding area.

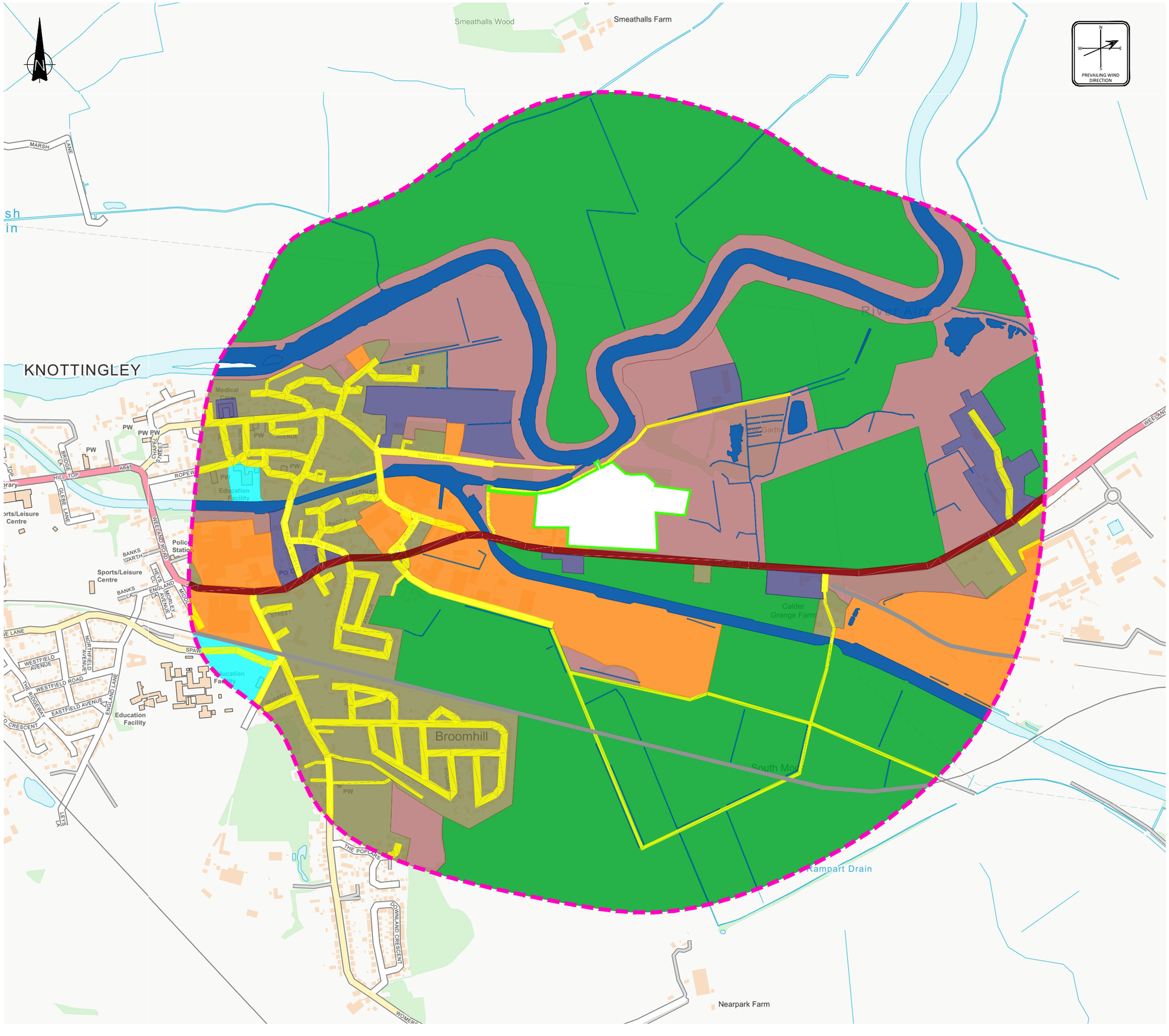
6.1.5 The materials will be transported to and from the facility and stored in containers that are appropriate for the types of waste (sealed containers for liquids, packaging or containers for solid waste.

6.1.6 Liquid products/materials as part of the treatment processing are stored in tanks are self-contained having capacity to hold in excess of 110% of the tanks content

6.1.7 Materials and wastes will be stored appropriately on site within bunded areas and a concrete surface. Materials and waste will also be stored in separate areas to ensure no mixing with incompatible materials. Storage is such that spillages should not occur, and control measures are in place in the unlikely event of spillage, failure or overfill. All surface water is collected on site and disposed of appropriately.

DRAWINGS

5827-CAU-XX-XX-DR-V-1800	Sensitive Receptors Plan
5827-CAU-XX-XX-DR-V-1804	Permit Boundary Plan



LEGEND

- PERMIT BOUNDARY
- 1000m OFFSET
- SURFACE WATER
- WOODLAND / SCRUBLAND
- COMMERCIAL / LEISURE
- EDUCATIONAL FACILITY
- INDUSTRIAL
- RESIDENTIAL
- MAJOR ROAD
- MINOR ROAD
- RAIL

REV					
P03	LEGEND UPDATED	EJD	JC	JC	06.08.25
P02	PERMIT BOUNDARY UPDATED	EJD	JC	JC	09.07.25
P01	ISSUED FOR INFORMATION	EJD	ER	ER	16.04.24
REV	MODIFICATIONS	BY	RE	AP	DATE

PURPOSE OF ISSUE: FOR INFORMATION

STATUS: S2

CLIENT: FCC Environment

PROJECT:

KNOTTINGLEY WASTE TO RESOURCE FACILITY

TITLE:

SENSITIVE RECEPTOR PLAN

DESIGNED BY	DRAWN BY	REVIEWED BY	AUTHORISED BY
EJD	EJD	ER	ER

DATE	SCALE @ A3	JOB REF:	REVISION
16.04.2024	1:10000	5827	P03

DRAWING NUMBER: 5827-CAU-XX-XX-DR-V-1800

Caulmert engineering environmental planning

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RIVER AIRE

DISCHARGE

STOCKING LANE

TRUNDLES LANE

Surface Water Storage

Waste Processing 07

INT 01

EP07

P07-ZP-01

Sewer Connection

Effluent

Waste Processing 02

EP02

P02-ZP-01

Waste Storage 02
(packaged only)

S02-ZS-01

General Storage 01

GS1-OS-01

General Storage 02

GS1-ZS-02

Packaged
Waste
Offloading
Area

Tanker
Holding
Area

Waste Processing 06

INT 02

EP26

EP06

EP16

P06-ZP-11

P06-ZP-21

P06-ZP-31

Surface Water Storage

INT 03

Waste Processing 03

EP03

P03-ZP-01

Waste Storage 01

S01-OS-01

Reception
Area

EP05

Diesel

EP11 EP01

Waste Processing 01

P01-ZP-01

Weighbridge

Waste Processing 05

P05-ZP-01

EP08

B01-ZP-01

EP18

B01-ZP-02

Boiler Complex

FIRE TANK

SUB

SUB

PUMP HOUSE

MANOEUVRING

YE Equipment
Transformer

Switchroom

Weighbridge

Switchroom
Transformer
YE Equipment

Offices and Labs

EP14

EP24

EP04

INT 04

P04-ZP-01

WEELAND ROAD

Gas Main

Water Main

Waste Processing 04

Water Main

NOTES

1. DO NOT SCALE FROM THIS DRAWING, WORK FROM FIGURED DIMENSIONS ONLY. ALL DIMENSIONS ARE IN METRES AND ALL LEVELS ARE IN METRES ABOVE ORDNANCE DATUM UNLESS NOTED OTHERWISE.

2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, ENGINEERS AND SPECIALIST DRAWINGS AND SPECIFICATIONS.

LEGEND

- OWNERSHIP BOUNDARY
- PERMIT BOUNDARY
- H — HYDRANT

REV	MODIFICATIONS	BY	RE	AP	DATE
P03	LEGEND AMENDED	EJD	JC	AS	06.08.25
P02	HYDRANTS ADDED TO DRAWING	EJD	JC	AS	28.07.25
P01	ISSUED FOR INFORMATION	EJD	JC	AS	10.07.25

CLIENT: FCC Environment

PROJECT: KNOTTINGLEY WASTE TO RESOURCE FACILITY

TITLE: PERMIT BOUNDARY PLAN

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APPENDIX 1

Updated Conceptual Site Model – Croda Distillates Limited

Former Tar Distillery, Knottingley

Updated Conceptual Site Model (Confidential)

Croda Distillates Limited

Ref: 2824.003

UNITED BY OUR DIFFERENCE

WSP

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1 Introduction

1.1 Authorisation

WSP Remediation Limited (WSP) have been retained by Croda Distillates Limited (Croda) to undertake additional characterisation at the site and construct further modifications to the conceptual site model (CSM) for the Knottingley site.

This document follows the previous issue of the CSM report, completed in December 2010 (ref: 2824.002) and presents the results of further characterisation works and studies at the site.

1.2 Site Location

The site is located to the eastern side of Knottingley, West Yorkshire, with the main site accessed from Weeland Road. A site location plan is presented in Figure 1.

The study site occupies a total land area of approximately 31 hectares and is separated into a number of distinct areas:

- SRM Lease Area – comprising solvent recovery operations operated by SRM Ltd (now part of Tradebe)
- Croda Site Areas – two vacant and secure areas comprising of:
    - *Croda Tar Distillery* – (situated between CEMEX and SRM lease areas) which was formerly occupied by coal tar refining operations which included distillation houses, tar wells and fractional distillation columns.
    - *Former Tar Lagoons Area* – situated to the north-east of the SRM lease area and currently comprises open land, characterised by the presence of former and redundant tar settling lagoons.
- CEMEX Land – former aggregates production, storage and distribution plant within the western portion of the site. Operations at the plant ceased in August 2011.
- Willow Garth – within the north-eastern area of the site. This land is currently leased to Yorkshire Wildlife Trust and is a designated wetland nature reserve.
- Farmland Areas – Areas to the south of Weeland Road and east of the SRM lease area comprising open farmland leased to local farmers for grazing.
- British Waterways Land – This land parcel is not owned by Croda International PLC but is located immediately to the north of the study site and has been included within the assessment and characterisation of the site.

Watercourses delimit the northern, western and southern boundaries of the study site, with the Aire and Calder Navigation and River Aire forming boundaries to the majority of the site. Open farmland and Willow Garth form the eastern margins of the site.

The site layout and boundary plans are presented within Figure 2.

1.3 Previous Studies and Reports

In preparing this report, WSP have completed an extensive review of archive and existing reports relating to the site. References are presented within Section 8.

1.4 Background and Objectives

Croda have been undertaking voluntary characterisation and remediation works at the Knottingley facility to meet with their corporate objectives and to support decisions relating to the future of the site.

Recent studies completed by WSP in 2010 and 2011 have focussed upon the detailed characterisation of ground and contamination conditions at the site together with the presentation of a conceptual site model report (CSM), detailed quantitative risk assessment (DQRA), a draft remedial action plan (RAP), issued to the Environment Agency (EA) during late 2010 and early 2011.

The EA have stated that their continued priority is the ongoing visible discharge of hydrocarbons (in the form of iridescent sheens) to the River Aire immediately adjacent to the Bank Dole Cut lock structure and surrounding an interceptor that was previously installed by Croda in an attempt to manage this discharge.

Recent studies undertaken by WSP have provided further understanding on the mechanisms for the outbreak of contamination within this area. The findings of this work have been presented to the EA who have indicated general acceptance of the pollutant linkages and contaminant pathway models currently understood to be ongoing at the site.

The objective of this report is to further refine the conceptual model for the site and draw together the findings and conclusions of additional characterisation works undertaken within key areas of the site.

The findings of the report will support the finalisation of the remedial objectives and remedial action plan, to be agreed by stakeholders prior to implementation at the site.

1.5 Further Activities

Following the issue of the previous WSP CSM Report (Ref: 2824-002), dated December 2010, a number of further activities associated with the characterisation of the site have been completed by WSP. The intention of these activities has been to further establish the ground model with particular emphasis being placed upon areas not previously investigated, or areas of potential uncertainty identified within the previous CSM.

Croda have retained WSP to carry out characterisation and investigation of the following areas:

- Intrusive investigation of the CEMEX Land.
- Detailed investigation of former tar well structures.
- Installation of further groundwater monitoring wells within the down-gradient hydraulic discharge zone.
- Further characterisation of the groundwater model and contamination impacts within the British Waterways land.

The findings of these further investigations have been incorporated within this updated assessment, with the Tar Well Investigation report presented within Appendix J.

1.6 Report Structure

This report presents the current Conceptual Site Model based on current and historic site information and is structured in the following way:

Section	Comment
Section 2	Provides a detailed description of the ground conditions and geological strata at the Croda site.
Section 3	Presents the groundwater data that has been gathered since June 2009 together with the hydrogeological tests and provides an assessment of the groundwater flow regimes within the various aquifers beneath the site.
Section 4	Summarises the sources of contamination on the site and reviews the evidence base for contaminant distribution on the site within both the unsaturated and saturated zones.
Section 5	Provides a summary and review of the pollutant linkages identified at the site.
Section 6	Presents the key conclusions together with a set of supporting recommendations.
Section 7	Lists the reports referenced or used within the development of the CSM.

WSP have completed historical research, further data reviews and a series of intrusive studies, field tests and monitoring to support the development of the CSM. These tasks and activities are described in detail in Appendix A of this report.

In addition, a detailed quantitative risk assessment (DQRA) has been undertaken with regard to residual dissolved phase contamination at the site. This is referenced within the report and presented in full within Appendix I.

1.7 Continued Remedial Works

WSP have been appointed to carry out continued operation of non-aqueous phase liquid (NAPL) recovery at the site. Groundwater remediation has been ongoing since late 2009 and incorporates an area known as Cell 1 and Cell 2, with the Croda vacant land.

WSP have undertaken remediation technology trials as part of this work, which has been reported under separate cover. The conclusions of the remedial trials will be used to select and determine the most appropriate technique for remedial implementation across the wider site.

The remedial works are not discussed within this report, however geological and hydrogeological information gathered during those works has been used within the construction of the CSM.

2 Geological Assessment

2.1 Summary of Ground Conditions

A summary of ground conditions encountered during recent and previous site investigations and remedial works at the Knottingley site is presented in Table 2.1 below. Detailed descriptions of ground conditions encountered during WSP's investigations between 2009 and 2011 are provided as borehole logs in Appendix B, with detailed discussion on site geology provided in Sections 2.2 to 2.5 below

Geological cross sections for a number of areas of the site are presented in Figures 7 to 10. These cross sections present the underlying geological and groundwater interactions within the site, and extend beyond the northern boundary to Bank Dole Cut canal and lock, and beyond the eastern boundary within the neighbouring agricultural land.

Table 3.1 presents a summary of ground conditions based upon a database of geological data collated over the several phases of site investigation completed at Knottingley and Bank Dole Lock between 1997 and 2011. This table represents a summary conceptualisation of ground conditions developed to date.

Table 2.1 Summary of consolidated ground conditions from 1997-2011 investigations

Stratum Description	Typical Thickness (m)
Made Ground A mixture of loose and cohesive materials, with areas of soft dark grey / black slightly sandy gravelly clay with occasional concrete and brick cobbles and areas of brown / red clayey gravel of brick and concrete with frequent brick cobbles and other occasional man-made products. Limited evidence of Made Ground within field areas and Willow Garth. Potentially reworked sandy clays of the underlying fluvial deposits also identified.	0.05 to 3.8m
Recent Fluvial Deposits Variable in presence but generally identified as a soft, grey, slightly gravelly sandy clay. Has been identified to be occasionally absent within areas of deeper Made Ground.	0.1 to 3.5
Vale of York Drift Deposits *Alluvial Clay* Typically encountered as stiff, thinly laminated, brown mottled grey clay. A limited number of boreholes encountered Alluvial Clay thicknesses of up to 4 m with specific locations described in Section 3.2. A key observation from drilling indicates the clay often becomes sandier with depth. *Middle Deposits* Typically grey, clayey, medium to coarse sand with occasional gravels of flint which becomes slightly clayey, silty fine sand with depth. This unit has only been observed to be absent from the stratigraphy of a single boundary well location. *Middle Clay* Generally encountered as a firm thinly laminated red / brown slightly sandy clay. However, the most recent Stage 2 investigation has indicated the absence of the Middle Clay in several locations, with further detail provided in Section 4.4.2. *Deep Deposits* Typically comprised grey coloured, gravelly sands and sands and gravels with occasional cobbles retrieved towards the base of these deposits.	0.2 to 3.8 0.3 to 6.4 0.0 to 2.0 1.3 to 8.4*

Stratum Description	Typical Thickness (m)
Roxby Formation Typically encountered as stiff to very stiff red clay with frequent gravel of flint. Becomes stiff silty grey clay with depth. Penetrated across full width at one location (MW1). Gypsum rock fragments more frequent towards the base.	c. 7.4

*where proven

Geological cross-sections based upon the ground conditions encountered through key sections of the site are presented in Figures 7 to 10.

2.2 Made Ground

Made Ground was encountered at all boreholes within the site boundary, extending to depths of between 0.2m and 3.8m bgl. The thickness of the Made Ground is locally variable across the site, with thicknesses in excess of 3m in areas associated with former tar distillation features, former tar wells and areas of former deposition (such as the former tar settling beds in north-eastern area).

An area in the south-eastern portion of the site CEMEX site recorded Made Ground to a thickness of 3.2m. This correlates with former land use in this area of the site comprising areas of likely deposition and settling beds/lagoons.

Made Ground was found to be absent at boreholes drilled on agricultural land east of the site boundary (WSP229, WSP230, WSP309, and WSP310).

The variability in the thickness of Made Ground is illustrated in Figure 7 (SW – NE transect). It is apparent that in three areas on this transect the sandy clay of the Shallow Deposits have been pinched out by the Made Ground (WSP250, WSP213, TW30). Furthermore, there are also several locations shown on Figure 8 (W – E) where this occurs including WSP239, WSP222, WSP312, WSP311.

The composition of the Made Ground was identified to be variable between exploratory locations with both granular and cohesive fill encountered. Made Ground primarily consists of gravels intermixed with brick and concrete cobbles within the hardstand areas in the centre of the SRM occupied site, with reworked cohesive materials more prominent in the north-eastern area of the site in soft cover areas, particularly in the vicinity of the tar lagoons/settling beds. Locations around the settling beds (WSP225, WSP226 and WSP314) exhibit thick layers (up to 3.8m thickness) of soft grey/black sandy clay, suggestive of possible reworked ground that may be connected with the construction of the adjacent former tar settling beds. The ground in this area was also known to have historically supported areas of deposition and tar sludge beds and is anticipated to have undergone variation in surface elevation.

Granular Made Ground varies in composition between sandy gravel to cobbles consisting of brick and concrete. The more cohesive Made Ground typically consisted of soft gravelly clay with occasional brick and concrete fragments.

Slight to strong hydrocarbon odours and visible free phase hydrocarbons were evident within the Made Ground materials of all exploratory locations in advanced and around NAPL Areas C and D (now occupied by product recovery wells and plant associated with the Cell 1 and 2 remedial areas), together with exploratory boreholes advanced to the west of these areas within the . Furthermore, during investigations within the British Waterways land, free phase hydrocarbons in Made Ground were observed at one location on the southern bank of the canal (WSP232) and evidence of coal tar contamination observed within WSP239 and WSP323, adjacent to the tar offloading point.

2.3 Recent Fluvial Deposits (Alluvium, Shallow Deposits)

Alluvium, understood to be recent deposits associated with the River Aire, underlie Made Ground in the majority of the boreholes drilled to the Middle and Deep horizons. The alluvium has been encountered as a strata varying in thickness between 0.1m and 3.5m, with an average thickness of 1.2m. The alluvium strata typically consisted of soft sandy clay with occasional gravel or clayey medium to course sands.

As discussed above, these deposits have been indicated to be pinched out by Made Ground, with records of the absence of these deposits in up to 49no. investigation locations to date. Further information is provided within the WSP borehole logs presented in Appendix B.

Areas within the footprint of the former tar distillery and south-western portion of the CEMEX site are noted to be missing this horizon, likely to correlate with areas of deeper Made Ground; suggesting site development resulted in the excavation and reworking of this horizon.

Evident hydrocarbon odours and staining were noted within this horizon, which is anticipated to be associated with vertical contamination migration from overlying Made Ground and shallow perched groundwater.

2.4 Vale of York Drift Deposits (Pleistocene)

These drift deposits are understood to be stratified into sand and clay horizons as follows:

Alluvial Clay (Shallow Deposits)

The alluvial clay was encountered underlying the Recent Fluvial Deposits or Made Ground. It comprises grey/brown firm to stiff thinly laminated orange brown sandy clay encountered at depths between 1.4m and 4.1m bgl, with an average thickness of 1.5m.

Limited contaminant impact was recorded within the firm alluvial clay, although staining and free product has been observed within sandy layers and clay fissures of this stratum during drilling at some locations (e.g. TW01, WSP219B).

Middle Deposits (Middle Deposits)

The 'Middle Deposits' comprising silty sands and clayey sands were encountered below the alluvial clay horizon at depths of between 1.8m and 5.9m bgl, with an average encountered depth of 3.8m bgl. Where present, the strata thickness ranged between 0.3m and 4.0m, with an average thickness of 1.8m. These deposits were generally described as grey, slightly clayey coarse sands becoming fine clayey sand at depth. Where present, gravels were encountered as fine to medium gravels of mixed lithology. A confined groundwater body was present within this stratum in all locations.

The elevation of the Middle Deposits base generally decreases towards the east of the site, with higher areas on the north-western, south-western and southern site boundaries. These variations in base elevation are illustrated in Figure 14 (Middle Deposits base elevation plot). There is also a general thickening of the aquifer towards the east of the site; however there are several thinner areas (≤1.5m) towards the north-west and south of the site including the southern portion of the SRM operational site and the southern field area to the south of Weeland Road. Information from the south-west portion of the site, including the CEMEX site and to the south of Weeland Road, adjacent to the Aire and Calder Navigation suggests that this strata is slightly thicker, generally 2 to 2.5m in thickness. Borehole data also shows that at the eastern site boundary the Middle Deposits appear to thicken to over 3m. This is also supported by borehole evidence in Willow Garth where thicknesses of up to 5m were observed.

A review of the geological conditions encountered in boreholes beyond the northern site boundary and local to the south of Bank Dole Lock indicates there is some thinning of the Middle Deposits, particularly at WSP231 and BH3, with this feature illustrated in Figure 9 (N-S transect through lock). Figure 10 also indicates the full depth of Bank Dole lock structure extends to the base of the Middle Deposits and the underlying Middle Clay ('Clay 2'). The basis of this lock invert depth is taken from an original design drawing for Bank Dole Lock (dated January 1886) provided to WSP by British Waterways. This drawing indicates the lock was originally constructed to an invert depth of approximately 5.50 m bgl, with the depth to the head cill of 3.05 m bgl (allowing for sandstone blockwork construction of c. 40cm) which corresponds to the base of the upper alluvial clay

To the north of Bank Dole Lock and the canal, investigation has illustrated an apparent thinning of the Middle Deposits on the north side of the lock at WSP 234, although information from the western portion of the British Waterways Land suggests that the strata is slightly thicker, trending to a thickness of 2.4m within WSP254A. Information contained within the 'as-built' drawings for the Croda interceptor adjacent to the River Aire (Figures 9 and 41) indicate that the levels of the Middle Deposits and this structure closely correspond.

Strong hydrocarbon odours and evident free phase hydrocarbon product were noted in the soils and groundwater recovered from the Middle Deposits in the majority of exploratory locations across the former and current operational areas of the site, indicating relatively widespread contamination impact in the western, central and north-eastern areas of the site. Peripheral areas to the far west, north-west, south and east did not record evidence of hydrocarbon contamination.

Evidence of free phase contamination was observed in all exploratory works for Cell 1 and Cell 2, together with eight out of the nine exploratory boreholes advanced around Bank Dole Lock. An assessment of the extent of NAPL impacts to the Middle Deposits from monitoring well measurements and indications from borehole logs is presented in Figure 80.

2.5 Middle Clay

The Middle Clay was identified beneath the Middle Deposits at depths of between 2.8m and 8.2m bgl and comprised a layer of firm, locally stiff red/brown, thinly laminated, slightly sandy clay with an average thickness of 0.4m. This stratum is not continuous and was not observed in seventeen exploratory borehole locations in discrete areas of the site, including one location in the south of the CEMEX site, eight locations to the north of the former tar distillery plant within the WSP Cell 1 and Cell 2 recovery system, one location (AE08/04) to the south-east of the former RB1tar well, two isolated locations to the south of Weeland Road within the southern fields area and two locations in the eastern fields.

The Middle Clay thickness across site is illustrated on Figure 15. The plot illustrates the areas where this strata is absent, including the area within the Cell 1 and Cell 2 system. There is a high density of data at the Cell 2 treatment works area, which is not replicated across the site. Elsewhere on site the stratum appears to be largely intact, although is noted to thin down to thicknesses of <0.2m within the eastern portion of the former tar distillery and northern portion of the SRM plant, in the vicinity of the former tar wells RB1-RB4.

There are noted to be areas of thicker clay in the south-western area within the CEMEX site, the southern portion of the SRM facility and the eastern and north-eastern areas including Willow Garth, where the clay layer exceeds 1m in thickness, although these may be localised on the basis that proximate exploratory holes record slightly thinner clays.

To the south of Bank Dole Lock there is an area of slightly thicker clay (≥0.4 up to 0.8m) compared to the surrounding area, which corresponds with an elevated base of the Middle Deposits and the surface of the Deep Deposits. This increase in elevation and thickness is illustrated in Figure 9 (N-S transect through the lock) between WSP233 and the lock structure. Figure 10 (N-S section through lock and interceptor) also illustrates how the main lock structure is likely to bisect the Middle Clay (but not in the area of the cill -Figure 9) and also illustrates the absence of the Middle Clay at a location in the Cell 2 treatment area (TW28).

Limited visual or olfactory evidence of hydrocarbon contamination was detected within this Middle Clay with the exception of localised areas in close proximity to the former tar wells, where hydrocarbon odours and staining were observed. Generally, the limited evidence of impact may indicate that this low permeability horizon may act to limit vertical migration of contamination from the overlying Middle Deposits, where it is present.

Deep Sands and Gravels (Deep Deposits)

The deep sand and gravel unit was encountered at elevations of between 6.5mAOD and -0.3mAOD with an average thickness of 3.6m. These deposits were generally described as grey coloured sand grading to a sandy gravel with occasional coarse gravels and broken cobbles retrieved towards the base. The gravel was predominantly angular to rounded flint, with occasional sandstone and coal. The sand was fine to coarse and varied with depth at most locations, typically becoming more coarse with depth. The proportion of sand to gravel decreased with depth at many locations. Coarse gravels and cobbles were rounded flint and sandstone.

A number of boreholes in the north and east of the site recorded discontinuous thin red clay bands within the sand and gravel deposits, however these were not consistent within all locations and may represent discrete lenses of clay in some locations. The elevation where these were encountered typically ranged from 0.5 to 1.5mAOD and were not observed within the western portion of the site.

The base of this unit becomes deeper towards the eastern site boundary (illustrated in Figure 18 – Deep Deposits Base AOD), particularly at AEAT33, AEAT LIF29 and BH05/05A. To the east of these boreholes there are indications of

thinning at WSP314, WSP315 and WSP310. This suggests a possible channel type feature or local deepening within this unit that runs in a North-South direction approximately corresponding to the eastern boundary of the SRM area.

To the south of the lock structure the aquifer is thicker than the surrounding area. There is also an increase in the base elevation (BH3 1.43mAOD, nearest BH2 0.19mAOD. Exploratory holes to the north of the canal recorded a slightly reduced basal elevation, ranging from 0.753mAOD (WSP321) to 0.664mAOD (WSP322). With the exception of the Binnie and Partners BH3 drilled in 1979, the general trend is for the base elevation of the Deep Deposits to deepen toward the east north-east.

Figure 10 (N-S transect through lock and interceptor) illustrates the relationship between the Deep Deposits, Bank Dole Lock, the Croda interceptor and River Aire. The Croda interceptor is known to have been keyed into the gravels of the Deep Deposits upon construction, bisecting the Middle Deposits and clays, and potentially linking the Middle and Deep Deposits within the structure. In contrast the historical drawings of Bank Dole Lock do not provide evidence that the invert level of the structure extended to the base of the Deep Deposits.

Evidence of hydrocarbon contamination was generally absent in the majority of exploratory locations advanced into the Deep Deposits. Staining of soil or strong tar odour was noted during drilling activity in AE04/04, AE08/04, AE09/04, GA10, BH101C, BH102C, BH03/07/D and BH09/07/D. In WSP302, WSP303 and WSP323, visible free phase hydrocarbons were noted towards the base of this unit. These boreholes are situated on the northern site boundary towards the Bank Dole lock structure.

There was no significant evidence of hydrocarbon contamination within WSP322, drilled to the north of Bank Dole Lock nor within WSP321, to the north of Bank Dole Cut and west of the Lock Keepers Cottage.

Follow on monitoring has recorded the presence of a measurable thickness of NAPL within three locations; BH101C (however this NAPL appears to have diminished in recent monitoring rounds), MW1A and BH10/07D. Possible NAPL has been observed within WSP308, however this is not present as a measurable thickness but as staining on the interface meter tape.

2.6 Roxby Formation and Brotherton Limestone

The Roxby Formation was encountered at depths of between 6.5m and 13.8m bgl and typically comprised of stiff to very stiff red clay with frequent gravels of flint. The drilling of the deeper WSP boreholes was terminated upon encountering this stratum, with each borehole backfilled with bentonite to create a seal above this unit and limit vertical migration of contamination from the overlying sands and gravels. No evidence of contamination penetration of this layer was noted within any of the boreholes advanced to this unit.

Historically, one borehole was identified to have been advanced through the Roxby Formation and named as MW1, located adjacent to and south-east of the above ground tar tank S&L21 (Tank 23 - Figure 88). It is understood that this borehole was advanced as part of a site investigation by a third party in 2002. A review of the borehole log for MW1 indicates the borehole was drilled through the Roxby Formation (encountered at depths of 9.8 m bgl), and advanced to the Brotherton Limestone Formation underlying the Roxby Beds, which was identified at a depth of 17.5m bgl. The borehole was further progressed to a maximum depth of 28.5 m bgl within the Brotherton Limestone. At this location the Roxby Formation was found to have a thickness of 5.0m (9.8m – 14.8m bgl), with the clay described as stiff red/brown with increasing gypsum fragments towards the base. The Brotherton Limestone Formation was described as medium strong to strong limestone with thin interbeds of siltstone and mudstone.

2.7 Former Tar Wells and Interactions with Geology

Historical information and studies confirmed the presence of a number of below ground tar wells at the site, thought to be at least 10no. on the basis of full review work (see Section 5). These were constructed and utilised throughout the development of the site since the 1870s. At the time of the previous CSM report, WSP surmised that the tar wells had the potential to act as both sources and pathways for pollutant linkages to persist at the site.

On the basis of those conclusions, further characterisation and investigation of the tar well structures was undertaken during 2011. A full report detailing the findings and conclusions of this work is presented within Reference X. Tar well details and the relationship with site geology is summarised in the table below.

Table 2.2 Summary of Tar Well Investigations (WSP, 2011)

Feature	Summary
Construction	It was possible to undertake intrusive investigations of 6no of the former tar wells at the site, with the remaining 4 no. inaccessible due to operational restrictions in the CEMEX and SRM plants. The investigations confirmed that the tar wells were constructed using broadly similar techniques. Each well was constructed with a brickwork wall and a blockwork masonry base. The exception to this was tar well S+L6, where a masonry base was not identified during investigations. In the majority of cases, the brickwork walls had been broken down and removed to depths of circa 2.0m bgl. The exception to this was S+L5, where the brick walls remain intact to surface. To the exterior of the brickwork walls, a reworked 'puddle clay' appears to have been emplaced to form a seal/lining extending approximately 1 metre laterally from the tar well wall.
Backfill	Historical information and discussions held with Croda staff indicate that the majority of the tar wells were decommissioned as part of an environmental project that took place in the 1980s and early 1990s. Investigations indicated that the majority of backfilled material within the footprints of the former wells comprised of granular limestone and sandstone backfill with evidence of brick and concrete likely to be associated with breaking down of the brick walls. Tar well RB1 contained a greater proportion of brick and concrete backfill. This well was understood to have been backfilled in 2004, later than the other wells.
Relationship with Geology	Investigations and archive information indicate that the tar wells typically extended to depths of circa 3 to 3.5m, to the top of the masonry base. A review of geological and exploratory hole records from the vicinity of proven tar wells indicates the following: *Tar Well S+L8* The masonry base of this well was identified at a depth of 3.5m bgl within trial pit S+L8W. Comparing this to surrounding borehole records suggests that the likely founding stratum will be within the lower margins of the first clay horizon of the Vale of York Drift Deposits. WSP251, five metres to the west of the tar well recorded the upper surface of the Middle Deposits at a depth of 3.5m bgl. It is therefore possible that this tar well was founded at the interface of the confining clay layer and the Middle Deposits. *Tar Well S+L5* The base of this well was proven in only a portion of its footprint at a depth of ~3.0m bgl within WSPWS3. WSP219B and BH07/07M were both drilled into the Middle Deposits in the vicinity of this well and identified the Middle Deposits at a depth of 3.7 and 3.8m bgl respectively. This suggests that the base of the tar well was likely to have been founded in the overlying clay, where evidence of coal tar contamination within fissures was noted within WSP219B. *Tar Well S+L6* A masonry base was not identified within this tar well, instead a firm brown clay was recorded at a depth of 2.7m bgl. On the basis that the outer walls of the tar well remain intact, it is possible that this tar well did not have a constructed base and instead the superficial clays were used as a means of maintaining a vertical barrier. It is noted that the base of the superficial clays in this area was recorded at a depth of 3.6m bgl, where the Middle Deposits were encountered. Consistent with WSP219B, evidence of coal tar contamination within fissures within the clay was apparent.

Feature	Summary
	Tar Wells RB1, RB2 and RB4 The base of these tar wells were recorded at depths of 3.5m, 4.0m and 4.2m respectively. Masonry bases were identified in part in each well at those corresponding depths. Borehole records suggest that the Middle Deposits were encountered at depths of between 3.6m bgl and 4.2m bgl within WSP240 and WSP223B respectively. This information suggests that these tar wells may have been founded toward the base of the superficial clays and in close proximity of the surface of the Middle Deposits.
Additional Wells	There remain a number of additional tar wells that have not been investigated or characterised at this stage. The locations of these are presented within Figure 88.

2.8 Bank Dole Cut Canal and Lock Structure Interactions with Geology

A full and detailed review of the history and structure of the Bank Dole Cut Canal and Lock is included in Appendix C.

Canal Construction

The review of archive and historical information indicates that there have been three separate episodes of sheet piling works on the Bank Dole Cut canal, occurring in the late 1940s, 1970s and 1980s. A summary of the location of these piling works, and the development of the canal, are presented within Figure 6.

Southern Bank

It has not been possible to locate records for the sheet piles on the southern bank of the canal. In order to assess sheet pile depths on a portion of the southern side of the canal, Testconsult Ltd were commissioned by WSP during the previous CSM report to carry out testing of the steel sheet piling which forms the embankments of the Aire & Calder Navigation at Croda Distillates, Knottingley. The Testconsult report is included in Appendix H.

Testing was carried out along a 20m length of embankment where the sheet piles were exposed and tests were possible. Results indicate pile lengths were typically between 8.7m – 11.0m bgl deep. The nearest exploratory borehole to the test location is WSP239. In this location, the Middle Clay was encountered at 5.0m bgl.

The area tested by TDR (time domain reflectometer) is believed to be part of the 1980s piling works. The depth of these piles indicates that this section of sheet pile likely to be keyed into the Deep Deposits, or even the underlying Marl, and could therefore act as a potential barrier to retard or divert groundwater and contaminant movement within both the middle and Deep Deposits in this area.

No records of the depth of the 1940s sheet piling next to the Lock on the southern embankment have been found. Also, this area of piling is unsuitable for TDR testing. Extrapolating from evidence of piling length on the northern and southern canal embankment, it is reasonable to assume that the sheet piling in this area may extend to depths of between 5m – 11m bgl, assuming that the piling was undertaken under similar circumstances Local exploratory boreholes encounter Middle Clay at between 3.601m bgl (LIF1) and 4.315m bgl (WSP233). If the sheet piles have been advanced to at least 5m bgl it is likely that they will have reached the Middle Clay and may provide a potential barrier to groundwater movement in this area.

A substantial length of the southern canal bank is believed to be a graded bank of balled stone pitching laid on Terram 1000 geotextile. A 1987 British Waterways document (Figure 83) illustrates cross sections at various points between the Lock and Trundles Bridge. The sections indicate that at this time the southern bank was not piled for c.100m east of Trundles Bridge. Recent photographs (Appendix G) show the bank in this area sloped and highly vegetated, which suggests that this area has not been piled in the intervening years.

Northern Side

Following the completion of the TDR survey on the sheet piles on the southern bank of the canal, a further survey of the northern canal bank piling was undertaken by TestConsult Ltd in February 2011. The survey included the testing of several lengths of sheet pile wall on the northern bank and to the west of the Trundles Lane Footbridge. A further section

of piles on the southern bank of the canal, west of the bridge, were also tested. The locations of the survey tests are depicted on the TestConsult report presented within Appendix H.

The results indicate that where pile toe lengths could be successfully determined, the pile lengths ranged from 5.7 to 11.5m in length with an average length of 7.6m. Geological records from the nearest boreholes on the British Waterways land suggest that the Middle Deposits to the north of the sheet pile wall is generally encountered at a depth of between 3.2 to 3.7m bgl, with the base of the deposits identified between 4.6 and 6m bgl. The elevation of the length of tested piles is slightly below the elevation of the boreholes on the British Waterways land.

This would therefore suggest that the sheet piles on the northern bank of the canal are likely to extend beyond the Middle Deposits and toe into the Deep Deposits. Records from WSP321, recently drilled to the north of the Bank Dole Cut, suggest that the base of the Deep Deposits was recorded at a depth of 9.1m bgl (0.53mAOD) so it is possible that some of the sheet piles were toed into the underlying Roxby Formation.

Lock Structure

The 1886 British Waterways plan and section (Figure 83) provides dimensions and some construction details for Bank Dole Lock. The structure of the lock in relation to the geology is illustrated by Figures 9 and 10 (N – S through lock cill or main structure and interceptor).

These sections provide various dimensions, including the height of the main lock structure (Figure 10) and its cill (Figure 9). It is noted that the depth to the base of the lock toward the 'front' (toward the River Aire) is given as 5.33m (17'6'') bgl at the front of the lock (towards the River Aire). The depth to base of structure at the rear of the Lock (in front of the cill) is given as 5.5m (18'3'') bgl. The depth to base of the structure on the cill is given as 3.05m (10'0'') bgl.

These dimensions indicate the main body of the lock is bedded into the Deep Deposits, as illustrated by Figure 10. As the structure cuts across the Middle Deposits and Middle Clay strata completely it is likely to act as a barrier to groundwater movement within the Middle Deposits.

As shown on Figure 9 (N – S transect through rear lock & interceptor) the base of the cill extends to the top of the Middle Deposits / base of the upper clay. There is no documentary evidence that the sides of this structure have been sheet piled, or otherwise infilled, since the Lock was built. It is therefore plausible that there is no hydraulic barrier to groundwater movement in the Middle Deposits across the canal at the location of the cill.

3 Groundwater Assessment

3.1 Introduction

This chapter presents the findings of hydrogeological investigations which have been undertaken by WSP. Investigation has comprised extensive groundwater elevation monitoring, surface water elevation monitoring and pumping tests. The purpose of the hydrogeological assessment is to develop the conceptual understanding of likely groundwater flow paths and identify plausible contamination migration pathways which will allow the pollutant linkage assessment to be completed. This assessment has been completed in conjunction with the geological assessment and with consideration of adjacent surface water engineering features which have been identified and researched.

3.2 Hydrogeological Setting

Site investigation works undertaken by WSP have identified a hydrogeological regime which broadly reflects the findings from historical site investigation works, with three distinct groundwater bodies identified beneath the site (as defined below), together with two confining clay layers and a basal mudstone which is considered to form the vertical limit of the hydrogeological regime.

Perched (Shallow) Groundwater

The uppermost groundwater body was identified within the predominantly granular made ground and shallow alluvial deposits where present and is an unconfined groundwater body perched above the upper clay horizon of the Vale of York Drift Deposits. The piezometric surface (water table) was typically encountered between 0.1 to 2.1m below ground level and at an elevation of between 9.6mAOD to 7.5mAOD. Within the shallow wells closest to the River Aire, perched groundwater elevations were identified to range between 2.0 to 3.0m above the average river stage recorded within the River Aire (5.8mAOD), and those adjacent to the canal are above the water levels within the Bank Dole Cut by approximately 0.8 – 1.0m.

In addition to perched groundwater within the Shallow Deposits, there are local areas of influence and groundwater retention, governed by the presence of below-ground structures and obstructions such as concrete foundations and former tar wells.

The base of the shallow groundwater saturated zone is formed by the underlying alluvial clay which acts as a basal confining layer between the Shallow Deposits and the underlying Middle Deposits.

Shallow Dewatering and Pumping Trials

As part of the characterisation of shallow ground conditions, perched groundwater behaviour and the potential to recover NAPL from Shallow Deposits, a shallow dewatering trial was undertaken in late 2010. This comprised the excavation and construction of a shallow dewatering trench together with associated dewatering infrastructure and collection sumps. The intention of the study was to establish whether perched groundwater and associated NAPL contamination was recoverable. Following the commissioning of the system, it became apparent that whilst dewatering could be achieved within an area proximate to the recovery trench, the pumping operations had limited effect on surrounding groundwater. The trials indicated that the presence of subsurface structures including concrete plinths and foundations associated with the former tar distillery were governing groundwater flows and continuity within this area, which correlates to the variability in groundwater presence and elevations discussed previously.

Tar Well Pumping Trials

As part of the tar well investigations carried out in early 2011, an element of the investigations were to establish whether a direct hydraulic link existed between the tar well structures and surrounding groundwater, both within the Shallow Deposits and the Middle Deposits.

It was noted during the exploratory excavations carried out that a number of the tar wells were retaining perched groundwater within them, possibly driven by the remaining presence of the masonry bases and brick walls.

Dewatering was undertaken during the excavations and a number of shallow monitoring wells and collection sumps were also installed at this time. Following the excavation works and as part of the characterisation of shallow groundwater conditions, pumping trials were undertaken within the former RB2 and S+L5 tar wells.

The results of the trials are presented within the Tar Well Investigation report (Appendix J) and indicate that in the case of the RB2 well, sustained dewatering of the perched groundwater yielded no measurable effect on the elevation of groundwater within the shallow or Middle Deposits in close proximity.

A similar exercise, carried out within the S+L5 tar well utilised the presence of the Cell 1 and Cell 2 remediation system to establish whether dewatering of the Middle Deposits could establish the presence of a hydraulic link between the tar well and the Middle Deposits. The results indicated that whilst the Middle Deposits were being dewatered, and drawdown was maintained, the groundwater elevations within the tar wells fluctuated, possibly as a result of the influence of meteorological fluctuations. It is probably that perched water is being contained within the remnants of the tar wells with limited evidence of significant lateral or vertical groundwater flow from these features.

There are a number of additional former tar wells that have not yet undergone investigation.

Middle Deposits

Groundwater heads within the Middle Deposits typically ranges between 8.5mAOD to 6.0mAOD across the site. The groundwater within this unit is confined by the overlying alluvial clay which appears to be laterally continuous and whose base is encountered at elevations of approximately 5.0 to 7mAOD, typically some 0.8m to 1.8m below the measured piezometric level. The base of this deposit is confined by the Middle Clay, although in a number of locations as indicated on Figure 14 this has been shown to be absent. The groundwater elevation of the Middle Deposits in wells nearest to the River Aire was identified to be some 0.5m to 1m higher than the average river stage within the River Aire.

As noted by the geological contour plots it can be seen from Figures 12 and 14 that the top and base of the Middle Deposits rise in elevation towards the river to the east of the lock with the inferred top the Middle Deposits being at approximately 6mAOD and the base at 4.3mAOD. Under this configuration the top of the unit lies at or slightly above the average water stage within the River Aire while the base extends some 1.5m beneath this level.

As discussed within Section 3, it is considered that the construction of the lock and the presence of sheet piling on the northern and southern banks of the canal are likely to hydraulically isolate the Middle Deposits from the canal and are also considered likely to be presenting a barrier for groundwater flow within the Middle Deposits across the canal. Previously, it was considered possible that one isolated location, the upper cill within the Bank Dole Lock, could permit connectivity between the Middle Deposits across the canal, based upon strata elevations and the British Waterways Record of Survey (Figure 84). Further studies, discussed in more detail later in this section, have demonstrated that this potential is likely to be diminished.

Deep Deposits

The groundwater within the Deep Deposits is present within a thicker band of sands and gravels which underlie the Middle Clay and rest on top of the basal Permian mudstone. Groundwater piezometric levels within the Deep Deposits are typically seen to range between 5.8 – 8.6mAOD. Groundwater within this unit is confined by the overlying Middle Clay (where present) with groundwater heads typically 3.5m above the confining layer.

Groundwater heads within the Deep Deposits in the wells closest to the River Aire to the east of Bank Dole Lock are shown to be some 0.2 – 0.5m above the average river stage. The top of the Deep Deposits within the locality and to the east of Bank Dole Lock are encountered at an elevation of between 3.2 – 4.5mAOD which is marginally higher than the river bed elevations calculated at between 2.6 – 4.0mAOD from the 1885 river bed survey depicted within Figure 84.

3.3 Groundwater Monitoring

As a result of previous site investigation work undertaken by others on and around the site, a total of forty serviceable historic groundwater monitoring wells were found to be present on the site as at January 2010. The location of the serviceable wells and the lost (presumed destroyed) wells are presented as Figure 4.

An initial round of groundwater monitoring was undertaken by WSP in December 2008 during a site orientation visit. During this visit all located wells were monitored for groundwater level, and the presence of NAPLs using an electrical contact interface meter. The factual recordings and observations from this visit are included in Appendix D.

Between September 2009 and November 2011, WSP have installed a further 155 groundwater monitoring wells at the site. Twenty-five have been installed within the Perched Groundwater, including within the footprint of former tar wells, 106 No. in the Middle Deposits and 24 No. within the Deep Deposits.

During all investigations, the first groundwater strikes were typically observed within the Made Ground and Shallow Deposits indicating the presence of a perched, unconfined shallow groundwater unit. Subsequent strikes were encountered at the top of the Middle and Deep Deposits. Groundwater monitoring of available historic wells and new WSP groundwater monitoring wells has been undertaken on an approximately monthly basis since October 2009 using an electronic dip meter with interface probe.

Groundwater dips were measured to a known reference point which was either the top of well pipe or cover elevation. Groundwater heads were calculated with reference to Ordnance Datum as determined from the SVS topographic survey of September 2010 and August 2011.

3.4 Groundwater Flow Directions

Dip data for the Shallow, Middle and Deep Deposits was used to calculate groundwater head elevations across the site within these strata.

The resulting groundwater head elevations within the three water bearing units have been gridded and contoured to provide a distribution of groundwater heads across the study area for two rounds of monitoring, the visits of November 2010 and October 2011, the latter visit incorporating the inclusion of the additional wells installed during 2011. Groundwater elevation plots for this period are presented within Figures 19 to 25.

Shallow (Perched) Groundwater

The shallow groundwater within the Made Ground and alluvium is unconfined and is considered to be perched above the alluvial clay. It is typically encountered between 0.1 – 2.1mbgl and at elevations of approximately 7.5m to 9.6m AOD. The resulting output suggests that the thickness of perched groundwater is between 1.0m to 2.5m. This analysis suggests that where data is available, there is limited apparent interruption due to the underlying topography of the alluvial clay and it is possible that perched groundwater is locally continuous in discrete areas of the site. Excavations undertaken during the tar well investigations suggested that perched groundwater may not be continuous within the western portion of the Tar Distillery site. Due to the heterogeneous nature of Made Ground at the site and the likely presence of present and historical below ground foundations and structures, it is considered that groundwater flow directions within this unit will be highly variable on a local scale.

Figures 19 to 20 show groundwater contours for the shallow groundwater for the 16th August 2011 and the 12th October 2011 respectively. An anomaly previously observed within BH07/07S has been ratified by the installation of two additional shallow wells within this area, WSP114 and WSP114a, both of which are installed within the footprint of the former tar well S+L5, suggesting a groundwater low is maintained within this feature. Additional wells installed within the CEMEX land indicate that perched groundwater elevations are higher in this area, typically 0.2-0.5m higher than the remainder of the site.

Groundwater heads within the Shallow Deposits adjacent to the canal continue to indicate that the shallow perched groundwater heads are above the water levels within the Bank Dole Cut by approximately 0.7 – 0.9m. Based upon the evidence presented in Section 3 regarding the extent and depth of the sheet pile wall, and the recorded perched groundwater heads, it is considered that there is no significant hydraulic linkage between the canal and the perched groundwater body. Insufficient data is available to assess the degree of potential flow towards the canal (if any) along the length of the canal which is not lined by sheet piles, approximately westwards of borehole BH01/07/M. Within the cluster of shallow wells closest to the River Aire, perched groundwater elevations were identified to range between 2.0 to 3.0m above the average river stage recorded within the River Aire (5.8mAOD).

This, as well as the identified elevation of the underlying alluvial clay which is typically between 6.5mAOD and 8.1mAOD to the east of Bank Dole Lock suggests that groundwater within the Shallow Deposits is unlikely to be in direct hydraulic continuity with the river although seepage at the river bank could theoretically occur. Towards the northeast and to the east of the lock, groundwater level data suggests that the perched groundwater in this area around WSP106 is in a state

of discharge, either to the underlying Middle Deposits or through the river bank to the north via seepage. There has been no confirmation of an identified gap in the Upper Clay in this location or an identified structure that could puncture this clay. Furthermore, there are no observed visible discharges from the river bank, suggesting that the most plausible possible discharge route would be to the Middle Deposits.

Middle Aquifer

Groundwater elevation data within the Middle Deposits has been collected from November 2009 to October 2011. Assessment of groundwater levels indicates that the piezometric surface for the Middle Deposits lies within, and occasionally above, the alluvial clay which acts as a confining layer to this unit.. The data shows that the piezometric elevations within the Middle Aquifer consistently range between ~6.0m to 8.5mAOD.

Two updated time periods are presented for the Middle Deposits in Figures 21 and 22, August 2011 and October 2011. Overall flow continues to be from SW to NE across the site generally parallel to the canal then trending eastwards toward Willow Garth. The findings of more recent groundwater monitoring events are broadly consistent with those from November 2010, indicating that towards the east of the Lock, groundwater head gradients appear to turn towards a more northerly direction, broadly parallel to the line of the River Aire. Additional monitoring wells installed in the north-eastern portion of the site, adjacent to the River Aire, have confirmed the general eastward groundwater flow, affirming the likelihood that a direct discharge or convergence to the River Aire is unlikely to occur in this area. In addition, it is probable that any direct discharge to the river is limited by the permeability of the river sediments which are likely to line the shallow river bank to the east of Bank Dole Lock. Further discussion on the interaction of the River Aire and groundwater is discussed within Section 4.6.

Based on the available evidence it is concluded that groundwater flow via a direct hydraulic connection between the Middle Deposits and the River Aire is unlikely other than via relatively localised occurrences, and that a component of the flux into the River Aire, to the east of Bank Dole Lock is considered to be through leakage into the underlying Deep Deposits, with the remainder trending in a north-easterly direction.

Time Series Observations within the Middle Deposits at Bank Dole Cut

Study information and the results of previous groundwater monitoring indicated that the likelihood for significant groundwater flow across the canal via the Middle Deposits was unlikely based on the presence of sheet piled walls and the overall hydraulic head observed during the monitoring period.

The installation of additional monitoring wells within the vicinity of Bank Dole Cut has allowed for additional monitoring data to be gathered.

Two stages of detailed groundwater observations have been gathered, firstly during the early part of 2011, prior to the installation of additional wells, and secondly during August and September 2011 following the installation of further wells.

Time Series No. 1

The first set of time series observations related to the interaction of the River Aire and groundwater within the Middle Deposits on the northern and southern side of Bank Dole Cut. The findings of the exercise are reported within a technical note within Appendix K.

The information suggested that a substantial hydraulic link across Bank Dole Cut and the lock structure was unlikely within the Middle Deposits, with groundwater appearing to behave independently across the canal. Where flood conditions within the River Aire were monitored, fluctuations within hydraulic head elevations on the northern and southern side of the canal were observed however the general easterly flow regime was maintained with a decreasing hydraulic head maintained from north of the canal to south of the canal. When the groundwater recovery system within Cell 1 and Cell 2 operates, reduction in groundwater heads within the Middle Deposits is observed on the southern side of the canal, with no evidence of fluctuation within wells to the north of the canal, suggesting groundwater across the canal is not in continuity. The conclusions of the study also indicated that there was limited information by which to confirm the hydraulic regime within the Deep Deposits. This is discussed in more detail later in this section.

Time Series No. 2

Following the installation of additional wells within the Middle and Deep Deposits in the Bank Dole Cut area as part of the additional activities, monitoring and observations have taken place to further investigate the groundwater regime in this location.

A number of groundwater dataloggers were deployed within wells within the Middle Deposits to the north and south of Bank Dole Cut and a time series of approximately 1 month was gathered. The graphical summary of the time series are presented within Chart 1.

It can be seen from the information within Chart 1 that steady state hydraulic heads typically fluctuate between 0.2 to 0.3m, outside of groundwater recovery operations. Water levels within the River Aire were observed to fluctuate by approximately 0.5 to 0.7m during the same period. Groundwater head elevations within the monitoring wells to the north of the canal were consistently higher than those to the south of the canal, with WSP254a, WSP258 and WSP234 recording elevations of at least 0.2m higher than those to the south of the canal. This trend was maintained throughout the period.

During the operation of the groundwater recovery system within Cell 1 and Cell 2, clear drawdown can be seen within wells to the south of the canal, with a reduction in groundwater head of approximately 0.6m recorded within WSP239. Similar responses were noted within WSP232 and WSP236, both located on the southern side of Bank Dole Lock, to the north of Stocking Lane. Groundwater elevations within wells to the north of the canal did not exhibit a similar pattern, with fluctuations in these wells more closely matching those recorded within the River Aire. It is noted that WSP234, to the north of the canal, is located approximately 41m from the nearest recovery well (TW38), whereas WSP236 to the south of the canal, is approximately 50m from TW38.

Discussion

In the vicinity of Bank Dole Cut, any component of groundwater flow to the north is restricted by the presence of canal sheet piling which is known to be present along the northern and southern banks of the canal in this location. Information on the construction of the sheet pile wall (Section 3) suggests that the sheet piling is likely to be deep enough to provide a barrier to groundwater flow in the Middle Deposits in this area. In Bank Dole Lock, construction details show that the Middle Deposits are cut by the lock structure although it was considered possible that granular strata from the Middle Deposits could be present beneath the upper cill structure and potentially capable of transmitting groundwater across this part of the lock structure. However, the results of the time series monitoring carried out during two stages have indicated that a hydraulic connection across the cill is considered very unlikely, with no evidence to support this. Furthermore, groundwater elevation data collected since the installation of additional boreholes around Bank Dole Cut (Figures 21 and 22) confirms that hydraulic heads on either side of the canal and the canal lock are similar or generally higher on the northern side of the canal. Additionally, discharge across this structure is likely to be further limited given the estimated cross sectional area available for groundwater flow of approximately 11m^2. In extreme river flow events, there is the potential for influence within the flow regime in this area. Further discussion on the river interaction with site groundwater is presented within Section 4.6.

There is a localised groundwater low in the vicinity of WSP239, within the northern portion of the tar distillation site, which is close to the join of the 1940s and 1970s sheet pile walls and may suggest localised leakage through the pile wall via the Middle Deposits. There is the possibility that this could indicate a localised element of flux to the underlying Deep Deposits, however the recently drilled deep borehole WSP323, has not identified a groundwater high in this area and recorded a Middle Clay thickness of 0.7m. This location is however slightly north of the area where a gap in the Middle Clay has been observed.

A localised area of groundwater mounding has been observed immediately to the south-west of the lock structure, generally centred around BH06/07M and WSP202, this has been consistently recorded within a number of dip rounds and is considered that this may be due to a degree of recharge into this strata from the adjacent canal through a possible leak in the sheet piling at this location. It is considered that such a recharge mound will also act to divert north-easterly flowing groundwater away from the lock structure in this locality. Further local groundwater mounds have been observed within the Cell 1 treatment area, with TW12 and TW10 recording elevation differences of approximately 1.5 and 0.5m higher than expected, respectively. It is possible that this relates to temporal variance as a result of groundwater reinjection that has taken place within these locations and this situation will be monitored as the recovery and monitoring works progress.

As described in Section 3 and illustrated on Figure 15 a number of investigation locations did not encounter the Middle Clay. Groundwater elevations for the Middle Deposits have been reviewed at these locations to examine whether groundwater from the Middle Deposits might be recharging the underlying sands and gravels where the underlying clay confining layer is absent. In general there is limited evidence to suggest that significant downwards groundwater flux is occurring at these locations, however a moderately lower groundwater head is observed within the northern of these boreholes, and toward the area of WSP239 as discussed previously.

A slight groundwater low has been observed within the Middle Deposits in the vicinity of the eastern former tar wells, with AE08/04M, WSP223B, WSP240 and WSP241 recording a slight depression in elevation, approximately 0.2m lower than that to be expected from inferred groundwater elevations. This location did not record the Middle Clay, suggesting the possibility of localised groundwater flux to the underlying Deep Deposits.

Elsewhere within the site, the lowest point of the groundwater head within the Middle Deposits was measured in WSP260 to the north of the former tar settlement lagoons. Since installation of this well, groundwater heads in this location varied between 5.747 – 6.020mAOD the lower bound of which is broadly similar to the average stage of the River Aire. However, it is noted from WSP259 and WSP226, approximately 25 and 50m toward the river respectively that these have exhibited consistently higher groundwater head elevations during the monitoring period.

Deep Aquifer

Groundwater heads within the Deep Deposits were determined over the same period and frequency as the Middle Deposits. Groundwater piezometric heads within the Deep Deposits were seen to range between 5.8m to 7.2m AOD and are confined by the Middle Clay, where present.

A hydraulic connection is inferred between the Deep Deposits and the River Aire, due to the coincidence of layers and hydraulic heads. Previously, it was considered that to the west of the Bank Dole Lock, a broadly easterly groundwater flow regime exists at the site. The installation of additional groundwater wells as part of the additional activities discussed within Section 1 has allowed this area, together with the north-easterly area of the site toward the River Aire to be studied further and is discussed in more detail below.

The general groundwater flow regime within the deep deposits continues to demonstrate an easterly to north-easterly flow direction.

A component of northerly groundwater flow in the western portion of the site has been recorded, with monitoring wells drilled to the north of Bank Dole Cut generally recording lower groundwater elevations than those within the main site. Previous and recent sheet pile testing suggests a number of sheet piles may have been driven into the Deep Deposits and potentially into the underlying Roxby Formation, resulting in a partial barrier being formed to groundwater flow. However, a number of the sheet piles are unlikely to have penetrated to full depth of the Deep Deposits and therefore, at least some groundwater flow beneath the canal is likely to be occurring. Further discussion on groundwater behaviour in this area follows below.

Within the wider site, the geological profile of the Deep Deposits continues to show a general downward trend in the surface elevation and the base elevation toward the east of the site, with a thickening of the unit in this area. The surface of the unit dips in the north-east area of the site, demonstrated within the Willow Garth investigations carried out by Golder and AEA Technologies with further confirmation during recent borehole installation carried out by WSP. This information suggests that the elevation of the top of the Deep Deposits falls progressively from ~2.5mAOD to -0.3mAOD and may suggest that the bed of the River Aire is unlikely to intersect the Deep Deposits beyond some 300m downstream of the lock. The Deep Deposits therefore are likely to be hydraulically isolated from the River Aire to the east of this area.

In order to assess the relationship between the middle and deep aquifers the average grid file calculated for the Deep Deposits has been subtracted from the Middle Deposits groundwater head file covering the period of the July 2011 (Figure 25) and October 2011 (Figure 26) monitoring visits. It can be seen that in the western portion of the site, including the CEMEX land and the western part of the former Tar Distillery, the groundwater head variance is typically 0.5 to 1.1m, with a head gradient from the overlying Middle Deposits to the Deep Deposits. Generally, this trend diminishes toward the east of the site, where groundwater heads converge broadly at the eastern boundary of the SRM

facility and in the vicinity of the tar settling lagoons in the north east. In this area, groundwater head within the Deep Deposits is noted to exceed those within the Middle Deposits.

One isolated area where there is also a convergence is in the eastern portion of the former tar distillery site, where the groundwater head within the Deep Deposits exceeds that within the Middle Deposits. This area is slightly to the east of where the Middle Clay has been determined to be absent, suggesting that this confining layer may not prevent increased heads within the Deep Deposits. However, on the basis of the available data, it is generally seen that there is no appreciable effect on groundwater heads within the Deep Deposits at these locations,

General Time Series Observations – Northern Boundary

Groundwater level monitoring was undertaken using pressure transducers with an integrated data logger in the Perched, Middle and Deep groundwater bodies in order to assess temporal fluctuations in groundwater levels across the site and how these might be affected by rainfall and river level fluctuation events. Loggers were placed in a well cluster near to the River Aire in the north western area of the site and within a more centrally located cluster, closer to the river and adjacent to the northern site boundary to compare interactions with changing distance from the river.

Groundwater and surface water level data from this monitoring is included electronically in Appendix D. Baseline water level observations from groundwater wells were recorded for a period of two weeks to characterise:

- The different responses in each aquifer unit to different hydrogeological events;
- The behaviour of the different units with respect to changes in the river levels.
- The rainfall characteristics of the two weeks from the 5th November 2009 to the 19th November 2009 were also obtained to compare the different responses to recharge throughout the period.

Barometric pressure was monitored and recorded continuously over the study period, with a Barologger placed within the unsaturated portion of BH07/07/S. The Barologger data was utilised to correct the logger data file for the effect of barometric pressure. A summary of the data logger placements is shown in Table 3.1 below.

Table 3.1 - Summary of Aquifer and River Interaction Data Logger Placements

Well	Aquifer	Site Location	Distance from River Aire
BH06/07/S	Shallow	North Western Area	57m
BH06/07/M	Middle	North Western Area	59m
WSP301	Deep	North Western Area	68m
BH09/07/S	Shallow	Central Northern Area	29m
WSP208	Middle	Central Northern Area	30m
BH09/07/D	Deep	Central Northern Area	32m
River Aire	Surface Water	River Aire – Pontoon at Bank Dole Lock	N/A
BH07/07/S	Barologger	Central Area	N/A

Figure 27 shows the river level and rainfall at a nearby weather station throughout the monitoring period. The initial eight days of monitoring from the 3rd November to the 11th November were relatively dry. Significant rainfall events were observed through the period of the 12th November to the 19th November. The first of these rainfall events is marked and occurred on the 12th November and continued at a high level throughout the 13th and 14th November. The river data appears to reflect this, with a period of recession to a base flow level of below 6m AOD up until late on the 12th November. A sharp rise is seen throughout the 13th November over a period of about six hours. This is interpreted as the rivers response to the rainfall event, with a time lag of about 20 to 24 hours, consistent with the site's location low down in the Aire Catchment, with a distant upland component.

Groundwater responses in an area close to the river are illustrated in Figure 28. The recession in the river levels is also shown as a similar response in the piezometric levels in both the Middle Aquifer (as monitored in WSP208) and in the Deep Aquifer (as monitored in BH09/07D). Through the recession period, piezometric levels in both these groundwater units are above the river levels, implying flow from groundwater to river. The response to the river rise on the 14th November is quite marked and echoed in piezometric rises in both Middle and Deep Aquifers. The effect is much more marked in the Deep Aquifer, implying a higher permeability and much better degree of connection in this unit. The shallow unit shows very minor response to recharge from the rainfall events.

More distant from the river (Figure 29) the effects of the river on both middle and deep aquifers are reduced. Both groundwater units have piezometric responses, with a greater response again in the Deep Aquifer.

Figure 30 shows the effect of the river rise in more detail, which illustrates the changes in piezometric level in both deep wells – BH09/07D which is approximately 30 m from the river, and in well WSP301 which is approximately 60m from the river. There is a lag between the peak response in the river and in the aquifer, which increases with distance away from the river. The maximum river levels occur at about 10 am on the 14th November, with maximum levels in well BH09/07D about an hour later. There is then a further lag of approximately 3.5 hours before maximum levels are seen at well WSP301, approximately 60m from the River. The figure also shows that the piezometric levels in the aquifer rise, even though the head in the aquifer is still higher than the river, and flow is still towards the river. This suggests that the effect of the change in piezometric head would be a reduction in groundwater flux towards the river during the time that these events change the head difference between the groundwater body and the receiving river.

Figure 31 shows the detail of the same event for the Middle Aquifer, though the response is lesser in this unit, with a longer initial lag time before the effect is observed in WSP208 at about five hours.

The results of the river and aquifer monitoring show the following:

- That there is a degree of hydraulic connection between the river and the aquifers;
- That the connection appears to much better in the Deep Aquifer than in the Middle Aquifer
- That the effects of an event in the river are seen in the Deep Aquifer, before the Middle Aquifer;
- That the effects of a river event are propagated as a piezometric pressure wave into the site, with increasing time lag as the distance from the river increases;
- That in very high river stage events, the flow from the aquifer to the river is reversed temporarily in the Deep Aquifer predominantly, but potentially in the Middle Aquifer for a short while also;
- The river event causes a rise in piezometric pressure in the two aquifers, before the river level has risen to the point where flow is reversed.

The pressure wave propagates rapidly into the Deep Aquifer near the river, and then takes a long time to propagate through to the main site. In contrast, the Middle Aquifer takes a long time to respond even close to the river. This is probably a combination of flow in the Middle Aquifer being primarily parallel to the river at this point, and due to the less permeable geology with more clay present in the Middle Aquifer. It may also be a reflection of a connection between the two aquifers distant from the point of measurement. In this respect the piezometric pressure wave would need to travel into the site within the Deep Aquifer to the point of connectivity and then back within the Middle Aquifer over potentially the same distance. In general the Middle Deposits become more clayey towards the river and the Deep Deposits become less gravelly towards the river.

The above observations can be interpreted as follows:

- The river is identified to be connected much more closely to the Deep Deposits as there is the potential for a scour channel at depth which lies below the inferred top of the Deep Deposits. It is possible that lower permeability sediments are present higher up the river bank, which may be limiting direct continuity between the Middle Deposits and the river itself. The lack of any observed seepage or discharge to the river in this location and the results of river interaction studies provide further evidence to support this conclusion.
- From the timings of the responses, it is possible that there is no direct connection between the river and the Middle Aquifer. The responses observed in the Middle Aquifer could be caused by a rise in piezometric head in the lower

aquifer, in a leaky aquifer situation. In the river event seen, the head in the lower aquifer does not rise to a point where the vertical hydraulic gradient between the lower and Middle Aquifer is reversed but this is not beyond possibility at least locally. In any respect a reduction in hydraulic head difference between the two units caused by a surge in piezometric pressure within the Deep Deposits would be sufficient to reduce any vertical hydraulic flux which in turn would trigger a change in piezometric head within the Middle Deposits as has been observed.

- Groundwater flow directions have indicated that the actual flux towards the river adjacent to the site within the Middle Deposits is limited. Flow within these deposits is principally parallel to the river although more recent groundwater wells installed to the east of Bank Dole Lock carry a suggestion of a deflection towards the north, however given that the River Aire also turns towards the north in this area, groundwater flow, broadly parallel to the river is maintained. It is considered most likely that in the immediate vicinity of the Croda site and especially within 200m of Bank Dole Lock that the responses to the changes in river levels within the Middle Deposits are likely to be the result of changes in hydraulic head difference between the Middle and Deep Deposits rather than direct flow to or from the river adjacent to the site within the Middle Deposits.
- The piezometric response from within the Deep Deposits suggests that this unit is the primary route of groundwater flux to the River Aire. The groundwater level monitoring has demonstrated a connection and the configuration of groundwater heads observed within the deep wells is strongly suggestive that the reach to the east of the Bank Dole Cut functions as a primary discharge point for groundwater within the Deep Deposits.

3.5 Time Series Observations – Bank Dole Cut

Discussion surrounding the behaviour and interactions of the groundwater within the Middle Deposits in the vicinity of Bank Dole Cut have been presented in the preceding section. During the same observation event, groundwater within the Deep Deposits was subject to monitoring via the use of pressure transducers and river elevation data from the River Aire. Furthermore, the potential for groundwater flow to be occurring beneath the canal, only partially disrupted by the presence of sheet piling has formed the basis for further studies to take place.

The results of the Deep Deposits time series observation are presented within Chart 2 and summarise the results of groundwater elevation fluctuations in a number of deep monitoring wells both within the main portion of the site but also to the north of Bank Dole Cut toward the River Aire.

Under steady state conditions, groundwater response to fluctuations in the River Aire are apparent, with variation in river stage levels observed after varying lengths of time within the Deep Deposits.

A river event occurred on the 12th August 2011, peaking at a level of 6.35mAOD at approx. 1.45am. As has previously been demonstrated, the relationship between the river and the Deep Deposits is closely linked and monitoring wells exhibited a fluctuation in groundwater elevation following this river event.

The quickest well to respond was WSP321, newly installed to the north of Bank Dole Cut. This well is located approximately 40m from the River Aire but is notably the most westerly of all the deep monitoring wells in this area and therefore up-gradient with respect to river flow. This reached a maximum response at approximately 3.45am, two hours after the river peak.

The next wells to respond were WSP322 and WSP323, to the north of Bank Dole Lock and south of Bank Dole Cut respectively. Increase in the piezometric elevation was slightly reduced in these boreholes when compared to WSP321, but still yielded an increase in elevation of approximately 300mm, compared to circa 500m within the River Aire.

The slowest wells to respond were WSP303 (within the Cell 2 recovery area) and BH101C, adjacent to the Croda Tar Interceptor. WSP303 is located approximately 70m from the River, the most distant of the study wells. The proximity of BH101C to the tar interceptor may explain the delay in response as this feature is understood to be keyed into the underlying Roxby Formation and therefore could interfere with groundwater behaviour locally. Further discussion on this interceptor follows below. The increase in groundwater elevation in WSP303 was circa 40mm, an order of magnitude lower than wells closer to the river; reflecting the distance and weaker influence of the River Aire cognisant to lateral travel. The peak response in WSP303 was recorded at approximately 10.06am on the 12th August, approximately 8.25 hours after the river peak.

Response times during recessional river conditions were broadly similar across all the wells.

Fluctuations observed within the Deep Deposits during groundwater pumping operation could be used to determine whether a connection exists across Bank Dole Cut. On the basis that the Middle Clay has been demonstrated to be absent in the vicinity of the Cell 1 and Cell 2 recovery areas and groundwater heads within the Middle Deposits and Deep Deposits could possibly converge in this area, it was thought that operation of the low-shear pneumatic abstraction pumps could influence groundwater within the Deep Deposits.

The results of the pumping operations can be seen within Chart 2. Following shutdown of the system for site wide groundwater monitoring on the 15th/16th August, the groundwater system was recommissioned on the 17th August. At this time, drawdown of approximately 300mm was observed within WSP323, located to the north of the Cell 1 system adjacent to the southern bank of Bank Dole Cut.

A similar, albeit smaller response was observed within WSP322 and WSP321, both newly installed and to the north of Bank Dole Cut. Whilst the drawdown was lower in these locations, the information suggests that there is hydraulic connectivity beneath the canal within the Deep Deposits. The recovery system had a temporary shutdown on the 25th August 2011 when a valve failed and was re-commissioned the next day. This spike is observed within the chart.

The system was shut down again for maintenance and reconfiguration on the 31st August, at which point the groundwater returned to stable conditions. a fast rebound was observed within WSP323, with lesser responses noted in WSP302, WSP304, both south of the canal, and WSP321 and WSP322 to the north of the canal. BH101C and WSP303 did not record obvious rebound responses.

When the recovery system was re-commissioned on the 9th September, this coincided with a river event at the same time, where falling river elevations masked the concurrent drawdown within the Deep Deposits, although the response within WSP323 was clear on this date.

3.6 Pumping Tests and Interpretation

Introduction

A series of aquifer pumping tests were conducted between 21st October 2009 and 30th October 2009, to obtain information as follows:

- Hydraulic parameters of the Middle Aquifer, such as: hydraulic conductivity, transmissivity, leakance, storativity; and anisotropy.
- Evidence for the River bank acting as a boundary to either aquifer;
- Evidence for leakage between the identified aquifers.

Details of the pumping test programme and method is presented in Appendix F, with locations illustrated in Figure 32. The pump tests were conducted under a Water Resources Act 1991 Section 32 Application issued by the Environment Agency to WSP on 16th September 2009 (Reference: NE0270018002).

Pump tests were initially proposed to be conducted over a 24 hour period, however, due to Health and Safety restrictions imposed by SRM Ltd on night working in the area of the pump tests which limited supervision of the test to daylight hours, 24 hour pumping periods could not be achieved. Therefore, two shorter term tests were carried out during daylight hours, with the first over a 6 hour period, and the second test conducted over 15 hours. Upon completion of these tests, the field data was provided to the Environment Agency in support of the Groundwater Abstraction Licence application.

The results of the 15 hour constant rate test have been analysed by a number of different methods:

- Theis method for a confined aquifer;
- Hantush-Jacob's method for a leaky confined aquifer;
- Stallman's method for a bounded confined aquifer.

Time drawdown plots were generated for observation wells in the Middle and Deep Aquifers. The results are shown as Figures 33 to 36. River data was also monitored to evaluate the effect of river events in the test on the test data. From the river data analysis, lag times of 1 hour for the Deep Aquifer and 5 hours for the Middle Aquifer were used to inspect the data for river influence events and exclude these from the interpretation and curve fitting.

Six Hour Test

The results of the 6 hour constant rate test were analysed by the Theis and Hantush-Jacob Methods using the ESI software Aquifer Win32 V3.0. Wells WSP206, 207, 209 and 211 showed an excellent fit for the Hantush-Jacob curves for a leaky confined aquifer (leakage from above). Transmissivity values for the Middle Aquifer ranged from 1 – 4 m^2/day giving hydraulic conductivity values in the order of 0.5 – 1.5 m/day. Storage coefficients were around 0.0005 - 0.005. Leakage factors for the overlying clay were in the region of 0.9 to 1.5 giving permeability estimates for the overlaying clay in the region of 0.01 m/day.

The monitoring data for the Deep Aquifer is more problematic to interpret, as the tests were not long enough to fully characterise the steady state response. However initial fits were much closer to a Theis curve, rather than the Hantush-Jacob curve, tentatively suggesting much lower leakage from the Middle Aquifer to the Deep Aquifer.

Fifteen Hour Test

The results of the 15 hour constant rate test were analysed by the Theis, and Hantush-Jacob Methods using the ESI software Aquifer Win32 V3.0. Middle Aquifer data showed a better fit to the Hantush-Jacob type curves, whereas the Deep Aquifer data showed a better fit towards the Theis type curves for a confined aquifer, though again longer time data might have been more revealing. Example plots are presented in Figures 37 to 40.

Hantush Jacob results

This method is designed to analyse data from a leaky confined aquifer. This method does not take into account any interaction of the adjacent River Aire Boundary. Values of transmissivity, storativity and leakage have been calculated and are summarised in Table 3.2 below. Based on the leakance factors, the permeability of the clay layer between the shallow and Middle Aquifer is estimated at about 0.01 m/day. Tentative estimates of permeability in the lower clay which separates the Middle and Deep Aquifer are thought to be an order of magnitude lower, in the region of 0.002 m/day.

Table 3.2 - Results of Pump Test Analysis by Hantush-Jacob Method

Monitoring Well	Transmissivity (m2/day)	Storativity (unitless)	Leakance factor (unitless)
WSP206	1.9	0.0004	1.4
WSP207	4.3	0.0007	0.5
WSP209	5.4	0.0008	0.5
WSP211	4.2	0.0033	0.3

Bounded Confined Aquifer Methods

Interpretation of boundary effects was difficult as the effects of river events would to some extent mask the boundary signals. Overall, there was little evidence for boundary effects in the Middle Aquifer – either from a recharge or a low flow barrier boundary. However, there is an event seen in WSP206 at approximately 20,000 seconds where the response of the aquifer departs from the best fit Hantush Jacob curve for a leaky confined aquifer. The drawdown is less than would be expected, suggesting an additional source of recharge, either from leakage or from a recharge boundary such as the river. However, this event is seen also to a lesser extent in all the wells simultaneously and is more likely to be attributed to a change in pumping rates.

There is weak evidence for a barrier boundary in the Deep Aquifer where after approximately 11,000 seconds the drawdown increases over what would be expected in a normal infinite extent confined aquifer. This event does not

appear to be related to a change in river levels, and does not show the expected characteristic response for leakage from above or below. It therefore may be tentatively interpreted as a boundary (barrier type). The 1895 Bank Dole Lock construction drawings indicate a length of driven pile wall proposed into the underlying mudstone and along the bank of the River Aire adjacent to WSP206, however, no evidence has been found to indicate that this structure remains in existence at the time of writing.

3.7 River Bank Survey

River Interceptor – October 2009

To inspect for evidence of potential hydrocarbon outbreak within the River Aire, WSP undertook a visual river bank survey on 1st October 2009 using a canoe. The visual survey included an inspection of the river water and river bank to the west of Bank Dole Cut lock structure, together with Gascoigne Hill Reach to the east of the lock. During the survey, WSP inspected for locations of evident hydrocarbon sheen or 'starbursts' on the river water surface, together with potential outfalls to the river, and locations of contaminated sediment. Where evidence of starbursts was encountered on the water surface, the surveyor disturbed the underlying shallow river bed sediment to identify any potential contribution from residual contamination. Photographs from the survey are presented in Appendix G.

The only location of visual hydrocarbon sheen along the boundary was noted to be in limited extent on river water in the vicinity of the Bank Dole interceptor. Further inspection of the interceptor from the river level indicated low flow seepages between the interlocks of the sheet pile wall which may be contributing to this break-out, with sediments on the riverside of the pile wall also generating hydrocarbon sheen when disturbed by the surveyor. Furthermore, the water level within the interceptor at the time of the survey was noted to be approximately 1m higher than river level, which may be related to a combination of unconfined water level rise from the Middle Deposits, and the barrier formed by the sheet pile wall which restricts water flow to the river.

As-built drawings provided by Croda (Figure 41) for the interceptor indicate the sheet piles to be keyed into the Deep Deposits, with Made Ground and Middle Deposits reported to have been excavated to the top of the Deep Deposits aquifer, and granular material (single size 200mm) backfilled between the top of Deep Deposits and lower part of the Middle Deposits.

With the exception of the river interceptor, no other locations of hydrocarbon sheen, starbursts, or direct discharge from outfalls were evident along the river boundary in either Bank Dole or Gascoigne Reach at the time of the survey.

River Aire and Bank Dole Lock Survey – October 2010

WSP undertook a second visual river bank survey on 5th October 2010 using a kayak and trained operative. The reasons for this survey were to inspect for evidence of potential hydrocarbon outbreak within the River Aire, to inspect sheet piling on the Aire & Calder Navigation at Croda, to inspect the river abstraction chamber and to identify any further outfalls to the River Aire. The visual survey included an inspection of Bank Dole Lock and the Aire and Calder Navigation. During the survey, WSP inspected for locations of evident hydrocarbon sheen or 'starbursts' on the river water surface, together with potential outfalls to the river, and locations of contaminated sediment. Where evidence of starbursts was encountered on the water surface, the surveyor disturbed the underlying shallow river bed sediment to identify any potential contribution from residual contamination.

As in the previous river bank survey, the only location of visual hydrocarbon sheen along the boundary was noted to be in limited extent on river water in the vicinity of the Croda interceptor. Sediments on the riverside of the pile wall generated more extensive hydrocarbon sheen when disturbed by the surveyor (as illustrated in Plate 18, Appendix G).

The lock and canal bank were surveyed and no starbursts or hydrocarbon sheen were observed. Photographs of the sheet piling on the canal bank are given in Appendix G.

The exterior of the abstraction chamber was visually inspected. There were no visible starbursts or hydrocarbon sheens observed in this area.

3.8 River Water Abstraction Chamber

In addition to the inspection of the interceptor chamber, in April 2010 WSP undertook a visual inspection of the river water abstraction chamber located to the east of Bank Dole Lock on the bank of the River Aire, as presented in Figure 42. On-site discussions with operatives from SRM Limited, who utilise the current chamber for abstraction of river water for on-site solvent recovery processes, highlighted that the river chamber has remained out of use since October 2009 due to the presence of NAPL in the pump sump, and the impaired quality of the hydrocarbon impacted water pumped back to the SRM site from the chamber. WSP dipped the pump chamber with an interface probe during the inspection to ascertain an approximate thickness of NAPL within the structure, with measurement of up to 0.77 m of DNAPL within the pump chamber as at April 2010. Photos from the inspection are presented in Appendix G.

A subsequent attempt to remove the NAPL from the chamber was made by WSP on 18 October 2010 by use of a vacuum tanker. However, the removal of NAPL and NAPL contaminated sludge was not fully completed due to health and safety and access restrictions which would have required confined space entry into the chamber in order successfully complete the removal. As a result of the vacuum operation NAPL and sludge thicknesses were reduced from 0.77m to a maximum of 0.15m following the works.

Monitoring of this chamber continues as part of the on-going monitoring regime.

3.9 Discussion

Shallow Deposits

The shallow groundwater appears to be dominated by localised recharge in most areas possibly resulting from leaking infrastructure and rainwater infiltration. Groundwater heads are above those within the canal although available data suggests that hydraulic continuity is not present.

This perched groundwater is shown to be variable and discontinuous and will be governed by the presence of below ground infrastructure and remnant features such as former tar wells.

The tar wells have been observed to be partially broken out and retaining volumes of water potentially recharged by infiltration and local seepage. However, pumping trials indicated that groundwater within these structures was not linked to surrounding perched water or the underlying Middle Deposits, although historically, an element of flux may have occurred over time.

Middle Deposits

Groundwater flow in the Middle Deposits has been shown to be predominantly parallel to the canal and river within the western and central areas of the site. This is illustrated within the rounds of groundwater monitoring undertaken at the site to date, the most recent of which was between August and October 2011. As additional site investigation works have been progressed at the site a fuller picture of the groundwater flow regime has been developed as is apparent from Figures 19 to 24. The installation of additional groundwater monitoring wells within the western portion of the site (CEMEX Land), northern portion (British Waterways Land) and north-eastern area (Tar Settling Beds) has enabled further development and characterisation of the groundwater flow regime within this groundwater unit.

The flow in the Middle Deposits continues to be shown to be broadly parallel to Bank Dole Cut to the west and centre of the site. To the east of Bank Dole Lock groundwater head distributions have been shown to contain a more north-easterly component of flow within the Middle Deposits but maintain a direction that is either parallel or only modestly convergent with the River Aire, trending eastwards beyond the boundary of the main part of the site. Within the Deep Deposits a more marked diversion of groundwater flow is seen, with flow towards the north and north west indicating groundwater flows directly towards the River Aire.

The absence of the confining Middle Clay layer is likely to be contributing to a possible recharge mound within the Middle Deposits within the former Tar Distillery portion of the site (from the underlying Deep Deposits). This is most notable within the Middle Deposits although more limited evidence suggests there may be some recharge into Deep Deposits in this vicinity also, with convergence of groundwater heads observed within this area. Furthermore, the results of time

series observations confirm this potential connectivity via responses within the Deep Deposits during pumping operations within the Middle Deposits.

Groundwater flows in the Middle Deposits are considered to be controlled by a number of distinct hydraulic interactions. Along most of the northern boundary of the site adjacent to Bank Dole Cut it is considered that the observed groundwater flow directions are controlled by the presence of sheet piling along the canal and construction materials of the lock structure. This is supported by the groundwater heads recorded on either side of the canal and time series observations relating to pumping operations to the south of the canal. It is concluded that groundwater in the Middle Deposits on the Bank Dole promontory is hydraulically isolated from the main site.

Away from the lock to the east, no evidence exists to suggest that groundwater is discharging directly to the River Aire, despite the absence of engineered structures. After the lock, groundwater gradients trend more towards the north but maintain a flow direction roughly parallel with the River Aire.

Deep Deposits

Groundwater flow directions in the Deep Deposits are considered to be broadly similar to the Middle Deposits within the southern and western portions of the site. The installation of additional groundwater wells within British Waterways Land and within the north-eastern groundwater discharge zone indicates that a more northerly component of groundwater flow is likely to occur within the Deep Deposits, suggesting possible discharge points within British Waterways Land (theoretically in the vicinity of the Croda tar interceptor) and to the east of the lock, toward Willow Garth. Beyond this area to the east, the elevation of the Deep Deposits is likely to take groundwater flow beneath the basal elevation of the River Aire.

There is only limited evidence to suggest that the Deep Deposits are recharged significantly by leakage from the Middle Deposits, although locally this appears to be occurring where the confining Middle Clay layer is absent.

Groundwater Interactions with the River Aire

Groundwater monitoring shows that river levels have an influence and an effect on groundwater levels within both the Deep and Middle Deposits. However, the response in the Middle Aquifer is significantly less than the response in the Deep Aquifer. It is seen that at the same distance from the river, within the Middle Deposits the piezometric response is some 20% of the head change within the River Aire, whereas within the Deep Deposits the piezometric response is 50% of that observed head change within the River Aire. The time lags suggest that the Deep Aquifer responds relatively rapidly to changes in river stage, with a considerably slower response observed in the Middle Aquifer, even close to the river bank, although it is acknowledged that the Middle Deposits have a low hydraulic conductivity.

River stage data compared to the groundwater elevation response suggests that over the majority of a single flood event within the river, hydraulic gradients are maintained towards the river over much of this time, however, at peak river stage it is seen that the head of water within the river exceeds that within the groundwater local to the river bank and in this configuration groundwater gradients will be locally and temporarily reversed. Locally, this has been observed within the isolated groundwater unit to the north of Bank Dole Cut. As distance from the river increases the hydraulic groundwater heads are not seen to be as significantly affected and no substantial reversal of hydraulic gradient is observed.

The river is indicated to be connected more closely to the Deep Deposits. This is likely to be via a scour channel at depth.

There is unlikely to be a connection between the river and the Middle Deposits, as the effects seen in this aquifer are likely to be caused through the response in the Deep Deposits, via leakance, or through areas where there are breaches in the Middle Clay, or potentially via north-easterly flow within the Middle Deposits. The piezometric response to the changes in river level is likely to affect the magnitude of groundwater flux due to changes in hydraulic head difference between the two strata.

4 Contamination Assessment

4.1 Introduction and Summary of Understanding

The previous CSM report included a review of primary sources (namely storage tanks, tar wells etc) and their relationship with encountered contamination. Further investigations carried out at the site have provided additional information on areas previously subject to limited historical investigation, such as the CEMEX site, and also bulk sources, such as the former tar wells. Where further assessment of groundwater quality has taken place, the findings of these investigations will also be reviewed.

The intention of this chapter is to review and update the understanding of contaminant distribution at the site, its historic and current relationship with the geological profile.

4.2 Review of Site History and Contamination Sources

The development and operation of the site has resulted in the presence of large numbers of contaminant sources relating to the former coal tar distillation activities.

This section will include updated information on further studies that have been carried out, together with the pertinent findings of targeted investigations. This section builds upon the previous CSM report and work carried out by Atkins during 2007 (Ref: 11).

Included within Appendix L is a review of pertinent site historical information and discussion around historical and current operations and potential contaminant sources at the site.

Tar Wells

Chapter 2.6 provides an introduction to the presence, structure and interaction of the former tar wells in relation to the geological ground model. It is known that the Knottingley site imported coal tar from numerous gas works along the Aire and Calder Navigation, Calder and Hebble Navigation and the Selby and South Yorkshire Navigation. This raw coal tar was stored in a number of below ground tar wells across the site. None of these wells remain operational; however a review of historical archive information, historical plans and aerial photographs confirm their existence.

Previously, it was understood that there were eight below ground tar wells at the site; three of which existed within the tar distillation plant, one within the western site currently leased to CEMEX and three within the SRM leased land to the north of the solvent distillation facility. Further archive and study review has indicated that a further two below ground tar wells may also have existed, one to the south of the former tar distillery, within the northern margins of the SRM operational area, and one to the east of the former RBTT tar well, in the eastern portion of the SRM facility.

Intrusive investigations, detailed within Appendix J, have confirmed that the majority of the tar wells appear to be of similar construction detail, comprising brickwork walls surrounded by an engineered puddle clay lining and a masonry blockwork base. The depth of the investigated tar wells varied from ~3m to 4m depth, although it is likely that the foundation structure will have extended further.

It is noted that a number of the identified historic tar wells have not been investigated to date, including those within the SRM operational areas and the well within the CEMEX land area. Consideration of groundwater impacts from this well have been undertaken via the installation of monitoring wells.

It is known from archive information and previous reviews that a number of the tar wells were decommissioned during the1980s, during Croda's operational phase at the site. The intrusive investigations have confirmed the presence of imported clean fill materials.

The locations of these former tar wells are illustrated within Figure 88 (Historical Records).

Above Ground Tank Farms and Storage Areas

In addition to the below ground tar wells, a substantial number of below and above ground storage tanks existed at the site. The exact number of tanks will have varied and it is possible that further unrecorded tanks may have been present on site. The Atkins drawing illustrates a large number of tank locations, however the exact contents and storage purposes of the majority of these tanks were not known.

Using available information, an inventory of tanks and vessels with known locations and known previous contents has been developed. This information is summarised below and also within Figure 88. The list is not intended to be exhaustive and it is acknowledged that further tanks and vessels existed across the site which may have contained bulk tar and distillation related compounds.

Table 4.1 - Summary of Tar Distillation Chemical and Product Storage Vessels

Vessel Name/Number	Location on Figure 88	Known Contents
Tar Wells		
S&L5	13	Coal Tar
S&L8	4	
S&L6	28	
RB1	30	
RB2	31	
RB4	32	
RBTT	29	
'CEMEX Land' Tar Well	2	Coal Tar
Unnamed Tar well	34	Assumed Coal Tar
Unnamed Tar well	35	Assumed Coal Tar
Above Ground Tanks		
S&L 11	14	Tar Sludge
S&L 14	5	Oily Water 'aromatic distillate'
S&L 15	6	Oily Water 'aromatic distillate'
S&L 17	19	Solid and Liquid Tar Residues
S&L 18	20	Phenolic Water
S&L 19	21	
S&L 20	22	Effluent Water
S&L 21	23	Effluent Water
S&L 22	1	Tar residues waste *'Steam Cracker Fuel Oil'*
A1 – A4	12	Tar Fractions
A10		Acid Water
A11		Aliphatic cracked products, light oil fraction
A23 - A24	8	'1606 Oil' 'aromatic distillate'
A25	7	'1606 Oil' 'aromatic distillate'
C2	3	'Pitch' possibly later 'Gas Oil'
C4 + C5	27	'Pitch'
E36	9	'Black Creosote'

Vessel Name/Number	Location on Figure 88	Known Contents
		Later 'steam cracker fuel oil'
H8	16	Oil Tar Solids
H9	17	Tar Solids
H10	18	Tar
US13	10	'dark oil/water'
US14	11	'light oil/water'
US15	33	Bitumen
US17	26	Tar
US18	24	Petroleum pitch / xylene blend
US19	25	'X water phase'

CEMEX Land

Following the previous CSM report, further studies and investigation of the CEMEX leased land have been undertaken. This portion of the site historically supported ancillary operations associated with the Coal Tar Distillery, including the presence of tar and sludge settling beds, confirmed by historical mapping and aerial photography. During the 1930s and 1940s, a below ground tar well was known to have existed (see above).

Reference to the AEA Technologies Desk Study report (*Ref. 5*) and information within Appendix L suggests that the former pyridine plant was formerly housed within the southern portion of the CEMEX site. Precise details on the processes that took place in this area are not known however a number of above ground storage tanks are known to have existed in this area and it is likely that reactive bases (such as caustic soda, lime or similar) may have been used within these operations.

A roadstone aggregates coating operation was established at the site during the 1980s. The site has been leased by different operators since this time, including Hargreaves, RMC Roadstone and latterly, CEMEX Aggregates.

It is understood that the aggregates operations were undertaken under a Local Authority Pollution Prevention Control (LAPPC) permit, subsequently modified to become a Part B Environmental Permit under the 2007 Environmental Permitting Regulations. At the time of reporting, CEMEX have ceased operations at the site and surrendered the permit, which was accepted by Wakefield Council.

The roadstone coating operations are understood to have comprised the importation of various grades of aggregates, stored at surface in a number of bays across the site. The coating is blended on site using imported materials comprising bitumens, binders and flux oil, a type of refined light lubricating oil used to reduce the viscosity of the bitumen.

Prior to coating, aggregates are dried within a furnace/kiln powered by recycled fuel oil. Once dry, they are loaded into hoppers and blended with bitumen, binders, stainding and flux oil, the mixture of which depends on the grade of asphalt being produced. These are loaded into hoppers for direct offloading into road wagons.

It is understood that former operations at the site incorporated the use of gas oil that was sprayed onto the hoppers as a type of solvent to clean residual tar. The resulting effluent was not contained and was known to drain directly to surface. During WSP's initial inspections of the site, visible surface staining was noted in the vicinity of the hopper conveyor. This practise ceased in recent years.

The site surface water drainage infrastructure is limited, with surface water pooling and flooding evident following rainfall. Surface water is understood to collect in a collection sump in the centre of the site, from which it is pumped to a three stage interceptor within the former Tar Distillery site ('Vacant Land'). There is not known to be any further managed surface drainage infrastructure.

SRM Ltd Lease Area

In addition to the tar distillation plant, Croda's former operations extended to the east within the area of land currently leased by SRM for solvent recovery operations. It is understood that solvent recovery activities have been undertaken within this area since the 1980s, when Croda established Croda Solvents. These operations have continued since that time, with SRM taking over operation of the site in 2004.

In discrete areas of the SRM operated plant, activities associated with tar storage and distillation processes took place, including above and below ground storage tanks and the presence of six no. tar wells, together with areas of tar and sludge deposition and settling that have been identified in the north-eastern portion of the site. Areas relevant to the operation of the tar distillation facility have been included within this assessment.

The on-going solvent recovery operations carried out by SRM are subject to an Environmental Permit. Risks associated with contaminative activities are subject to baseline information and the requirement to return the site to baseline conditions on surrender of the permit. As such, this area is considered beyond the scope of detailed investigations and assessment however consideration will be given to the presence of any groundwater contamination likely to be derived from the solvent recovery operations.

4.3 Observations of Contamination from WSP Investigations (2009 – 2011)

Background

Ground investigations at the site have identified consistent and extensive evidence of contamination impacts within the former main operational and production areas of the site. The following section provides a summary of the further additional findings/observations from the additional targeted ground investigations carried out by WSP are presented within Appendix B.

A graphical summary of the locations where observations of shallow soil contamination have been observed is presented within Figure 43.

CEMEX Land

Exploratory holes in this area identified significant hydrocarbon odours, staining and free phase hydrocarbons within Made Ground and perched waters to depths beneath the hardstanding at the site. The presence of perched groundwater and hydrocarbon impacts correlated with the presence of granular made ground and sub-base that underlies much of the site. This was noted to extend to depths of up to 1.7m bgl. Follow-on monitoring undertaken within the aggregates batching plant recorded a measurable thickness of fuel oil LNAPL within WSPWS04, installed within perched groundwater in this location. In the south-eastern portion of the site, phenolic and coal tar odours were recorded within deep made ground.

Hydrocarbon odours and staining were also recorded within the Shallow Deposits, comprising slight to strong hydrocarbon odours and sheens recorded during drilling.

Contamination within the Middle Deposits was recorded within many of the investigation locations, with tar saturated silty sands observed from 3.7m to 5.2m bgl within WSP245 in the centre of the site. Further observations of hydrocarbon odours and sheens were recorded within the Middle Deposits in the majority of locations.

In the western periphery of the site, in WSP247, the Middle Deposits did not indicate any evidence of contamination impact.

Exploratory holes advanced into the Deep Deposits (WSP316 and WSP320) did not record evidence of hydrocarbon contamination within this strata.

Tar Distillation Site (Croda Vacant Land)

Extensive previous investigations have been undertaken within this area of the site, dating back to Binnie and Partners in 1979. All phases of investigation have identified evidence of hydrocarbon contamination within shallow and deeper soils.

Evidence of contamination within Made Ground comprises the presence of solidified 'pitch' type materials, bituminous deposits, running tars and hydrocarbon and coal tar saturated granular soils. The contamination is broadly consistent in its

nature across the site, however the presence of deposits of solidified pitch and bituminous materials is more prevalent in the north-western area, which was understood to have formerly housed pitch storage tanks (S+L22, C1 and C2) and pitch deposition that took place in the CEMEX Land, prior to its change of use.

Broadly, contamination impacts within wider areas have comprised tar and pitch type inclusions within shallow soils together with hydrocarbon and coal tar odours, staining and sheens within perched groundwater. The presence of contamination within perched water is likely to be linked to and governed by the presence of subsurface structures, as discussed within the groundwater assessment.

Hydrocarbon odours and staining were observed to extend into the underlying Shallow Deposits, typically to depths of circa 2.0 to 2.5m bgl. Locally, evidence of tar saturated soils were observed in the western portion of the site, in the vicinity of former tar well S+L8. Contamination was observed to extend into the underlying Shallow Clay ('Clay 1'), typically in the form of hydrocarbon odours and staining within fissures in the clay. This was observed within TW24, TW25, TW31 and TW38 in the eastern portion of this area and within proximity of former tar wells, such as WSP219B, BH02/07M and BH07/07M.

Evidence of coal tar and hydrocarbon contamination was observed throughout the Middle Deposits across much of this area, generally recorded in the form of hydrocarbon odours and staining however localised observations of hydrocarbon saturated soils and separated product were recorded within the western, north and eastern areas.

Observations of contamination were such that more severe impacts were apparent toward the base of the Middle Deposits, often coinciding with more coarse grained sands at these elevations. The maximum depth of observed contamination correlates with the maximum identified depth of this unit, extending to an elevation of 3.19mAOD (WSP201).

It is noted from the geological profiling that there is an absence of the Middle Clay horizon within a number of exploratory holes in the centre of the tar distillery site, with eight locations (BH11/07/D, BH11/07M, TW01, TW27-TW30 and TW42).

Tar Well Investigations

Evidence of hydrocarbon contamination was recorded during these investigations within accessible areas of the tar distillery site. Limited evidence of residual coal tar contamination was identified within the backfilled tar well structures, with S+L5 and to a lesser degree, S+L6, indicating the presence of residual hydrocarbons and tars within the backfilled remnant structures. Follow on monitoring from a number of shallow sumps and monitoring wells installed within these tar wells has not recorded phase separated NAPL.

Contamination to the exterior of the tar well walls and puddle clay lining was consistent with the wider profile in this area of the site.

SRM Operational Site (Tar Distillery areas)

Investigations within the operational portion of the SRM facility have been limited by health and safety restrictions associated with the site's operation as a Lower Tier COMAH facility.

Several phases of investigation have been carried out within the northern portion of the site, within the areas that previously housed ancillary operations associated with the tar distillery, including a number of below ground tar wells. This area also includes the northern portion of the site currently housing the SRM effluent treatment plant and effluent storage tanks (S+L20 and S+L21).

Contamination observations within these areas indicated impact with hydrocarbons, with evidence of coal tar derived impacts observed within boreholes in the vicinity of the former tar wells, effluent treatment plant and the vacant area that formerly housed tar and sludge settling beds. Contamination was observed within Made Ground comprising hydrocarbon odours and staining, together with fuel type odours and organic odours from Shallow Deposits in close proximity to the effluent treatment plant.

Evidence of contamination extending into the Shallow Clay horizon was apparent with odours and phase separated product recorded in laminae and fissures within the clay in a number of locations (BH10/07D, AE08/04).

The Middle Deposits recorded hydrocarbon contamination in the form of odours, sheens, staining and occasional phase separated product. The spatial extent of observed impacts included the areas associated with the former tar wells, together with locations within the area of the effluent treatment plant; with the majority of WSP locations installed as part of the leaky bank investigation (WSP205-WSP211) all recording significant impact within the Middle Deposits. There was limited evidence of impact within the Middle Deposits to the north-east of the former tar wells and toward the east of the SRM operated site, with WSP225, Golder BHD, WSP228 and WSP229 all recording no observations of contamination within this strata.

Locally, evidence of hydrocarbon impacts were recorded within the Middle Clay layer, comprising odours and staining within clay fissures was recorded within BH10/07D, to the north of the former RB1 tar well. This location has subsequently recorded measurable thicknesses of DNAPL within the Deep Deposits.

Aside from a sheen observed during the installation of WSP312, no visual or olfactory evidence of contamination was observed within the Deep Deposits within this area of the site.

British Waterways Land Investigations

The British Waterways Land (Figure 5) has undergone several phases of intrusive investigation, in 2010 and 2011. Hydrocarbon contamination was observed within a number of additional boreholes and MIP/LIF locations drilled as part of these works. The distribution of contamination was generally consistent with those observations from the main Croda site, with hydrocarbon odours and evidence of phase separated product recorded within both shallow made ground to the south of Bank Dole Cut and within the Middle Deposits. Boreholes drilled to the north of the canal recorded evidence of phase separated contamination within the Middle Deposits only both to the west and east of the Lock-Keepers cottage (WSP234, WSP235, WSP237, WSP255, WSP257 and WSP258). Light sheens were also noted during the drilling of WSP238.

Contamination observations within the Deep Deposits were noted within WSP323, drilled to the south of Bank Dole Cut, adjacent to the former tar offloading point. Contamination was recorded in the form of hydrocarbon odours and sheens within this stratum.

Stocking Lane and Tar Settling Lagoons

As part of recent investigations carried out in the north-western portion of the site, a number of exploratory holes have been advanced to the north of the main site and tar settling lagoons.

Evidence of contamination in these areas was less severe than those within the main site, with boreholes drilled along Stocking Lane recording faint hydrocarbon odours within the Middle Deposits and no evidence of contamination within the Deep Deposits.

One location, WSP260, recorded a hydrocarbon sheen and odours within the Middle Deposits at a depth of 2.5m to 4.7m bgl.

Summary of Contamination Observations

Extensive investigations at the site dating back to 1979 have indicated that contamination is present within soils, perched groundwater and natural deposits below the site. Contamination has been observed in the majority of exploratory holes advanced within the former tar distillery site, including areas previously used for tar storage, settling beds and peripheral areas of the main facility.

Impacts have also been identified within discrete areas of the SRM lease area, primarily around known storage locations. Off-site to the north, in the vicinity of Bank Dole Cut, evidence of tar contamination has been recorded in the majority of investigation locations.

Contaminants appear consistent across the site with evidence of more solid ‘viscous’ pitch, bitumen and tar type contamination within shallow near surface deposits and less viscous phase separated product and ‘creosote’ type contamination within deeper soils and groundwater.

A review of the distribution of recorded observations suggest that contamination is widespread and not necessarily confined or attributed to local sources or individual areas. This suggests that the contamination is likely to have emanated from a number or sources, including the below ground tar wells previously in operation at the site, where a close correlation between these features and contamination within the Middle Deposits have been identified.

4.4 Field Assessment of Hydrocarbon Contamination

2004 AEA MIP + LIF Investigations

Two stages of Membrane Interface Probe (MIP) and Laser Induced Fluorescence (LIF) investigation have been carried out at the site. AEA Technologies undertook a site wide investigation in 2004 (REF) comprising the advancement of approximately 45 LIF and 32 MIP probeholes across the Croda, SRM and CEMEX sites. The following represents a summary of the findings of that investigation:

Croda Tar Distillation Facility

The results from 10 MIP and LIF probehole locations indicated that shallow hydrocarbon contamination (generally within the top 2.0m of the soil profile) was consistent and uniform across this area. Furthermore, elevated peaks of FID and PID responses were observed within soils from between 4 and 8m bgl, with interpretation suggesting that the majority of the contamination was likely to be indicative of 'crude' oil, tars and creosote type materials. LIF position AEAT12 on the northern boundary of the former distillation facility recorded consistent 'creosote' and 'tar' indicators from ground level to 7m bgl.

Additional Areas

MIP and LIF locations within the CEMEX land to the west of the Tar Distillery facility identified similar trends, with FID peaks recorded within AEAT3, together with deeper observations of hydrocarbons recorded between 6m and 8m bgl toward the southern portion of the CEMEX site.

Within the SRM lease areas, shallow soils were noted to record elevated peaks within the PID screens in the main tank farm area. Further elevated readings were noted within proximity of the effluent treatment plant to the north of Tar Well RB1.

2010 WSP MIP + LIF Investigation

Observations and findings from the Bank Dole Cut investigation works are presented within Appendix B. In total, 11 MIP locations were advanced, with a further 14 LIF probeholes drilled.

The findings and observations of the investigation works broadly correlated with the observations from boreholes drilled within this area.

All locations identified evidence of hydrocarbon contamination, with particular emphasis on the Middle Deposits, where consistent evidence of hydrocarbon and tar impacts were recorded.

Probeholes advanced along the northern boundary of Stocking Lane (LIF1 – LIF8) all suggested evidence of hydrocarbon impacts within shallow soils (<2.5m), with LIF5 and LIF8 in particular recording elevated 'light fraction' readings between depths of 1m and 2m bgl. Two scenarios exist for these observations, either a historical spill within this location that was filled over during works associated with Stocking Lane, or potentially that hydrocarbon contamination has migrated or is migrating within shallow soils from the former tar distillery site in a northerly direction.

Interpreted 'Tar' fractions were consistently recorded at depth within the Middle Deposits both to the south and the north of the Bank Dole Lock structure, confirming that contamination is present within the Middle Deposits beyond the lock itself. The scale of fluorescence observed within the MIP surveys suggests that more severe impacts were observed within an area to the immediate north of the former S&L20 and S&L21 tanks on the tar distillery site. In addition, evidence of tar and hydrocarbon impacts were observed within MIP and LIF locations 1, 2 and 3 drilled within close proximity of the River Abstraction Chamber at depths of between 4m and 6m bgl.

4.5 Site Specific Contamination

Background

The previous WSP CSM report included a review and assessment of soil contamination across the site, incorporating the results of historical investigations together with WSP characterisation works.

The assessment concluded that contaminants at the site were consistent with those anticipated and determined during previous investigations were reflective of the historical operations undertaken at the site. The intention of this section is to provide further information on the nature of the contamination, both in chemical form but also in the context of environmental fate and transport.

Coal Tar Composition and Properties

The coal tar imported to site was understood to comprise a low temperature coal tar derived from coking ovens and gas works in the West Riding. Low temperature derived coal tars were generally more valuable to tar distillers as they contain a higher proportion of naphthalene, phenols and anthracenes.

Coal tars comprise a very complex mixture of materials, comprising a range of poly-cyclic aromatic, phenolic and heterocyclic aromatic hydrocarbons, together with sulphate and nitrogen containing bases, tar acids and aliphatic hydrocarbons. PAHs will typically comprise ~80% of the composition of the coal tar, with up to 200 PAH compounds present within a coal tar (Guillen et al, 1992). Overall coal tars are estimated to contain up to 5,000 organic compounds.

A raw coal tar will typically have a specific gravity in the order of 1.18 to 1.23g/cc (Hawley, 1981). Site specific analysis of samples of coal tar derived NAPL recovered from the site indicate a material with a specific gravity marginally greater than water (1.025 to 1.08g/cc), with a viscosity of 20 centipoise (cp) at 15ºC, suggesting that the NAPL being identified within groundwater at the site is slightly less dense than a raw coal tar, possibly indicating that it is the more mobile, low molecular weight constituent compounds that are migrating from source. Further discussion on the presence of NAPL contamination follows in subsequent sections.

PAH characterisation

As noted above, coal tar contains a large number of PAH compounds, ranging in toxicity, solubility and aromaticity. Typically, an imported coal tar will contain numerous volatile and semi-volatile PAHs, with Naphthalene generally regarded as the most abundant of the PAHs typically analysed in contaminated land investigations.

To determine the percentage composition of coal tar impacted materials at the site, a review of the PAH data from recent investigations has been undertaken. This is not intended to be an exhaustive or detailed assessment, but has mainly been undertaken to confirm that naphthalene is an appropriate indicator compound for further consideration at the site.

Selected soil samples taken during the recent Tar Well investigation (Appendix J) were analysed for Speciated PAH compounds, based on the US EPA priority 16, typically analysed during investigations of coal carbonisation and gas production sites. The full results of these are presented within Appendix E. These samples were selected on the basis that they were the closest samples likely to be related to the presence of the un-distilled coal tar at the site, in the absence of a historical sample of the raw coal tar itself. Table 4.1 below represents a summary of this information:

Table 4.1 Selected Soil Sample PAH Analysis - Overview

PAH Compound	Minimum (mg/kg)	Maximum (mg/kg)	Average Percentage Composition
Naphthalene	0.191	5,060	30.6
Acenaphthylene	0.044	379	0.8
Acenaphthene	0.738	1,240	8.0
Fluorene	0.395	733	5.2
Phenanthrene	0.289	2,330	13.2

PAH Compound	Minimum (mg/kg)	Maximum (mg/kg)	Average Percentage Composition
Anthracene	0.122	1,380	5.0
Fluoranthene	0.346	2,940	9.8
Pyrene	0.228	2,390	7.8
Benz(a)anthracene	0.14	1,100	3.8
Chrysene	0.1	716	3.1
Benzo(b)fluoranthene	0.15	824	3.8
Benzo(k)fluoranthene	0.0727	358	1.5
Benzo(a)pyrene	0.15	773	3.4
Indeno(1,2,3-cd)pyrene	0.0895	260	1.6
Dibenzo(a,h)anthracene	0.0288	74.1	0.5
Benzo(g,h,i)perylene	0.114	302	1.9
PAH, Total Detected USEPA 16	3.45	17,900	NA

The information and results from the analysis indicate that PAH concentrations recorded vary significantly, reflecting the variable nature of the impacted soils recorded. The comparison of the data confirms that naphthalene is the most abundant of the priority 16 PAH compounds analysed, with phenanthrene, fluoranthene, pyrene and acenaphthene accounting for a further 39% of the total PAH mass analysed.

Whilst it is possible that a substantial number of additional PAH compounds are likely to exist within the coal tar mixture, it is not possible or practical to analyse for such a large number of contaminants. Naphthalene, being the most soluble of the readily identified PAH compounds and the most abundant identified within the composition assessment, is considered to remain the most suitable coal tar derived PAH compound to review as part of this contamination assessment. Where appropriate, further commentary will be provided on the further four abundant PAH compounds above.

Phenol Characterisation

Phenolic compounds are present in abundance within coal tars, although less so than the PAH compounds. Historically, investigations and assessment at the site has focussed upon the presence of 'total phenols' or 'monohydric phenols', which were simple analytical methods used as a bulk form of calculating a total phenolic composition.

As part of the tar well investigations, speciated phenol analysis was carried out on a number of tar well soil samples for a range of phenol compounds typically identified and assessed within coal carbonisation investigations. The results, contained within Appendix E are summarised below:

Table 4.2 Selected Soil Sample Phenol Analysis - Overview

Phenolic Compound	Minimum (mg/kg)	Maximum (mg/kg)	Average Percentage Composition
Catechol	*Not Detected*	*Not Detected*	*NA*
Phenol	<0.1	151	9.6
Cresol (o-, m-, and p-)	<0.4	484	23.9
Resorcinol	*Not Detected*	*Not Detected*	*NA*
Xylenols	<0.2	632	40.6

Phenolic Compound	Minimum (mg/kg)	Maximum (mg/kg)	Average Percentage Composition
1-Napthol	<0.01	23.3	2.9
2,3,5-Trimethylphenol	<0.2	15.3	2.3
2-Isopropylphenol	<0.2	296	27.4

The information suggests that xylenols, cresols and 2-isopropylphenol are the most abundant of the readily analysed coal tar phenols. On the basis that individual phenol compounds account for a greater percentage of the total phenolic mass, further consideration and commentary on these three compounds will be provided, where appropriate.

Selection of Contaminants of Concern

Following the review above and understanding of previously agreed criteria and historical investigation at the site, it is considered appropriate to retain the contaminants of concern from the previous CSM, however subsequent discussion will also consider the presence of other PAH and phenol compounds, where deemed suitable. The contaminants of concern to take forward for further consideration are:

- Benzene
- Xylene
- Naphthalene
- Phenol
- Aromatic EC_{10}-EC_{12}
- Aromatic EC_{12}-EC_{16}
- Aromatic EC_{16}-EC_{21} and
- Aliphatic C_6-C_8

4.6 Summary of Additional Site Investigation Data

Croda Tar Distillation Site (including Tar Well Investigations)

Shallow soil contamination within this portion of the site was typically identified within the northern and western margins of the site, generally in close proximity to historical product storage areas and tar wells. Elevated concentrations of the key contaminants of concern were noted to correlate with observations of gross visual and/or olfactory evidence or phase separated product during field investigations.

Hydrocarbon contamination is noted to be widespread within shallow soils within this area of the site, with middle to heavy range aromatic hydrocarbons recorded at average concentrations in excess of 1,000mg/kg. Peak aromatic hydrocarbon fractions were generally recorded in the vicinity of the former tar distillation plant and the S&L 5, S&L 8 and S&L 22 tar storage facilities. These are known to have stored coal tar and pitch respectively. Elevated concentrations of total phenols have also been recorded in proximity of S&L5 and S&L22, suggesting that localised impact from coal tar derivatives is present, with recent detailed analysis of soils within the S+L8 tar well recording total phenol concentrations of 736mg/kg and the S+L6 tar well at 1,440mg/kg. Further evidence of phenol impact was recorded within natural soils at the base and exterior of this former tar well.

Within the vicinity of the former creosote ASTs, aromatic EC_{12}-EC_{16} hydrocarbons were recorded at 7,800mg/kg within TP15 at 0.4m bgl and Aromatic C_{16}-C_{21} hydrocarbons were recorded at a peak concentration of 9,900mg/kg within BH04/07/M at 1.0m bgl.

Further evidence of coal tar derivatives were noted in this area with elevated naphthalene recorded in TP15 and BH04/07M, with more widespread contamination observed within the vicinity of the former boiler house/tar stills area,

along the northern site boundary, in the vicinity of the former tar offloading point and cracked aromatic oil tanks (see Figure 88). Maximum concentrations were recorded within TP15 at 0.4m bgl (8,000mg/kg), with further concentrations in excess of 2,000mg/kg identified within TP07, TP09, TP10 and BH10/07/M, all during the Atkins investigations of 2007.

Benzene and xylene were recorded at peak concentrations in proximity to the former creosote blending tanks to the west of S&L5 (AEAT07 at 2m bgl) and along the northern boundary of the site to the north of the 'tar fractions' storage tanks (BH12/07/S at 0.5m bgl). Benzene was recorded at a maximum concentration of 40.7mg/kg at AEAT07 and xylene at a maximum of 176.9mg/kg in the same location.

Wider Site

CEMEX operated site

Data within the CEMEX land has been expanded following the completion of the further investigations in 2011. This has enabled further understanding of the contaminant profile at the site.

Shallow soil contamination has been identified to be broadly consistent with that identified within the tar distillery site, with evidence of coal tar impacts within shallow soils in the southern, eastern and northern areas of the site. Further contamination was identified in the form of fuel oil hydrocarbons, characterised by a greater proportion of aliphatic hydrocarbon bands in the range EC_{12}-EC_{21}. It is noted that light non-aqueous phase liquid (LNAPL) impacts have been recorded within WSPWS04, within the aggregates batching plant. These are discussed later in more detail.

Aromatic hydrocarbons and PAH compounds, including naphthalene, have been recorded in a number of locations within shallow soils. Samples from Made Ground in WSPWS01, in the footprint of the former pyridine plant, recorded aromatic hydrocarbons at concentrations of 10,100mg/kg and 15,700mg/kg for EC_{12}-EC_{16} and EC_{16}-EC_{21} respectively. Naphthalene was recorded at 11,200mg/kg at this location.

Within the northern portion of the CEMEX site, adjacent to the former below ground tar well, a shallow soil sample from WSPWS06 recorded aromatic hydrocarbon and naphthalene concentrations at similar orders of magnitude.

BTEX compounds were recorded within shallow samples of Made Ground at the site, typically in peripheral areas such as the north-western corner, south-eastern corner and adjacent to the former tar well.

The vertical profile of the contamination generally indicated impacts to be restricted to Made Ground, however locally there was impact within the Shallow Alluvial Deposits, with WSPWS01 in the south-eastern corner recording impact at a depth of 1.2m to 1.4m bgl in this location.

SRM Site – Former Tar Distillation Operations

For the purpose of this assessment, consideration has been given to the distribution of contamination in relation to previous and ongoing operations. Within proximity of former tar wells and potential tar distillation features, shallow soil contamination was recorded in the form of elevated hydrocarbons and coal tar derivatives.

The main areas of contaminant impact within shallow soils are in proximity to the former Tar Wells RB1-RB4 and the effluent treatment plant in the north-east of the site. It is noted that whilst this area has been used in recent years by SRM for storage of drums and waste materials, the area was historically operated within the former tar distillation process and was known to be used as an area of tar and sludge deposition and settling.

Peak concentrations of aromatic hydrocarbon fractions, naphthalene and elevated benzene were all identified within this area, notably within AEAT21 at 1.2m where Benzene was identified at 205mg/kg and naphthalene at 3,602mg/kg. Strong solvent odours were noted at this depth during the drilling of this borehole. Further naphthalene and aromatic hydrocarbon contamination was identified within BH09/07/S and GA6, both within the upper 1m of the soil profile. Field evidence of strong hydrocarbon odours, tars and free product were noted at this depth, with evidence of hydrocarbon odours extending to a depth of 2.7mbgl, within natural sand beneath the made ground.

To the north of the former tar wells, toward the former settling lagoons, aromatic hydrocarbons in excess of 20,000mg/kg were identified within TP12 of the Atkins investigation, correlating with field evidence of strong sulphurous and hydrocarbon odours at 1.5m bgl.

SRM Permitted Site – not including Former Tar Distillation Operations

This portion of the site has been afforded limited historical investigation due to the solvent recovery operation taking place in this area. The main area that has been investigated has been the north-eastern portion of the site, to the east of the former RB1-RB4 tar wells, in the area currently defined by three large above ground product storage tanks. Maximum soil contamination in this area was recorded within AE23/04, where naphthalene and phenol were recorded at 104mg/kg and 21mg/kg respectively at a depth of 0.6m. Further boreholes within this area have not indicated significant evidence of shallow soil contamination, which generally correlates with field observations noted during drilling.

Data from within the main solvent recovery plant is limited, with only six exploratory holes having been advanced in this area. Naphthalene contamination was the principal contaminant identified, with AE07/04 recording a concentration of 1763mg/kg at 1.2m. It is noted however that this is located to the south of former tar well RBTT and therefore may exhibit local influence from that feature.

Marginally elevated concentrations of naphthalene, xylene and aromatic hydrocarbons were recorded in shallow soils in the south-western portion of the SRM operated land, within the vicinity of BH02/05/A and BH13/07/S, where tar odours and hydrocarbon staining and sheens were noted in shallow soils. Historically, a number of tanks are understood to have existed within this area, although their exact contents and function are unknown.

Bank Dole Lock

Recent investigations undertaken in the vicinity of Bank Dole identified generally limited contamination within shallow soils. However, on the basis of the LIF survey work, where evidence of potential volatile contamination was observed within the shallow soil profile, laboratory analysis was undertaken for contaminants of concern within WSP234 and WSP235. The results indicated only moderately elevated concentrations of aromatic hydrocarbons (up to 970mg/kg) and naphthalene (up to 54mg/kg), identified in both locations at depths of 0.6 and 1.1m bgl respectively.

No evidence of phase separated tars or product were noted in these shallow soils.

4.7 NAPL Contamination

Introduction

With the exception of localised impact within an isolated location within the CEMEX site, Light Non Aqueous Phase Liquids (LNAPL) have not been observed in measurable thicknesses during recent site investigations or subsequent monitoring rounds.

The impact with the CEMEX site relates to the recent and historical use of fuel oil and gas oil during the aggregates coating operation in this area. Measurable LNAPL has been recorded within WSPWS04 following its installation during the recent investigations (1,220mm of LNAPL, October 2011).

LNAPL has not been recorded elsewhere at the site, and therefore, the assessment of NAPL at the site has continued to focus upon 'Buoyant' and Dense Non Aqueous Phase Liquids (DNAPL). Previously, WSP reviewed historical groundwater monitoring data from previous investigations and noted elevated dissolved phase concentrations, which could indicate the potential presence of NAPL in the form of a suspended emulsion whose density is similar to that of water (buoyant), *To update the conceptual understanding of groundwater contamination conditions, WSP have undertaken further dissolved phase monitoring and analysis and this will be discussed in more detail in Section 5.7 below.*

WSP have undertaken a programme of NAPL monitoring at the site from an extensive network of monitoring wells, identifying measurable thicknesses of NAPL in a number of locations. In these wells, it is likely that there is the presence of pooled NAPL, where the dense fraction has formed a pool, predominantly at the base of the Middle Deposits. This section provides further information on the spatial distribution and characteristics of the NAPL at the site, with further discussion on the potential for NAPL migration.

Laboratory NAPL Characterisation

Previously, samples of NAPL were obtained from remediation wells in Cell 1 using bottom loading, low shear pumps. These samples were subsequently scheduled for specific gravity and viscosity analysis at a specialist hydrocarbon

laboratory with the aim of obtaining a measure of the physical properties of the NAPL. Analysis certificates are presented in Appendix E.

The specific gravity of the recovered NAPL was measured as 1.0254 kg/m^3, which falls closer to the lower end of the typical density range for coal tar of 1,010 to 1,100 kg/m^3, indicating a specific gravity marginally greater than water. Viscosity analysis of the coal tar recorded a value of 7.586 Centistokes (cSt) which actually falls well below the lower end of typical coal tar viscosity ranges of 20 to 50 Centistokes (cSt), and therefore indicating a very low fluid viscosity.

The physical characteristics of the NAPL and the observations recorded during the laboratory trials would suggest that although the density is not that much greater than water, it has a potential to pool where conditions allow. However, the low density contrast would also support the presence of suspended emulsions of buoyant NAPL, either where NAPL has not yet pooled, or where the hydraulic gradient is strong enough to overcome capillary forces to entrain NAPL in the form of mobile droplets. Although there is no evidence strongly either way, typically NAPL emulsions would be more likely to be generated by residual contamination, rather than through remobilised pools.

Croda Materials Datasheets (MSDS)

In addition to the laboratory assessment, Croda provided information on materials and product data characteristics, which included typical density values for a range of site derived products and derivatives. The information suggested that typical densities ranged from 0.850kg/m3 (Diesel Fuel) to 1.375kg/m3 (PetroCarb 0310 – a Croda 'Pitch/Oil' product). The majority of distillation products/derivatives had specific gravity in excess of 1.0kg/m3, with only Aromatic Oils 860 and 1603 being less. This information further suggests that the contaminants and hydrocarbon products at the site are typically either of a similar density to water (buoyant) or more dense (such as a DNAPL).

Soil Core Analysis

To further improve an understanding of the distribution and behaviour of the NAPL within the subsurface, WSP have completed further advancement of soil cores in several locations at the site. Initially, these were carried out within the Cell 1 remediation area for forensic assessment of NAPL distribution within the Middle Deposits profile. Cores were recovered from above and below the water table using a push sampling rig, with visual examination of saturated NAPL. Gross NAPL distribution was particularly evident in undisturbed cores at depths ranging between 2.0 – 3.5 m bgl within laminations of sandy clay, and within saturated sands at depths ranging between 4.0 – 6.0 m bgl which was consistent with the findings of NAPL distribution encountered during drilling of the northern boundary and in Cell 1.

As part of the 2011 Bank Dole Lock Investigations, additional soil core samples were retrieved within WSP234 and WSP235 and inspected for contamination. The findings and results of these cores were consistent with those from the initial investigation, with visually impacted granular soils noted at depths of between 3.7m and 5.4m bgl, with significant NAPL recorded toward the base of the Middle Deposits.

NAPL Distribution

LNAPL is largely absent at the site, with only a localised area identified within he CEMEX site, thought to be associated with the use of gas oil at the site. Elsewhere, measurable settled NAPL recorded at the base of monitoring wells using interface meters and potential buoyant NAPL inferred from dissolved phase data (see section 5.7). The initial WSP CSM report discussed the presence of NAPL generally within the northern section of the tar distillery site, focussed upon the 'Leaky Bank' investigation. For the purposes of this discussion, comment has been made on measurable NAPL identified within the former tar distillation site, including areas associated with former production operations (such as former tar wells etc).

The following discussion therefore summarises the presence and distribution of measurable NAPL detected within Middle and Deep wells throughout ongoing monitoring undertaken between January 2011 to October 2011, with information presented below and illustrated in Figures 69 to 78.

Cell 1 and 2 Remediation Wells – Middle Deposits

The following table summarises the maximum recorded NAPL thickness throughout the 2011 monitoring programme identified within the Cell 1 and 2 product recovery wells.

Table 4.3 – Summary of Monitoring Wells with Measurable NAPL (Cell 1 and Cell 2 Remediation Zones)

Monitoring Well	Unit	Maximum recorded NAPL thickness and month (mm)	Recorded NAPL thickness (October 2011) (mm)
TW03	Middle Deposits	125 (June 2010)	NR
TW04	Middle Deposits	1,130 (January 2010)	NR
TW06	Middle Deposits	200 (January 2010)	NR
TW07	Middle Deposits	150 (March 2010)	NR
TW08	Middle Deposits	40 (September 2010)	NR
TW09	Middle Deposits	110 (April 2010)	NR
TW10	Middle Deposits	210 (January 2010)	NR
TW13	Middle Deposits	670 (May 2010)	NR
TW14	Middle Deposits	45 (April 2011)	NR
TW15	Middle Deposits	135 (May 2011)	NR
TW16	Middle Deposits	210 (August 2010)	NR
TW17	Middle Deposits	430 (January 2011)	110
TW20	Middle Deposits	351 (April 2011)	NR
TW22	Middle Deposits	2,705 (May 2011)	NR
TW24	Middle Deposits	10 (May 2011)	NR
TW27	Middle Deposits	110 (September 2010)	NR
TW29	Middle Deposits	3,050 (August 2011)	NR
TW30	Middle Deposits	90 (October 2010)	NR
TW31	Middle Deposits	90 (October 2010)	NR
TW32	Middle Deposits	395 (August 2010)	NR
TW34	Middle Deposits	125 (August 2011)	NR
TW35	Middle Deposits	60 (October 10)	60
TW38	Middle Deposits	95 (October 10)	30
TW39	Middle Deposits	185 (October 10)	NR
TW40	Middle Deposits	140 (September 10)	NR
TW41	Middle Deposits	190 (September 10)	NR
TW42	Middle Deposits	814 (August 2011)	4
Abstraction BH (Heat Trial)	Middle Deposits	183 (April 2011)	100
Injection BH2 (Heat Trial)	Middle Deposits	200 (October 2011)	200
Injection BH3 (Heat Trial)	Middle Deposits	72 (April 2011)	70

It is noted that monitoring observations of the other remediation treatment wells recorded evidence of NAPL within the wells, but not at measurable thicknesses. It is likely that NAPL in these locations is present as a buoyant 'smear' rather than a distinct layer or separable quantity.

The distribution of NAPL thickness within the remediation cell areas indicates that NAPL thickness varies, with greater thicknesses observed within the western and eastern areas of Cell 1 and Cell 2 respectively. The maximum recorded NAPL thickness within these areas was within TW29 in January 2011, where 3,050mm was identified. The results indicate that NAPL thicknesses have fluctuated within this location during the 10 months of monitoring.

Since the additional treatment/monitoring wells were installed and commissioned in August 2010, the total number of operable remediation wells has increased to 42, with the number of wells recording measurable thicknesses of NAPL fluctuating from 4 to 20 in September 2010 and 17 in May 2011.

Wider Site – Middle Deposits

Monitoring data from wells located outside the main Cell 1 and 2 remediation zone has been summarised below:

Table 4.4 - Summary of Monitoring Wells with Measurable NAPL (Wider Site)

Monitoring Well	Unit	Maximum recorded NAPL thickness and month (mm)	Recorded NAPL thickness (October 2010) (mm)
AE08/04	Middle Deposits	1,160 (May 2011)	1,110
BH01/07M	Middle Deposits	130 (February 2011)	NR
BH02/07/M	Middle Deposits	618 (May 2011)	400
BH04/05B	Middle Deposits	230 (October 2010)	NR
BH04/07/M	Middle Deposits	270 (April 2011)	NR
BH07/07/M	Middle Deposits	70 (November 2010)	NR
BH08/07/M	Middle Deposits	110 (September 2010)	NR
QMW2/M	Middle Deposits	310 (September 2010)	NR
WSP201	Middle Deposits	280 (August 2010)	NR
WSP202	Middle Deposits	930 (January 2010)	NR
WSP207	Middle Deposits	200 (September 2010)	NR
WSP211	Middle Deposits	130 (October 2010)	NR
WSP212	Middle Deposits	390 (October 2010)	NR
WSP215	Middle Deposits	70 (October 2010)	NR
WSP216	Middle Deposits	120 (October 2010)	80
WSP219B	Middle Deposits	181(July 2011)	NR
WSP221	Middle Deposits	170 (October 2010)	NR
WSP232	Middle Deposits	760 (November 2010)	402
WSP244	Middle Deposits	1,111 (July 2011)	NR

The distribution of NAPL in these wells confirms that NAPL is present in measurable thicknesses outside of the main tar distillation facility. At the most recent monitoring event, (October 2011) notable thicknesses of NAPL were recorded within BH02/07/M on the boundary of the CEMEX site and within BH/01/07M in the north-western corner of the site,

adjacent to S&L22. Further evidence of NAPL impact in the vicinity of the CEMEX site has been confirmed by the presence of significant thicknesses (1,111mm) of NAPL within WSP244, newly installed adjacent to the west of the former 'CEMEX' tar well.

Monitoring wells along the northern boundary of the site have continued to record measurable NAPL, in line with the findings of the previous CSM. Furthermore, WSP232, installed to the north of Stocking Lane, recorded 760mm of NAPL in November 2010, confirming that NAPL is present beyond the site boundary and this has recorded consistent thicknesses of NAPL since installation.

To the north-east, in the northern portion of the SRM lease area, measurable NAPL has been consistently recorded within the area of the effluent treatment plant (WSP207 and WSP211) ranging from 90mm to 200mm, but generally in the order of 120mm. Middle Deposits in this area were noted to be contaminated at the time of drilling. No readily identifiable source of NAPL is known in this area however the main SRM interceptor and waste effluent plant operate here.

In close proximity of the former tar well RB1, AEAT08 has recorded thicknesses of NAPL throughout the monitoring period, ranging from 532 to 1,160mm, with the most recent visit being 1,110mm. The most plausible source for this NAPL occurrence is the proximity of the former tar well RB1 or possibly RBTT to the south-west. Visual evidence of NAPL contamination in the Middle Deposits was recorded during investigation works in this area, both within AEAT08 and WSP222.

NAPL Migration and Behaviour

Middle Deposits

To assess the potential for NAPL migration, particularly of the pooled NAPL, WSP has refined the overview of the main NAPL areas over the recorded depths to the topographic base of the Middle Deposits unit, to establish whether areas of potential pooled NAPL remain consistent with areas of depressed geological deposits. Furthermore, consideration has been given as to the plausibility of historical sources, based on the investigation data to date and the lines of evidence demonstrated during the data gathering exercise.

It is considered plausible that the presence and distribution of NAPL is closely linked to the former bulk storage of coal tar at the site and therefore, discussion around NAPL sources focuses upon these features.

With regards to the potential for the migration of buoyant NAPL, these are anticipated to migrate with groundwater flow and as such would be subject to the same pathways and receptors as those discussed for the dissolved phase contamination reviewed in section 4.7.

A review of the distribution of NAPL and the base of the Middle Deposits shows that in general the distribution of NAPL within the aquifer relates to variations in topography, and how the local topography is able to influence localised pooling, or potential migration, of NAPL within the Middle Deposits. Area specific commentary is summarised in Table 4.5.

Table 4.5 - Summary of DNAPL Distribution in relation to Aquifer Base Topography

Area	Commentary
Site Summary	The base topography of the Middle Deposits generally trends in a south-west to north-easterly direction, falling from an elevation of 4.8 to 5.0m AOD through to approximately 2.7 to 2.9mAOD in the north east of the site, to the north of the former tar settling beds. The base of the Middle Deposits trends in a direction broadly correlating to the direction of groundwater flow within this unit. Specific discussion on DNAPL impacted areas is presented below.
Western Area	The base topography of the Middle Deposits in the vicinity of the former CEMEX and S+L8 tar wells was encountered at a level of 4.0 to 5.35m AOD. The base of this unit was noted to be slightly lower within the CEMEX land than the western margins of the Tar Distillation site.

Area	Commentary
Tar Distillery	NAPL monitoring has identified measurable thickness of NAPL in the Cell 1 and Cell 2 remediation area and the remainder of the former tar distillation site, with distal impacts observed within WSP201 on the northern site boundary. A review of the base topography indicates a relatively flat aquifer base contour at 4.0 to 4.6m m AOD within the south-western portion of this area, extending eastwards within Cell 2, with localised lowering in the aquifer to the north at WSP201 (3.19 m AOD) which may have influenced potential lateral migration of NAPL across the base of the aquifer between Cell 1 and this northern boundary well with resultant pooling. To the south of the main Cell 1 area, a low point was recorded in the vicinity of borehole AEA17/04 at 3.77mAOD. This location is thought to be close to a former tar well previously located in this area. Historically, NAPL has been observed within WSP212, down-gradient of this location to the east. To the south-west of this location, in proximity of the former S+L5 tar well, base elevations of the Middle Deposits were higher, ranging from 4.3mAOD to 4.7mAOD. Following the drilling of additional treatment wells within Cell 2, it is apparent that no consistently obvious low point was noted. However, there was an area in the centre of Cell 1 and Cell 2 that recorded no Middle Clay layer being present, suggesting that the middle sand and Deep Deposits may be in continuity in this location. The topographic low of this area was slightly lower than surrounding locations, with several elevations of <4.0m AOD observed.
British Waterways Land	NAPL impacts have been recorded within the north-eastern portion of the former tar distillery site. The topography of aquifer base at this location is consistent with the general topography of 4.0m AOD encountered within the Cell 1 and Cell 2 areas. Toward the south-east, topography trends show a decrease in the base elevation of the Middle Deposits, trending easterly to a lower point of 3.3mAOD at WSP305. Evidence of NAPL was noted within BH04/05B, to the south of S&L21, with a recent monitored thickness of 230mm. Extending northward, monitoring wells to the north of Stocking Lane (namely WSP232) record an elevation in line with the Cell 2 area. It is noted that 760mm of NAPL was recently monitored in this location, confirming that northerly migration of NAPL has occurred from the primary source areas at the site. Boreholes and MIP and LIF locations advanced to the north of Stocking Lane, in the direction of Bank Dole Lock and the River Aire yielded fluctuating topographical results, with base elevations of the Middle Deposits varying from a low point of 3.6mAOD (LIF1) to 4.94mAOD in the north-east (LIF7). It is noted that LIF 7 and LIF8 were both drilled in proximity of the River Abstraction Chamber in this area, which is understood to be present at an elevation broadly consistent with the Middle Deposits in these areas. The construction of this structure may have led to local disturbance of the geological strata in this area. Monitoring wells drilled to the north of Bank Dole Lock generally recorded the base of Middle Deposits at elevations of between 3.8 and 4.5mAOD, exhibiting local variability between the lock structure and the Croda Tar Interceptor. No pooled NAPL has been observed within the Middle Deposits in this area however evidence of NAPL impact is apparent in the form of the tar seepage within the interceptor and observations during drilling on the promontory. On the basis of the groundwater flow regime in this area, it is considered unlikely that these NAPL observations are ongoing from a source to the south of the canal, but are residual impacts within this land prior to the construction of sheet pile canal banks.

Area	Commentary
SRM Area (Tar Distillation Legacy)	NAPL has been recorded in a number of locations within the SRM leased area, thought to formerly house tar distillation operations. Two main areas of impact have been recorded, namely around the former tar wells and a second location to the north of the effluent treatment area, with the base of the Middle Deposits encountered at 3.4 m AOD. The topography of this area suggests that a low point exists in the vicinity of WSP211, which recorded a DNAPL thickness of 130mm in October 2010. WSP207, with a base elevation of 3.7mAOD, also recorded DNAPL at 120mm. To the south-east of this area, an area of lower basal elevation exists, sinking to a low point of 2.8mAOD within AE08/04M, where 1,110mm of NAPL has recently been recorded. This location is also noted to have the Middle Clay absent. South-west of this area, WSP222 and WSP221 recorded base elevations of 2.79mAOD and 3.59mAOD respectively and have both previously recorded measurable NAPL.

NAPL Recoverability

WSP have undertaken a programme of NAPL investigation and recovery works, focussing upon the area known as Cell 1 (NAPL Area C as discussed above). In August 2010, the recovery wells in this area were extended to include additional wells within 'Cell 2' and operation recommenced in September 2010.

The primary focus of the remedial works have been the abstraction of groundwater and entrained phase separated NAPL from the Middle Deposits, in combination with technology trials to establish whether design and method enhancements could be applied to improve the recoverability on the NAPL. These enhancements have included the use of a dual phase vacuum enhanced recovery system, bench-scale trials of surfactant application and field scale trials of warm water application. The findings of these trials have been reported within a technology review report (Referenced in Section 8) which has provided commentary on the effectiveness of these enhancements and the practicality of expanding these to full field scale operation.

Deep Deposits

Evidence of measurable NAPL within the deeper sand and gravel deposits is limited. The majority of deep wells have no evidence of NAPL. To date, only three monitoring wells have identified measurable NAPL (BH101C, MW1A and BH10/07/D). Only BH10/07/D has recorded measurable NAPL during the last three visits.

BH10/07/D was installed by Atkins during their 2007 investigations and is located immediately adjacent to the former RB1 tar well discussed previously. The well has consistently recorded DNAPL thicknesses in excess of 1,000mm since WSP began monitoring in January 2010, with a previous monitoring visit in December 2008 recording a NAPL thickness of 1,755mm. The maximum recorded thickness was 2,366mm in May 2010.

BHMW1A was drilled and installed by ERM in 1998 and was installed with a response zone partially within the Deep Deposits. This was installed as a dual installation well and it is noted that the base of the well does not extend to the base of the Deep Deposits and there may therefore be a more significant thickness of NAPL present in this location than is being monitored. The last measured NAPL thickness was 181mm in May 2011.

BH101C is located on the northern side of Bank Dole Lock, on the canal promontory adjacent to the River Aire. This well was drilled and installed within the Deep Deposits and observations at the time of drilling suggested tarry impacts. It is noted that this borehole is located immediately adjacent to the Croda River Aire tar interceptor, which is understood to have been constructed in a manner which may allow a contamination pathway between the Middle and Deep Deposits. The presence of NAPL in this well is considered to be local, and an artefact of this pathway. Whilst this well previously recorded measurable NAPL, this has not been identified since the November 2010 visit, although sheens and odours remain prevalent during monitoring.

There are no obvious trends within the distribution of DNAPL within the Deep Deposits, and no apparent correlation with topographic lows on the base of the deep aquifer. Where encountered, it is considered that such events are governed by local pooling and collection of DNAPL within discrete locations immediately adjacent to primary

contamination sources. As such, we consider there is no evidence for significant presence or migration of DNAPL within the Deep Deposits.

NAPL Mass Estimates

Measurable DNAPL and NAPL Source Areas

Within the previous CSM report, outline free phase mass estimates were developed based upon measurable thicknesses of NAPL within the Middle Deposits detected during groundwater monitoring in January 2010. In these areas, it was considered likely that there is phase separated pooled NAPL, although this is qualified by acknowledging that the process of insertion of a monitoring well in these locations will to some extent encourage the splitting and pooling of the NAPL. However, there are several monitoring locations on the site where high residual dissolved phase concentrations are not accompanied by a measurable thickness of NAPL. As such, the measurable portion has been interpreted to a strong indication of the presence of pooled NAPL or the presence of buoyant NAPL emulsions in the water column.

Within the initial CSM review, potential remediation/NAPL source areas were established based upon the five known areas of measurable NAPL thickness in the Middle Deposits, known as Area A, B, C, D and E.

WSP have used the findings of further investigation works, together with the ongoing monitoring data to refine the understanding of these remediation/NAPL Source areas and further clarify the potential extent of NAPL impacts in these locations.

Figure 80 indicates an expanded drawing indicating the extent of these areas based upon contemporary monitoring data. The plots have used monitoring data from the August 2011 monitoring visit, which incorporates the largest dataset and includes data from additional boreholes installed during 2011.

Table 4.6 below represents a summary of the extrapolated product thicknesses and calculated areas based on the spatial extent.

Table 4.6 - Estimates of NAPL Mass within Middle Deposits – Measured NAPL (Only)

Area	Approximate NAPL Thickness (m)	Area (m^2)	Approximate Volume (m^3)	Comments
Western Area (CEMEX)	231	210	231	Based upon NAPL measured in WSP244 and BH02/07M.
	150	300	150	
Tar Distillery	90	300	90	Based upon NAPL measured within Cell 1, Cell 2 and surrounding NAPL delineation wells. Includes areas around suspected former tar well to south of Cell 2.
	40	200	40	
	73	730	73	
	175	3,500	175	
	208	10,350	207.5	
British Waterways	8	35	8.05	Based upon NAPL measured within WSP232 and BH04/05B.
	28	37	28.12	
SRM Tar Legacy	41	450	40.55	Based upon average NAPL thickness within WSP207, WSP211 and BH09/07M
	125	2,500	125	Based upon NAPL measured within WSP221 and extrapolation of potential NAPL plume from former Tar Well RBTT.
	484	440	484	Based upon NAPL measured within AE08/04M and extrapolation of potential

Area	Approximate NAPL Thickness (m)	Area (m^2)	Approximate Volume (m^3)	Comments
				NAPL plume from former Tar Well RB1
Sub-total			1,653	
Total*			496	

** Assuming that DNAPL will occupy approximately 30 % of pore space around the monitoring well in a sand aquifer.*

The volumes presented in Table 5.6 includes refinement of the previously estimated NAPL source areas A to E, together with additional NAPL source areas observed within easterly areas such as WSP221 and AE08/04M respectively. As with the initial assessment, this exercise has used measured NAPL thicknesses within monitoring wells only and does not consider minor observations of Buoyant NAPL and tar smearing often recorded within further monitoring wells.

The coverage of the dataset is improved following the increased frequency and number of monitoring events and the extended network of monitoring wells, particularly incorporating the CEMEX tar well in the western area. However, there remains the potential for changes to mass calculations to arise due to local variance within NAPL behaviour and movement and this is apparent when reviewing the monitoring data, which indicates fluctuations in a number of monitoring wells, notably those within the Cell 1 and Cell 2 recovery system.

Further potential for NAPL

In addition to measurable NAPL presence, WSP have reviewed the borehole and monitoring records for the remainder of the site. The data has been reviewed to establish whether observations of potential NAPL identified during drilling then results in notable dissolved phase concentrations suggestive of the presence of buoyant product emulsions or measurable NAPL within subsequent groundwater monitoring results. This technique and the presence of former tar legacy features, formed the basis of further investigations into the tar well delineation exercise and has provided useful further information.

Figure 81 represents a graphical summary of this information and indicates that a substantial number of exploratory holes recorded observations of hydrocarbon contamination or potential phase separated product

The results of this screening assessment can be used as an indicator of the possible presence of potentially mobile and therefore recoverable NAPL.

The diagram indicates that this potentially recoverable NAPL is present within broadly the same areas considered to represent the identified areas discussed above.

It is plausible that the primary driver behind the definition of the presence of measurable NAPL is the former tar wells and associated tar distillation operations. A close correlation between the distribution of NAPL and these features has been established during the characterisation of the site.

The findings have been used to refine additional areas of potential NAPL that have not yet been fully investigated or characterised. These are depicted on Figure 82.

4.8 Groundwater Contamination

Collection of Contemporary Dissolved Phase Data – 2010

A programme of groundwater sampling and targeted chemical analysis was undertaken during the previous CSM following the installation of additional monitoring wells at the site.

At the time, eighty four (84) groundwater samples were collected from a range of wells, both existing and newly installed, following the development of new monitoring wells. Fifty-nine of the wells were from within the Middle Deposits, with the remaining twenty-five from within the Deep Deposits. On the basis of the previously defined pollutant linkage assessment, perched groundwater was not assessed.

Groundwater samples were analysed for the contaminants of concern previously defined:

- Naphthalene;
- Phenols;
- Benzene;
- o-Xylene;
- m/p-Xylene;
- Aliphatic C6-C8;
- Aromatic EC_{10}-EC_{12};
- Aromatic EC_{12}-EC_{16}; and
- Aromatic EC_{16}-EC_{21}.

The collection of this information allowed for a discussion of contaminant distribution within both middle and Deep Deposits.

Consistent with the previous approach and in line with the previous Atkins work, WSP have identified concentrations of contaminants of concern that exceed 1% of the contaminant solubility as an indication of elevated contamination impact and the possible presence of residual or emulsified NAPL within the water column. This, in combination with the observations of NAPL within the monitoring wells was used to further discuss the potential for contaminant distribution across site.

Dissolved Phase Contamination within the Middle Deposits

Dissolved phase contamination distribution for benzene, xylenes, naphthalene, TPH aliphatic (C_6-C_8) and aromatic (EC_{10}-EC_{12}, EC_{12}-EC_{16} and EC_{16}-EC_{21}) were discussed within Table 4.7 below.

Table 4.7 - Summary of Dissolved Phase Contaminants of Concern – Middle Deposits

Contaminant	Commentary
Benzene	Benzene was recorded at concentrations above detection limits within thirty-four of the fifty-nine wells sampled in 2010. The maximum recorded concentration was 3,800ug/l within BH04/05B, located immediately south of S&L21, within the northern portion of the SRM lease area. Further elevated concentrations were recorded within WSP212, WSP221, AEAT08 (AE08/04), BH08/07M and WSP239, ranging from 1,200 to 2,200ug/l. The information suggests that elevated benzene concentrations exist within the Middle Deposits across much of the former Tar Distillery site, and extending in a north-easterly direction into SRM leased land, with concentrations identified to be highest within the centre and east of the SRM lease area. The distribution of benzene concentrations indicated that the elevated dissolved phase concentrations correlate with either locations of on-going NAPL dissolution within the Middle Deposits associated with pooled NAPL, or to migration of dissolved or buoyant NAPL with groundwater flow in a north-easterly direction.
Xylenes	Dissolved phase analysis did not record elevated xylene contamination, with only six monitoring wells identifying xylene above detectable limits. The maximum recorded concentration was 960ug/l within AEAT08 (AEA08/04). BH04/05/B recorded a concentration of 520ug/l and WSP239, adjacent to Bank Dole Cut recording 510ug/l. WSP237, to the north of the canal recorded a reduced concentration of xylene at 90ug/l. Comparison to historical data suggests that these concentrations are much reduced from previous investigations in 2007, where concentrations of up to 3,300ug/l were observed in a number of central and eastern locations (including BH10/07M).

Contaminant	Commentary
Naphthalene	Naphthalene was recorded at concentrations above 1% of the solubility limit in eighteen locations, with a maximum recorded concentration of 14,000ug/l identified within BHQWM2 on the western boundary of the Croda site, adjacent to the CEMEX operations. Consistently elevated concentrations were observed beneath the footprint of the former tar distillery with BH04/07M and WSP216 both recording concentrations of 13,000ug/l and WSP201 and WSP219B recording 10,000ug/l. The spatial distribution is consistent with the findings of the initial CSM review and suggests that the majority of elevated contamination is restricted to the tar distillery site, with only BH02/05B to the south, BH04/05B and WSP202 in the north and BH10/07M in the east recording slightly elevated concentrations, albeit an order of magnitude lower than concentrations within the tar distillery site. The concentrations observed within the main area of impact were consistent with those identified within historical investigation and suggest that a distinct source of naphthalene, potentially associated with NAPL, exists in this western area and potentially from within the CEMEX site. The distribution of naphthalene within the Middle Deposits corresponded closely to locations of either pooled free phase NAPL within the Middle Deposits, or to buoyant NAPL migrating with the predominant groundwater flow direction, both of which are related to contamination associated with former tar storage or refining source areas in these areas.
TPH	Petroleum hydrocarbon fractions were recorded at varying concentrations within the Middle Deposits. *Main Site* TPH Aliphatic EC_6-EC_8 was restricted in its spatial extent, observed within the western portion of the former tar distillation site (WSP217, WSP214 and BH05/07M), where the maximum identified concentration was 330ug/l. Similar concentrations were recorded in the vicinity of the effluent treatment plant, at a maximum concentration of 420ug/l (WSP207), with two slightly elevated concentrations in the eastern portion of the Cell 2 extension area, at 110ug/l (TW41). TPH Aromatic EC_{10}-EC_{12} was observed to be widespread in spatial extent and within the western portion of the site, broadly correlating with the observed distribution of naphthalene, correlating with the molecular structure of naphthalene, which is a C_{10} aromatic compound. Peak concentrations have been identified in BH02/07M (21,000ug/l) and BH04/07M (27,000ug/l), with a consistently elevated zone spanning the entire tar distillery site extending north-eastwards through the Cell 1 and Cell 2 remediation zones. WSP239, adjacent to Bank Dole Cut and outside the Croda site boundary recorded a concentration of 15,000ug/l. Toward the north-eastern extent of Cell 2, broadly on the boundary of the Croda site boundary, concentrations appear to reduce by roughly an order of magnitude, with monitoring wells within this area all exhibiting reduced concentrations. Heading north-eastwards, BH04/05B recorded a concentration of 18,000ug/l, with WSP231 and WSP236, both to the north of Stocking Lane outside the Croda boundary recording concentrations of 13,000ug/l respectively. A further area of impact was identified in the vicinity of Tar Well RB1, with WSP222, BH10/07M and AEAT08 (AE08/04M) recording concentrations between 13,000 and 29,000ug/l respectively. North-east of this area, 11,000ug/l was recorded within WSP225, to the north of the SRM storage area. Dissolved phase concentrations of TPH EC_{12}-EC_{16} and EC_{16}-EC_{21} Aromatic fractions all exhibited a similar spatial distribution to TPH EC_{10}-EC_{12}, with elevated concentrations of each fraction detected throughout the Croda vacant land, and extending to the north of the SRM lease area. The area of depleted concentrations on the Croda/SRM boundary is not repeated with these heavier hydrocarbon fractions. With consistently uniform concentrations being observed throughout this area, extending toward BH04/05B. It is noted that continued contamination is observed to the north of Stocking Lane, within WSP231 and WSP236. *Bank Dole Lock* TPH Aromatic EC_{10}-EC_{21} were observed in elevated concentrations within the four monitoring wells to

Contaminant	Commentary
	the north of Bank Dole Cut all recording aromatic hydrocarbon concentrations broadly in line with those observed within Cell 1 and Cell 2 on the tar distillery site. EC_{10}-EC_{12} Aromatic hydrocarbons were identified at 9,000ug/l within WSP237, a similar concentration to that recorded within the Cell 2 area. EC_{12}-$_{16}$ and EC_{16}-$_{21}$ aromatic TPH all indicated similar distributions and concentrations in the Bank Dole Area, consistent with the field observations of NAPL presence within the Middle Deposits observed during drilling.
Phenol	Monohydric phenol contamination was observed to be widespread within the majority of the western portion of the site. The distribution of the contamination follows a similar pattern within the area to naphthalene and aromatic hydrocarbon fractions. However, it is noted that more significant contamination is observed toward the south of the tar distillery site, within the SRM operational site. BH02/05A recorded a concentration of 980,000ug/l and WSP220, 30m west, recorded a concentration of 380,000ug/l. Concentrations recorded in the Croda vacant area were consistently elevated, typically ranging from 20,000ug/l to a peak of 250,000ug/l within WSP216. Phenol concentrations alongside the northern boundary of the Croda site typically diminished from the peak although remain elevated and in excess of 1mg/l in each monitoring well to the north of Stocking Lane. A further 'hotspot' of monohydric phenol contamination was identified within BH04/05B, adjacent to the S&L21 tank, at a concentration of 93,000ug/l. However, borehole WSP203, immediately north of this location, identified a concentration of 390ug/l, suggesting that this impact was localised and potentially influenced by the presence of NAPL in BH04/05B. Additional phenol contamination was identified within the vicinity of the RB1 tar well, with AEAT08 (AE08/04M) and BH10/07/M recording concentrations of 14,000 and 23,000ug/l respectively. North-east from this area, further contamination was observed within WSP225 and to the north of the former tar settling lagoons, within WSP226, at 2,300 and 2,200ug/l. Dissolved phenol concentrations were greatly reduced within the boreholes to the north of Bank Dole Cut, with a maximum concentration of 790ug/l recorded in WSP234.

Dissolved Phase Contamination – Deep Deposits, 2010 Data

A review of the data for 25 monitoring wells installed within the Deep Deposits indicated dissolved phase contamination substantially reduced from those identified within the overlying Middle Deposits.

Generally, the results of deep groundwater analysis suggested that background and down-gradient concentrations of the contaminants of concern were low, predominantly below detectable limits. Contamination within the Deep Deposits appears to be limited in extent and recorded as localised instances only. The findings were summarised as follows:

- Naphthalene and Xylene were not recorded above detectable limits in any of the deep groundwater samples. Similarly, benzene was limited to three boreholes (WSP303, WSP307 and BH09/07D) all recording concentrations of 150ug/l.
- Phenol contamination was recorded at elevated concentrations within MW1A, with a concentration of 100,000ug/l. However, as with the aromatic hydrocarbons, boreholes local to elevated readings recorded concentrations three orders of magnitude lower, with WSP305, 30m east of MW1A, recording a concentration of 350ug/l and WSP304, 5m north of MW1A, at 80ug/l. Observations of NAPL within this deep borehole correlate with the results of the dissolved phase contamination and suggest that this may have influenced the results of laboratory analysis.
- To the north of Bank Dole Lock, BH101C recorded a phenol concentration of 970ug/l; again correlating with measured NAPL in this monitoring well.
- Peak aliphatic C_6-C_8 contamination was recorded within BH10/07D at a concentration of 390ug/l with ERM MW1A recording a concentration of 270ug/l and WSP303 at 160ug/l.
- Elevated concentrations of aromatic EC_{10}-EC_{12} were recorded within BH10/07D and MW1A at 21,000ug/l and 23,000ug/l respectively, with surrounding wells to the north and east, in the vicinity of the effluent treatment plant,

recording greatly reduced concentrations, ranging from 14ug/l to 370ug/l (BH09/07D). BH101C to the north of Bank Dole Lock, recorded an aromatic EC_{10}-EC_{12} concentration of 1,200ug/l, suggesting localised impact within the Deep Deposits in this area.

- Similar patterns were observed with heavier aromatic fractions, with BH10/07D in particular recording concentrations greatly in excess of 1% of the hydrocarbon solubility limit. Further evidence of impact was noted within MW1A and BH101C, with the latter recording a concentration of 4,500ug/l and 1,900ug/l of Aromatic EC_{12}-EC_{16} and EC_{16}-EC_{21} respectively.
- Contamination observed within BH10/07D is likely to be associated with pooled NAPL detected within the Deep Deposits at this location).

4.9 Additional Groundwater Sampling Assessment, 2011

Introduction

Following the completion of the previous extensive groundwater sampling exercise discussed above, key conclusions were drawn on the basis of the dissolved phase contamination identified.

It was apparent from the data gathered that dissolved phase contamination within the Middle Deposits was significant and reflected the presence of NAPL within this unit. There was a strong correlation between the presence of former known sources, identified NAPL and hydrocarbon impacted soils and dissolved phase contaminants.

Furthermore, the results of the dissolved phase sampling within the Deep Deposits confirmed that the impact to this groundwater unit was greatly reduced, with localised contamination associated closely with the presence of NAPL and also down-gradient of locations where the Middle Clay was absent.

Rationale for Further Sampling

Further monitoring wells have been installed within discrete locations at the site, including wells within the Middle Deposits and the Deep Deposits. The intention of these wells has been to:

- Refine the groundwater model, the outputs of which have been discussed within Section 4.0.
- Provide information on the extent of peripheral groundwater contamination at the site
- Assess aquifer geochemistry in areas not impacted with NAPL to aid the consideration of natural attenuation processes for dissolved phase contaminants.
- Benchmark possible impacts from additional site processes such as the SRM solvent recovery operations.

Additional Groundwater Sampling

Following the development of the newly installed wells, groundwater sampling was undertaken on the 3rd August 2011. Prior to sampling, each well was assessed for water quality parameters using a YSI handheld multi-parameter probe linked to a sealed flow-through cell to reduce turbidity and equalise dissolved oxygen content. Groundwater from each well was passed through the flow-through cell containing the probe and real-time measurements of groundwater quality were taken.

The results of the field-testing are presented within Appendix D.

Sampling was undertaken using low-flow methodology in line with the previous sampling event and samples were submitted to Alcontrol laboratories for analysis.

2011 Dissolved Phase Contamination within the Middle Deposits

Dissolved phase contamination distribution for the contaminants of concern area discussed

Table 4.8 - Summary of 2011 Dissolved Phase Contaminants of Concern – Middle Deposits

Contaminant	Commentary
Benzene	Benzene was recorded at concentrations above detection limits within sixteen of the twenty wells sampled in 2010. The maximum recorded concentration was 5,370ug/l within WSP251, immediately adjacent to the east of the former S+L8 tar well in the former tar distillery. Further elevated concentrations were recorded within WSP252, to the north of the RB1-RB4 tar wells (3,570ug/l), WSP241, adjacent to the east of the RB4 tar well (4,220ug/l), WSP240, north of RB4 (2,270ug/l) and WSP244, CEMEX tar well. It is noted that each of these locations are in close proximity of a former tar well or tar deposition area (WSP252). Concentrations of benzene to the north of Bank Dole Cut were diminished, two orders of magnitude lower than those on the main site, with a peak of 36.6ug/l (WSP258). Groundwater within the down-gradient wells installed in the vicinity of the tar settling beds recorded a peak concentration of 30.7ug/l (WSP260), WSP259 was below detectable limits. These findings are generally consistent with those from the operational part of the site during the 2010 sampling event, suggesting that benzene contamination is relatively widespread within the Middle Deposits and broadly reflects the impact/presence of NAPL.
Xylenes	Xylene was recorded generally where benzene was identified. A maximum concentration was identified within WSP241 (2,050ug/l) to the east of RB4. Further concentrations in excess of 1,000ug/l included WSP240 adjacent to RB4 and WSP246 and WSP249, both within the CEMEX site. Xylene was recorded to the north of Bank Dole Cut, but at a maximum concentration of 162ug/l (WSP256), with WSP260 in the north-eastern corner of the site recording 25ug/l. Overall, the concentrations recorded during this event were generally slightly higher than the previous sampling events, although recognising that duplicate wells were not sampled at this event. The concentrations appear to be more in line with those recorded during the 2007 dissolved phase exercise.
Naphthalene	Naphthalene was recorded at concentrations above 1% of the solubility limit (1,900ug/l) in nine additional locations, totalling 27 including the 2010 data. The maximum recorded concentration from the additional sampling was 20,600ug/l (WSP240), with WSP244 in the CEMEX site recording a concentration of 19,600ug/l. Concentrations in excess of 10,000ug/l were recorded within WSP241, WSP246, WSP249 and WSP256, the latter to the north of Bank Dole Cut within British Waterways Land. The observed impact within peripheral areas such as WSP247 (up-gradient within the CEMEX site) and down-gradient locations in the vicinity of the tar lagoons was greatly reduced from the core impacted area within the main site. The identification of elevated concentrations within WSP240 and WSP241 confirms that localised impact from the former RB2 and RB4 tar wells is likely to have occurred as previous sampling of wells to the south of these features did not record naphthalene at detectable concentrations. The lateral extent of this contamination appears reasonably limited however, as previous data indicates limited easterly and northerly migration of this contamination with groundwater flow.
Additional PAH compounds	Following the review of PAH contamination and coal tar derived compounds earlier in this section, a review of the key identified contaminants has been undertaken: Phenanthrene: Recorded at a maximum concentration of 2,110ug/l (WSP244), with next highest concentration of 285ug/l within WSP240. No other wells exhibit concentrations in excess of 100ug/l. Fluoranthene: WSP244 recorded 576ug/l, with WSP240 recording a concentration of 61ug/l. All other locations were

Contaminant	Commentary
	less than 50ug/l, with the distribution of the most elevated results closely matching the presence of naphthalene. Acenaphthene: Slightly more elevated concentrations observed, but with consistent distribution to other PAH compounds. WSP244 recorded 1,320ug/l, WSP256 to the north of Bank Dole Cut identifying 479ug/l and WSP240 and WSP241 recording 398 and 386ug/l respectively. The identification of PAH compounds generally reflects the solubility and initial presence of each contaminant within the coal tar source. Naphthalene is the most soluble of the coal tar derived PAHs and would be expected to be present in greater quantities. Concentrations of other compounds generally decrease in line with their relative water solubility.
TPH	Petroleum hydrocarbon fractions were recorded at varying concentrations within the Middle Deposits. TPH Aliphatic EC6-EC8 was identified at 960ug/l within WSP244 within the CEMEX site, with additional boreholes in this area recording marginally elevated concentrations (WSP246 – 109ug/l). This fraction was also recorded within WSP240 and WSP241 surrounding RB4 at a maximum concentration of 380ug/l. TPH Aromatic EC10-EC12 was recorded in a large number of locations, with concentrations in excess of 1,000ug/l recorded in nine locations. The distribution of the contamination is consistent with the PAH compounds, which is reasonable based on the chemical composition of naphthalene and the other coal tar PAHs, that are generally C10 or C12 aromatics. Elevated concentrations were recorded within WSP256 to the north of Bank Dole Cut at a concentration of 3,880ug/l. Other wells in this area recorded contamination, albeit at reduced concentrations. Dissolved phase concentrations of TPH EC12-EC16 and EC16-EC21 Aromatic fractions continue to exhibit a similar spatial distribution to TPH EC10-EC12, with elevated concentrations of each fraction detected throughout the former tar distillery, extending westward into the CEMEX site, and extending to the north of the SRM lease area, with impacts noted within WSP240 and WSP241. In certain cases, the concentrations of the C12-C16 fraction are greater than the C10-C12 fraction, namely within WSP244 (13,800ug/l), WSP241 (5,770ug/l) and WSP240 (4,430ug/l). Concentrations of these fractions within the north-eastern area of the site were greatly reduced from the main site, with a maximum of 133ug/l (aromatic C12-C16) recorded within WSP260. WSP259, adjacent to the River Aire in Stocking Lane, did not record any hydrocarbon fractions above detectable limits.
Phenolics	Consistent with the soil assessment that was undertaken and discussed earlier, resorcinol, catechol and 2,3,5-trimethylphenol were not identified above detectable limits, with cresols, napthol, xylenols and phenols accounting for majority of phenolic contamination within groundwater at the site. Cresols: Peak concentrations were recorded within the western portion of the site (CEMEX), with WSP244 recording 74,900ug/l and WSP249 and WSP251 both recording concentrations in excess of 10,000ug/l. Further impacts were recorded within WSP240 and WSP241, both in excess of 10,000ug/l. Xylenols: Xylenols were more widespread in concentrations and distribution that cresols, with concentrations in excess of 10,000ug/l recorded in six locations, at a maximum of 38,900ug/l (WSP251). The observations were consistent with cresol however a further 'hotspot' of xylenol was recorded down-gradient with WSP260 to the north of the tar settling beds, at a concentration of 2,140ug/l. It is noted that no

Contaminant	Commentary
	observations of contamination were recorded within WSP259 and WSP261, toward the river from that location. Xylenol concentrations to the north of Bank Dole Cut were greatly reduced, with a maximum concentration of 180ug/l within WSP258. Phenol: Phenol was recorded in similar locations to the other phenolic compounds, with a maximum concentration of 37,200ug/l identified within WSP244 and further elevated concentrations within other tar well locations (WSP251, WSP240 and WSP241). The spatial extent of phenol was less than xylenol and cresol, with no recorded concentrations on Bank Dole Cut or within down-gradient areas of the site, in the vicinity of the tar setting beds.

Dissolved Phase Contamination – Deep Deposits, 2011 Data

A review of the data for 10 additional monitoring wells installed within the Deep Deposits indicated dissolved phase contamination substantially reduced from those identified within the overlying Middle Deposits, with the exception of impacts within two additional locations. The assessment included sampling of BHA, in the down-gradient location on the periphery of Willow Garth.

Broadly, the majority of boreholes indicated contaminant concentrations approaching background levels, with no to very limited impact identified within WSP318, WSP320, WSP321, WSP324 and WSP325 for each of the contaminants of concern. These boreholes are installed in up-gradient (CEMEX) and down-gradient (Bank Dole Cut and North-eastern) areas of the site. Measurable concentrations of contamination were recorded within the following locations:

- WSP316 (CEMEX tar well) – recorded marginally elevated concentrations of aromatic hydrocarbons and BTEX indicators, albeit at concentrations typically <10ug/l.
- WSP317 (North of RB2, SRM area) – elevated concentrations of aromatic hydrocarbons recorded, with 943ug/l aromatic C10-C12, together with BTEX and trace concentrations of phenolic compounds in this area. Limited PAH impact.
- WSP323 (South of canal, adjacent to former tar offloading point) – recorded elevated concentrations of phenols, including 21,900ug/l cresols and 15,000ug/l isopropylphenol. Elevated concentrations of naphthalene (15,700ug/l) and BTEX with and elevated concentrations of aromatic hydrocarbon fractions, with a total TPH concentration of 23,900ug/l.
- WSP322 (north of Bank Dole Lock) – recorded a similar quantum of contamination as WSP323, suggesting the migration of dissolved phase contamination may be occurring beneath the canal. The nature of the contamination is very similar to WSP323, with cresols, xylenols and isopropylphenol recorded in this location. Phenol was not identified in WSP322 and BTEX and naphthalene concentrations were slightly diminished but remaining elevated (7,690ug/l naphthalene).

The information suggests that across the majority of the site, groundwater conditions within the Deep Deposits remains relatively consistent with those identified during the previous groundwater sampling event. Peripheral and north-easterly areas record very low levels of contamination, suggesting that significant lateral migration of contamination is not likely to be occurring.

The results of analysis from the central-northern portion of the site, in the vicinity of Bank Dole Cut, suggest that localised impact of deep groundwater is occurring. It is known from geological and hydrogeological modelling that a potential direct pathway exists between the Middle Deposits and the Deep Deposits within the Cell 1 and Cell 2 area, and that further additional groundwater monitoring indicates that a component of northerly flow within the Deep Deposits is likely to be occurring beneath the canal.

The dissolved phase analysis indicates that the eastern area of the Bank Dole promontory, encompassing WSP322 and WSP323 to the south, are impacted with coal tar derived contaminants. Westerly migration of this contamination north of the canal has not been identified, with WSP321 not recording any evidence of contamination.

Additional Contamination

The results of chemical analysis for additional potential contaminants associated with solvent based operations did not record any contaminants in either Middle or Deep Deposit groundwater above detectable limits. The analysis included a full VOC suite, which incorporates chlorinated aromatics and chlorinated aliphatic compounds such as solvents and chemical intermediaries.

The results concur with the results of a similar exercise undertaken by Atkins in 2007 and confirm that the selection of coal tar derived contaminants of concern is appropriate for the site, with no evidence of any significant further contamination within groundwater at the site.

Groundwater Geochemistry and Preliminary Natural Attenuation Assessment

The results of geochemical analysis and aquifer condition surveying have been reviewed to determine the likely conditions at which the aquifer is likely to support attenuation of contamination. These results can be summarised below:

- Groundwater within the Middle Deposits is noted to be slightly basic in the westerly areas, trending toward acidic in down-gradient areas. This is possibly due to the historical use of lime and caustic soda in historical operations in the Cemex Land.
- Groundwater within the Deep Deposits is broadly neutral across the site.
- Redox conditions indicate a weakly reducing aquifer in both the Middle and Deep Deposits.
- Dissolved oxygen concentrations are low throughout the site suggesting either depletion through microbial activity or anoxic baseline conditions. Monitoring wells closest to the River Aire record slightly higher DO.
- Secondary indicator compounds suggest that contaminated zones indicate sulphate depletion, denitrification and nitrogen fixation processes could locally be occurring, notable within source zones. Evidence of ammoniacal nitrogen could potentially be skewed by the presence of ammoniacal liquors associated with unrefined coal tars.
- Iron and manganese indicators do not indicate clear trends, with localised but inconsistent observations of depletion (ferric iron) and proliferation (dissolved manganese(II)).
- Methanogenic conditions are apparent in source areas demonstrated by proliferation of dissolved methane. This is not restricted to the Middle Deposits, with the Deep Deposits recording significant concentrations in areas of contaminant impact.

The preliminary indicators suggest that there is some evidence for microbial degradation processes to be occurring within groundwater at the site. However, these patterns are highly variable and there are no clear trends. The presence of significant NAPL source in a number of locations, particularly within the Middle Deposits, will affect the clarity of these processes.

However, conditions within the Deep Deposits are likely to support processes relating to microbial degradation of residual hydrocarbons. As discussed in previous CSM reports, monitoring during the remediation will provide further evidence on degradation.

5 Updated Conceptual Site Model

5.1 Conclusions of WSP Works

Based upon the findings of works completed by WSP, this section summarises the key conclusions drawn and how these findings further inform the understanding of the conceptual site model.

5.2 Characterisation of Groundwater Flow and Surface Water Interactions

The recent site activities and monitoring have established an improved understanding of the hydrogeological regime.

Key conclusions are:

- Groundwater in the Shallow Deposits is concluded to be perched and not in direct hydraulic continuity with the adjacent surface waters, with no observed breakout within the canal or the River Aire.
- Groundwater in the Middle Deposits has been demonstrated to flow in an easterly direction parallel to the canal across the western half of the site and turns to the north east after the Bank Dole lock structure parallel to the River Aire. It is considered that groundwater in the Middle Deposits is likely to discharge to the Deep Deposits within the eastern portion of the site and may subsequently discharge to the River Aire, via the Deep Deposits 60m east of the lock structure. There is no evidence of flow towards any part of the River from the Middle Deposits. A proportion of the groundwater within the Middle Deposits will continue to flow in a north-easterly direction and the majority will converge with groundwater in the Deep Deposits in the north-east of the site. The significance of this potential pathway has been considered further within the DQRA, presented within Appendix I.
- There is evidence of potential leakage from the canal or the perched groundwater in to the Middle Deposits around the lock structure.
- Groundwater in the Deep Deposits flows northerly and north-easterly, becoming more northerly to north westerly in the eastern portion of the site and is considered to discharge to the River Aire within the confines of the site boundary (60m east of the lock). Locally, a component of groundwater flow in a northerly direction is likely in the vicinity of Bank Dole Cut.
- A component of deep groundwater flow is possible in an easterly direction and potentially extends below the river at a distance of 300m from the lock structure.

5.3 Contamination Migration Around the Bank Dole Lock Structure and across the Bank Dole Cut

Ground investigation work undertaken around Bank Dole Cut and Bank Dole Lock identified ground conditions broadly consistent with previous investigations. The Middle Deposits unit was identified at broadly consistent depths, with the base of the unit generally identified at an elevation of approximately 4.5mAOD.

Detailed assessment and studies of the structure of Bank Dole Lock confirm that the cill structure is present at an elevation of approximately 5.6mAOD, and although is physically able to provide a small connection, the hydraulic observations do not suggest any evidence for migration across this structure.

The main lock structure is deeper and is probably founded within the Middle Clay, with piles potentially extending beyond this into the underlying Deep Deposits and/or Roxby Formation.

With regards to NAPL migration, the base of the Middle Deposits rises from the site towards the River Aire providing further evidence that NAPL migration to the north in this area is very unlikely.

Ground investigations in this area recorded evidence of tar and hydrocarbon impact, with evidence of potential phase separated NAPL recorded within the Middle Deposits on either side of the canal. Groundwater monitoring has identified the presence of up to 760mm of NAPL within a borehole to the south of the lock (WSP223). No consistently measurable thicknesses of NAPL have been recorded on Bank Dole Lock itself. Dissolved phase monitoring has recorded elevated concentrations of the majority of the contaminants of concern on both sides of the lock, including within Deep Deposits on the northern side of the lock.

Investigations and assessment of steady state and pumped conditions have indicated that there is no evidence of a direct connection across the canal within the Middle Deposits, suggesting that the sheet piling is creating a barrier to connections across this feature.

Investigations on the northern side of the canal have recorded the presence of coal tar related contamination within the Middle Deposits, suggesting that impact of groundwater quality has occurred in this area. No measurable NAPL has been identified to date. It is possible that the contamination identified to the north of the canal may represent historical residual contamination that may have migrated prior to any sheet piling works acting to break this pathway.

River surveys did not identify evidence of tar seepages or hydrocarbon impacts along the River Aire or Aire and Calder Navigation within proximity of the site outside of the Croda interceptor.

NAPL has been recorded within one location immediately adjacent to the rear of Croda's interceptor on BWB land. On the basis that settled NAPL has not been identified within deep boreholes to the south of the lock and the canal, this is possibly a localised instance. However, evidence of hydraulic connectivity and dissolved phase groundwater contamination have been recorded within boreholes on either side of the canal within the Deep Deposits.

Conclusion:

- There is no evidence to support contamination migration in the Middle Deposits across the canal. , with evidence suggesting a hydraulic and physical separation preventing this from occurring. The observations of contamination on the northern side of the lock structure are likely to be historic remnants of migration that occurred prior to installation of sheet piles during the 20th century.
- There is a possibility of localised groundwater flow across this area to the north in the Deep Deposits.

5.4 Characteristics and Likely Distribution of NAPL

The WSP investigations have included characterisation of known NAPL impact together with the detailed investigation of suspected sources of NAPL (i.e. tar wells, tank farms etc) and installation of monitoring wells on down gradient boundary locations (Northern and Eastern boundaries).

Shallow Deposits

Field observations during the installation of a shallow dewatering trench (for remediation trials) and excavations associated with the tar well investigations indicates the presence of NAPL impacted perched waters within the former tar distillation areas. The dewatering trench was able to rapidly remove perched groundwater (indicating a finite source) and soil condition was observed to be less impacted than the removed waters.

Former tar wells, where investigated, have been demonstrated to be in reasonable condition, with no evidence of significant residual coal tars following the decommissioning programme in the 1980s/1990s. Hydraulically, these tar wells are likely to be predominantly isolated from Perched Groundwater and the Middle Deposits.

Middle Deposits

These investigations have confirmed the widespread occurrence of NAPL in areas of historical tar distillation and storage. The extent of impact has been further refined, with the total area likely to be impacted with NAPL now encompassing the majority of the former tar distillery, a portion of the CEMEX site, and an element of the northern portion of the SRM facility. Whilst data gaps exist in some of these areas, the understanding of ground conditions and historical sources is such that isolated areas are likely to form part of a larger impact.

The distribution and thickness of NAPL has been used to derive an estimate of 495m^3 of measureable NAPL within the Middle Deposits although it is possible that greater volumes could be inferred from field observations.

NAPL has been recorded in the Middle Deposits between the site boundary and the Bank Dole Cut and the Lock structure and NAPL is recorded in the monitoring well installed behind the Croda Interceptor (albeit installed in to the upper horizons of the Deep Deposits).

NAPL has been characterised as buoyant, being slightly denser than water and is considered to be present throughout the water column, although measureable quantities do accumulate within monitoring wells and there is apparent increases in

thickness of NAPL in areas where the base of the Middle Deposits deepens to form low points where dense NAPL could accumulate.

Deep Deposits

NAPL has historically been recorded in isolated deep monitoring wells (3 no.) although the number of deep monitoring wells, particularly in NAPL source areas is relatively limited. Recent monitoring suggests that only one location now records measurable NAPL.

Conclusion:

NAPL is present throughout the Croda site in the perched groundwater and the Middle Deposits from primary contamination sources such as tar wells, settling and depositional area and the distillery itself. Further investigations have confirmed that the CEMEX site, having formerly housed tar settling beds and a tar well, is also impacted.

The governing factor behind the distribution of NAPL within the Middle Deposits is considered to be the extent and location of the former tar well network (at least 10 no.) across the site.

There is not considered to be a significant remaining source of NAPL within the tar well structures; although some structures remain to be investigated.

5.5 Contamination within the Unsaturated Zone

Consolidation of chemical data for the unsaturated zone confirms the presence of elevated coal tar derived hydrocarbons in the unsaturated zone across the site. Concentrations do not vary significantly between the tar distillation site and the surrounding SRM and CEMEX leased land.

5.6 Dissolved Phase Contamination

A contemporary baseline of dissolved phase contamination within the Middle and Deep Deposits has been gathered as part of the WSP works, including recent sampling associated with the additional areas of study.

In general the dissolved phase concentrations are influenced by the presence of NAPL and emulsified NAPL within the water column, particularly in the Middle Deposits.

Conclusions:

- The baseline confirms that the Middle Deposits are heavily impacted with organic contaminants derived from coal tar distillation and this impact is also present on the northern side of the canal and the Bank Dole Lock. There is only limited evidence of significant dissolved phase migration outside of the NAPL impacted areas of the site and contaminant concentrations in the Middle Deposits are low along the eastern site boundary with the exception of WSP225 recording 11,000ug/l EC_{10}-EC_{12} Aromatic TPH and 2,300ug/l of Phenol.
- The principle exception to this is phenolic compounds, which are recorded at elevated concentrations in the southern portion of the site and outside of recorded NAPL impact.
- The Deep Deposits have been shown to be impacted with coal tar contaminants in the central northern portion of the site, to the south and north of Bank Dole Cut.
- Wider groundwater quality within the Deep Deposits does not suggest significant impact, with localised areas of dissolved phase associated with low levels of flux from overlying Middle Deposits.

5.7 Revised Conceptual Site Model

Introduction

Based on the consolidation of information from recent and historic assessments, the conceptual site model has been refined. A summary of the reviewed pollutant linkages is presented below in Table 6.1, 6.2 and 6.3, with the updated conceptual model presented in Figures 89, 90 and 91.

Table 5.1 - Revised Conceptual Model – Shallow Deposits Pollutant Linkages

Source	Pathway	Receptor	Comments	Pollutant Linkage
Soils Leaching to Shallow Groundwater Dissolved Phase Hydrocarbon in Shallow Groundwater	Lateral Migration via Shallow Deposits and Made Ground (illustrated on Figure 89 as key lateral migration pathway S1)	Canal	The canal is not in hydraulic continuity with Shallow Deposits and, where present, sheet pile wall along the southern canal bank will break this pathway.	Not present
		River Aire	Groundwater in the shallow deposits is not in continuity with the river, being 2.5 to 3.5 m above the level of the river. There has been no visual evidence of groundwater seepages emanating from the river bank to confirm any active linkage in this area.	Unlikely, and minor and insignificant
	Vertical migration of shallow groundwater to underlying Middle Deposits (via remnant historic structures or clay discontinuities – S2)	Middle Deposits	Investigation and characterisation of former tar well features has confirmed that historically, these are likely to have represented the most likely source of NAPL contamination within the Middle Deposits. Current condition suggests that these features have been decommissioned sufficiently to reduce the majority of residual contamination, with little evidence of a significant hydraulic link between the Shallow Deposits and the features themselves.	Historically present but minor and insignificant
NAPL	Lateral migration of NAPL within Shallow Deposits	Canal	No evidence for shallow groundwater in hydraulic continuity with canal. Physical barriers such as clay liner and sheet piling support this.	Not present
		River Aire	Groundwater monitoring has indicated that shallow groundwater levels are not likely to be in direct hydraulic continuity with River Aire (2.5 to 3.5 m above the river level). Furthermore, there is no evidence of direct free phase NAPL leakage from the bank of the River Aire to confirm this linkage.	Not present
	Vertical migration of NAPL via deep structures to Middle Deposits (S2)	Middle Deposits	The vertical pathway associated with the presence of former structures remains in place. However, local isolation of these features from Shallow Deposits and significant sources of residual contamination, limit the significance of this pathway. Locally, groundwater monitoring indicates areas of recharge to the Middle Deposits from the perched groundwater exist on the site.	Present but minor and insignificant

Table 5.2 - Revised Conceptual Model – Middle Deposits Pollutant Linkages

Source	Pathway	Receptor	Comments	Pollutant Linkage
Dissolved Phase	Lateral migration of dissolved phase and	Canal	The canal is not in hydraulic continuity with Middle Deposits as evidenced by the	Not present

Source	Pathway	Receptor	Comments	Pollutant Linkage
Hydrocarbons	buoyant NAPL contamination within Middle Deposits – shown on Figure 90 as key pathways M3 (and M10)		relative differences in water levels. This is likely to be due to the clay lining of the canal and the presence of sheet piling along the canal bank breaking any potential hydraulic connection between the canal and the Middle Deposits.	
		River Aire	Supplementary site investigation and detailed groundwater assessment has indicated the Middle Deposits are unlikely to be in direct connection with the River Aire. There is no evidence to support a pathway through the cill. The sheet pile walls along the southern side of the Bank Dole Cut terminate along the western corner of the Croda site providing a potential flow path for groundwater in the Middle Deposits. The pathway is however considered to be truncated by sheet piling on the northern side of the Bank Dole Cut and groundwater gradients confirm an easterly flow direction in this part of the site. In addition to the flow from the site, it is considered possible that the residual contamination recorded to the north of the Bank Dole Cut has been isolated from the primary sources of contamination on the main site by the sheet pile walls. Migration of this residual contamination in an apparent easterly direction (linkage M10) is likely be responsible for the contamination impacts noted at the Croda Interceptor, with groundwater flow regimes and hydraulic assessment supporting this conclusion. Thus whilst the interceptor is functioning correctly, there is no direct linkage to the river.	No evidence for presence, other than locally at *linkage M10) identified within Middle Deposits to north of Canal. Currently present due to malfunctioning of interceptor which was supposed to break this pathway.*
	Vertical migration of dissolved phase contamination from Middle to Deep Deposits	Deep Deposits and subsequently River Aire	Although a clay layer was identified between the Middle and Deep Deposits, which may afford protection to the Deep Deposits, there is potential for downwards migration via breaches in the clay. This has been demonstrated within the Tar Distillery site (Cell 1 and 2), where an absence of Middle Clay was recorded within eight monitoring wells in this location. Also known to occur	Present

Source	Pathway	Receptor	Comments	Pollutant Linkage
			elsewhere at the site. Hydraulic gradients may limit the vertical migration in to the Deep Deposits and high transmissivity in the Deep Deposits may mitigate any impacts or effects.	
NAPL	Lateral migration of pooled and entrained NAPL from sources in Middle Deposits towards River Aire – shown on Figure 90 as M2, and towards the river abstraction chamber (M4)	River Aire	NAPL migration from the tar distillery and NAPL source is likely to be controlled by the topography of the Middle Deposits, with NAPL migrating laterally with sloping topography until it collects and pools in low spots on the base of the aquifer. However, topography suggests NAPL from pooled areas is unlikely to migrate beyond the northern boundary due to topography and the sheet pile wall along the canal. Contemporary information suggests that local rising of the base of the middle clay along the northern boundary may provide a physical barrier to any pooled NAPL movement in this area. As there is no pathway in the middle groundwater directly to the River Aire, there is no evidence for a pathway for entrained NAPL directly to the Aire. It is deemed possible that the impacts to the north of the lock may be historic migration of contamination along an easterly flow path from contamination now isolated by sheet piling.	Pooled NAPL -Present – but Source Specific Entrained NAPL – pathway M2 and M4 not currently present
	Lateral migration of entrained NAPL from western area towards the River Aire (shown on Figure 90 as M9)	River Aire	The sheet piling along the northern canal embankment is deemed to break this linkage.	Absent
	Lateral migration of entrained NAPL from towards the River Aire (shown on Figure 90 as M10)	River Aire	Residual contamination in the form of dissolved phase and likely buoyant NAPL (presumably originated prior to installation of sheet piles) is present in the Middle Deposits on land north of Bank Dole Cut and this is considered to feed the Croda interceptor.	Present – only at M10
	Lateral migration of entrained NAPL from all remainder of source areas to the east via groundwater flow (M3 on Figure 90	Groundwater in the Middle Deposits at the eastern site boundary	There is the potential for eastwards migration towards the eastern site boundary with groundwater and NAPL movement trending towards the north east and potentially into the River Aire via the Deep Deposits.	Present, but NAPL not recorded in downgradient monitoring locations.

Source	Pathway	Receptor	Comments	Pollutant Linkage
	Lateral migration of pooled NAPL from all other areas on site. Area specific – refer to pathways M5, M6, M7, M8 on Figure 90	Middle Deposits	Some potential for pooled NAPL to migrate further to topographic lows, however requires changes to hydraulic gradient.	Unlikely to be present at current time
	Vertical migration of NAPL from Middle to Deep Deposits (Shown as D4 on Figure 91).	Deep Deposits	Although a clay layer was identified between the Middle and Deep Deposits, which may afford protection to the Deep Deposits, there is potential for downwards migration via breaches in the clay. Proven to exist within centre of site, in former tar distillery.	Present

Table 5.3 - Revised Conceptual Model – Deep Deposits Pollutant Linkages

Source	Pathway	Receptor	Comments	Pollutant Linkage
Deep Deposits				
Dissolved Phase Hydrocarbons	Lateral migration of dissolved phase contamination within Deep Deposits (D3 on Figure 91)	River Aire	The Deep Deposits are in hydraulic continuity with River Aire with groundwater assessment indicating flow in a north-east direction. Impacts in the Deep Deposits have been identified to the south and north of the Bank Dole Cut.	Present
NAPL	Lateral migration of pooled NAPL within Deep Deposits (D1 on Figure 91)	River Aire	The Deep Deposits are likely to be in hydraulic continuity with River Aire and therefore migration of NAPL to the River from the Deep Deposits is possible although the extent of NAPL within the Deep Deposits appears to be currently limited and restricted to only one location.	Unlikely to be present due to localised nature of NAPL within Deep Deposits.
	Lateral migration of entrained NAPL within the Deep Deposits (D2 on Figure 91)	River Aire	Where NAPL is present within the Deep Deposits, this has generally been observed to be localised in extent. Furthermore, elevated dissolved phase contamination within the Deep Deposits is restricted in proximity to the NAPL affected locations. Down hydraulic gradient wells have not recorded significant contamination that would suggest the presence of potentially entrained NAPL.	Unlikely to be present due to localised nature of NAPL within Deep Deposits.

5.8 Pollutant Linkage Assessment

On the basis of the linkage assessment, the following pollutant linkages presented in Table 6.4 are currently considered significant in order of priority:

Table 6.4 - Updated Pollutant Linkage Assessment

Pollutant Linkage	Present? Significant?
1) Source specific lateral migration of NAPL from Middle Deposits to River Aire	Source Specific and Limited Significance
General NAPL migration on the site is observed to occur through the movement of buoyant NAPL within the water column and also through accumulation and movement along the base of the Middle Deposits, with apparent increased thicknesses of NAPL within low points in the base of the Middle Deposits. *Bank Dole Cut (South)* Site investigation along the northern boundary confirms that NAPL is present within the Middle Deposits adjacent to the canal with visual evidence of impact in wells adjacent to the River Aire to the east of the lock, suggesting that NAPL migration is occurring as a buoyant phase within the water column. Whilst NAPL is identified on the southern side of the Bank Dole Cut and adjacent to the River Aire, there is limited or no connectivity between the River at this point and the Middle Deposits, which have been demonstrated to rise above the river level. *Bank Dole Cut (North)* The observations of NAPL on the northern side of the lock are therefore concluded to be either a relic of historical migration prior to installation of sheet piling along the canal. The NAPL appears to be limited to buoyant phase rather than measureable and appears contained by the interceptor. *Other Sources* Based on similar flow mechanisms, the following linkages may also exist: Flow of NAPL from the eastern areas of NAPL impact with the dominant easterly groundwater flow and then north easterly parallel to the River Aire or into the Deep Deposits and then towards the River Aire. Whilst this is feasible, the flow path is substantial from the identified sources and there is no evidence that NAPL migration of this extent has taken place. The primary issue therefore being dissolution of NAPL into the dissolved phase and subsequent migration within groundwater (Pollutant Linkage 2, 3 and 6). Flow of NAPL from the northern area of the site towards the river abstraction chamber where NAPL has accumulated within the chamber as a result of either groundwater ingress (with entrained NAPL) through the brick walls of the structure, or through a preferential pathway created by broken pipe work/pipe bedding material causing NAPL to enter the chamber.	
2) Vertical migration of dissolved phase contamination from Middle Deposits to Deep Deposits	Present
The hydrogeological information indicates that groundwater from the Deep Deposits is likely to discharge directly to the River, in an area approximately 60m to the east of the lock structure but also potentially to the north of Bank Dole Cut, where groundwater flow regimes have been identified. As part of the baseline groundwater monitoring exercise, contemporary dissolved phase contaminant data has been gathered for the Deep Deposits, which shows evidence of impact from the overlying primary sources or the Middle Deposits, particularly where the Middle Clay is absent, migrating north beneath the canal lock and in a north-easterly direction The pollutant linkage between the Middle and Deep Deposits is therefore confirmed and potentially material; although the impact is directly related to Pollutant Linkage 3.	
3) Lateral migration of dissolved phase contamination within Deep Deposits to River	Present

Pollutant Linkage	Present? Significant?
Aire	
Groundwater monitoring has indicated that groundwater within the Deep Deposits is likely to be in direct hydraulic continuity with the River Aire. Dissolved phase contamination has demonstrated that impact of this groundwater unit has occurred from NAPL and dissolved phase contamination. Where substantial impact has occurred, this has been influenced by the absence of the Middle Clay, in particular within the northern portion of the site. The DQRA has considered the migration of dissolved phase contamination within the Deep Deposits towards the River Aire. The DQRA predicts contaminants such as phenol, BTEX and aromatic hydrocarbons to exceed compliance criteria at the point of discharge. Dilution effects in the River Aire have been quantified as significant with dissolved phase naphthalene contamination arising from residual NAPL concentrations identified as the primary risk to the River Aire based on Level 4 dilution calculations.	
4) Vertical migration of dissolved phase and NAPL from Shallow to Middle Deposits	Present but significance is limited
Primary sources of contamination are present within the Shallow Deposits in the form of buried remnant structures associated with the former tar refining works, together with residual hydrocarbon contamination within soils and perched groundwater. Investigation of a number of primary historical sources (tar wells) have demonstrated that these are unlikely to represent a significant ongoing source of contamination and appear to be at least partially isolated from surrounding groundwater within the Shallow and Middle Deposits. These sources have historically contributed to on-going dissolved phase and free phase contamination within the underlying Middle Deposits through preferential pathways formed by remnant historic structures within the Shallow and Middle Deposits. Where this linkage feeds Pollutant Linkage 1 above in source areas, the linkage is material given the ongoing source of mobile NAPL to the Middle Deposits which can subsequently impact the river. However, out with the identified NAPL sources areas, it should be taken in context of the dissolved phase pollutant linkages.	
5) Vertical migration of NAPL from Middle to Deep Deposits	Likely to be present and significant
NAPL has been identified in the Deep Deposits in the form of free phase hydrocarbons in recovered aquifer materials, together with a recent measurable thickness of NAPL in one monitoring well (BH10/07/D). Given the presence of NAPL in the Deep Deposits, and the potential for breaches in the clay, it is considered that a pollutant linkage exists between the two aquifers. However, as lateral migration of NAPL to the identified surface water receptors is limited, this linkage is effectively providing an on-going source of dissolved phase contamination for Pollutant Linkage 3.	

6 Conclusions & Recommendations

6.1 Key Conclusions

Contamination

Through consolidation of historic and recent site investigation information, WSP have developed a detailed picture of the contaminant distribution on the site. Based on this process, the following conclusions are drawn:

- Soils on the site shows evidence of hydrocarbon impacts particularly around primary sources, although perched waters are concluded to be the primary impacted media with mobile contamination in the shallow horizons. Recent investigations and shallow perched water recovery trials observed the presence of NAPL within the perched groundwater.
- The presence of former tar distillation features such as below ground tar wells and tar settling and deposition areas are likely to be the main historical source of significant contamination at the site. In a number of cases, the sources have been addressed and potentially isolated and the significance of them is reduced.
- NAPL is present in the Middle Deposits across the majority of the former tar distillation facility originating from primary sources, with former tar wells presenting the major source of impact.
- NAPL is recorded beyond the site boundary adjacent to the Bank Dole Cut and the lock structure with further evidence of NAPL along the river bank between the lock and the river abstraction chamber. NAPL has not been recorded on the northern side of the lock (with the historical exception of one deep monitoring well immediately adjacent to the Croda interceptor).
- Dissolved phase contamination impacts with coal tar derived contaminants are widespread in the Middle Deposits, although these are typically restricted to areas of NAPL impacts and dissolved phase impacts reduce significantly outside of the NAPL impacted areas. Dissolved phase impacts are evident on the northern side of the Bank Dole Cut adjacent to the River Aire in both the Middle and Deep Deposits.
- NAPL has been identified in one isolated location in the Deep Deposits. Dissolved phase impacts are substantially reduced/limited with material elevations recorded within monitoring wells in proximity and down-gradient of areas where the confining Middle Clay is absent.
- Two river surveys have been conducted and these have not identified any visible impact to the River Aire or the Bank Dole Cut outside of the Croda interceptor.

Geological and Hydrogeological Regime

The geological conditions on site are also considered to influence the CSM. Primary features of note are:

- The absence of the Middle Clay in parts of the site, notably within the main NAPL source areas, particularly within the Cell 1 and Cell 2 areas, which may provide a vertical migration pathway into the Deep Deposits.
- The base of the Middle Clay rises towards the north and adjacent to the River Aire providing a potential physical barrier to gravity-fed NAPL migration.
- The Deep Deposits are shown to deepen in an east, north easterly direction and a possible channel is noted running in a north easterly direction along the eastern edge of the operational (SRM) facility.

A comprehensive programme of groundwater monitoring has been carried out over a 23 month period. This monitoring programme has confirmed the following groundwater flow regime:

- A layered sequence of groundwater bodies, with good evidence for leakage between perched groundwater and the Middle Deposits. There is less strong evidence for leakage between the Middle and Deep Aquifers, but the areas where the Middle Clay is absent as highlighted above, provides localised direct connection.
- Localised flow of the shallow perched groundwater is dominated by recharge. Groundwater heads are above those of the canal and there is no evidence for hydraulic continuity with the Canal or River Aire.
- Groundwater flow in the Middle Deposits is predominantly parallel to the canal and river within the western and central areas of the site. Evidence suggests that canal infrastructure such as sheet piling and the Bank Dole Lock structure are preventing northerly groundwater flow towards the River in this area;

- Groundwater flow in the Middle Deposits has a more north easterly aspect to the east of the site. However, flow is parallel to the River Aire, and pump tests, monitoring data and visual inspection of the River bank do not suggest any direct connection to the River;
- Groundwater in the Deep Deposits flows in a north-easterly direction, potentially discharging to the River Aire approximately 60m to the east of the Lock structure, supported by flow directions, strata elevations and pump test data. A local component of northerly flow is likely within the central part of the site, possible fed and governed by the absent Middle Clay in the tar distillation site.
- Beyond 300m east of the site, it is unlikely that the River intersects the Deep Aquifer.

Function of Bank Dole Cut and Lock

Detailed research in to the construction of the Bank Dole Cut and the lock has provided a clearer understanding of the function of these structures within the CSM:

- Sheet piling took place progressively during the 1940s, 1970s and 1980s and it is possible that contamination impacts on the northern side of the canal and lock maybe historic, occurring prior to the installation of the sheet piling.
- The canal is sheet piled along the northern boundary to depths of between ~7m and ~11m below ground and is likely to cut off groundwater flow within the Middle Deposits.
- On the southern side the canal has been sheet piled to depths of up to ~11m providing a potential barrier to northerly groundwater flow. This feature is further supported by monitored groundwater contours and flow paths, which continue to identify an easterly flow regime both to the south and the north of the canal.
- The lock construction details have been established and these confirm that the lock effectively seals the Middle Deposits with the exception of the cill which, according to archive information, is founded approximately 1m above the base of the Middle Deposits.
- There is no evidence of flow across the Lock.

Priority Pollutant Linkages

Based on this consolidation of site information and the developed CSM, the following are concluded to be the priority pollutant linkages requiring consideration within the remedial action plan:

1. Source specific lateral migration of NAPL from Middle Deposits to River Aire via the Deep Deposits (Fed by PL 4 and feeding PL2, PL3 and PL5).
2. Vertical migration of dissolved phase contamination from Middle Deposits to Deep Deposits (Fed by PL5).
3. Lateral migration of dissolved phase contamination within Deep Deposits to River Aire (Fed by PL2, PL3, PL4 and PL5).
4. Vertical migration of dissolved phase and NAPL from Shallow to Middle Deposits.
5. Vertical migration of NAPL from Middle to Deep Deposits (Fed by PL4 and PL1).

These pollutant linkages have been assessed within the DQRA, the full results of which are presented within Appendix I.

6.2 Future Data Requirements

A comprehensive CSM has been developed for the site to enable development of appropriate remedial objectives and supporting remedial action plan (RAP). As part of any future remedial works, consideration of the following further data requirements is recommended to validate the CSM:

- The British Waterways land to the north of the canal may now be isolated from the Croda site and represents a secondary source of residual contamination most likely to feed the impacts observed at the Croda interceptor. Derivation of remedial objectives and implementation within this area should be undertaken.
- In order to support the conclusions of the existing and future DQRA, on-going monitoring of surface water and selected groundwater installations is required throughout the remediation works.

WSP Remediation Limited

7 References

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(2) Investigation into Hydrocarbon Contamination in the Area of Bank Dole Cut, Knottingley – British Waterways. Report Reference: A71135, dated June 1997; [2]

(3) Site Investigation Report – Croda Hydrocarbon Ltd, Knottingley Site, West Yorkshire. Prepared by Golder Associates. Report Reference: 98528230, dated February 1999; [3]

(4) Site Investigation Report – Croda Hydrocarbon Ltd, Knottingley Site, West Yorkshire. Prepared by Golder Associates. Report Reference: 00525427, dated June 2001; [4]

(5) Phase I Report – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated December 2003; [5]

(6) Phase IIA Screening Report – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated March 2004; [6]

(7) Phase I/II Baseline Condition Survey Report - Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated May 2004; [7]

(8) Phase IIB Initial Characterisation report - Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated September 2004; [8]

(9) Phase III Groundwater Investigation Report - Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED48362, dated June 2005; [9]

(10) Outline Remediation Design – Interpretative Report – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by Atkins. Report Reference: 5040854, dated June 2006; [10]

(11) Site Investigation and Preliminary Environmental Risk Assessment – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by Atkins. Report Reference: 5040854_077_31635, dated October 2007; [11]

(12) Detailed Quantitative Risk Assessment (DQRA), Controlled Waters – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by Atkins. Report Reference: 5040854_077_31946, dated November 2007; [12]

(13) Technology Evaluation Report – Weeland Road, Knottingley. Prepared by QDS. Report Reference: 3447-01, dated January 2008; [13]

(14) Remediation Action Plan – Croda PLC, Former Coal Tar Distillery, Knottingley. Prepared by Atkins. Report Reference: 5040854_077_32250, dated February 2008. [14]

(15) Updated Conceptual Site Model: Croda Distillates, Knottingley, WSP, 2010 (Ref 2824.002)

(16) Stage 1 Technology Report: Former Croda Tar Distillery Knottingley, WSP, 2011 (Ref 2824-001 R001)

(17) Draft Remedial Action Plan, Former Tar Distillery, Knottingley, WSP, 2011 (Ref 2824.003.draft)

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(18) Guillen et al, Semi-Quantitative FTIR analysis of a coal tar pitch and its extracts and residues in several organic solvents; Energy and Fuels 6, 518-525, 1992.

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(20) Verification of Remediation of Land Contamination, Environment Agency, 2010 (Ref SCO30114)

(21) Model Procedures for the Management of Contaminated Land, CLR11, Environment Agency, 2004

(22) A Framework for Assessing the Sustainability of Soil and Groundwater Remediation, Sustainable Remediation Forum UK, 2010

(23) Cost and Benefits Associated with the Remediation of Contaminated Groundwater: A Review of the Issues, R&D Technical Report 278, Environment Agency, 1999

(24) Cost and Benefits Associated with the Remediation of Contaminated Groundwater: A Framework for Assessment, R&D Technical Report 279, Environment Agency, 2000

(25)

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APPENDIX 2

Remedial Action Plan – Former Tar Distillery, Knottingley

UNITED BY OUR DIFFERENCE

WSP

FORMER TAR DISTILLERY, KNOTTINGLEY

Remedial Action Plan (RAP)

03/06/2013

Revised: Revised: 2013-05-07

Confidentiality: Confidential

Quality Management

Issue/revision	Issue 1	Revision 1	Revision 2	Revision 3
Remarks		Regulatory Review		
Date	Draft for Comment	June 2013		
Prepared by	R Lewis R Pollock R Clayton	R Lewis		
Signature				
Checked by	S Mackay	S Mackay		
Signature				
Authorised by	R Clayton	R Clayton		
Signature				
Project number	2824.012	2824.012		
Report number		2824.012 RAP		
File reference				

Former Tar Distillery, Knottingley

Remedial Action Plan

03/06/2013

Remedial Action Plan (RAP)

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1 Introduction

1.1 Authorisation

This document has been prepared by WSP Remediation Limited (WSP) on behalf of Croda Distillates Limited (Croda) and sets out the proposed remedial action plan (RAP) for land at the former Knottingley tar distillery (**Figure 1**).

The RAP sets out the remediation philosophy, the remediation options, the remediation objectives and the core methodologies that will be applied during the voluntary land remediation programme instigated to address historical tar distillation contamination at the site.

The document also outlines proposals for the verification of the remediation works and follow up monitoring to demonstrate that the land remediation programme has achieved its objectives in line with the cost-benefit and risk based approach agreed with the lead regulatory authority.

1.2 Site Status and Proposed Phasing of the Remediation Works

The RAP has been designed based upon the findings of the WSP Conceptual Site Model (CSM) (Ref 1), which is summarised within Section 2 of this document, and assumes the continued use of the site for industrial purposes.

Historic tar distillation activities, which took place on the site between 1870s and 1990s, have resulted in contamination impacts to the underlying groundwater. Characterisation of these impacts has concluded that remedial action is required to address risks to Controlled Waters, namely the underlying groundwater and the adjacent River Aire.

Given the remedial works required, which will be discussed in detail within this document, it is intended to undertake a programme of voluntary land remediation to address contamination impacts identified to pose a potential risk to the water environment. For the purposes of this RAP, and in-line with previous documents produced, the Knottingley site is subdivided into the following areas and priorities. The subdivided areas are shown graphically as **Figure 2**:

Table 1 Summary of Land Areas and Priority Remedial Action

Land Owner	Site Area	Priority	Comment
Croda Distillates Limited (Croda)	Vacant Land	High	Site characterisation has established the bulk of the contamination source resides in this area resulting from the former tar distillery operations. Therefore this area remains a priority for remedial action. The site is currently vacant.
	Tradebe Tar Legacy Areas	High	Tradebe operate a permitted solvent recovery facility at the site however tar distillation impacts have been identified within portions of the site and will be subject to remedial action as a priority.
	'CEMEX' Site	Medium-High	This portion of the site housed historical tar distillation activities. For a number of years, an aggregates batching and coating facility operated at the site and these operations ceased in early 2012. Tar distillation impacts have been identified within groundwater together with a discrete area of shallow gas oil contamination within perched groundwater. This portion of the site is upgradient and is anticipated to be one of the first areas to commence remediation.

Land Owner	Site Area	Priority	Comment
	North East Land	Low	This area of the site lies between with the Tradebe site and Willow Garth to the north-east. The land is currently in a secure and vacant state and sits outside of the area of intended remediation documented within this RAP. Redundant tar settling beds are present within this area. This area of land does not require clean-up works under the proposed works detailed within this RAP.
	Willow Garth	Low	This comprises a nature reserve that has existed at the site for over 100 years. The site is currently stewarded by Yorkshire Wildlife Trust and has not previously housed any industrial activities. This area of land does not require clean-up works under the proposed works detailed within this RAP.
	Agricultural Land	Low	Land to the east of the Tradebe Site and the south of Weeland Road is currently leased to local farmers. This area of land does not require clean-up works under the proposed works detailed within this RAP.
Canal and River Trust (CaRT)	CaRT Land	High	Historic contamination has been recorded on this area of third party owned land (although access to the area to facilitate remediation is agreed between the two parties). A visible discharge of hydrocarbon impact is observed to the River Aire from a Tar Interceptor which is located on this land and the Environment Agency (EA) have stated that this on-going impact is to form an area of remedial action – this is subject to a separate RAP.

1.3 Scope of the Remedial Action Plan

This RAP covers the main Croda owned land associated with the former tar distillery operations, including the Vacant Land, former CEMEX Site and Tradebe Tar Legacy Areas, defined herein as '**The Site'**.

The CaRT owned land referenced above will be subject to a separate remedial action plan and will be presented under separate cover. This is not discussed further within this RAP.

1.4 Legal Context

The legal framework around which contaminated land in the UK is governed is via Part IIa of the Environmental Protection Act (1990), Section 57 (1995). The act, defines contaminated land for the purposes of Part IIA as:

'any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that;

(a) significant harm is being caused or there is a significant possibility of such

harm being caused; or

(b) pollution of controlled waters is being, or is likely to be caused.'

The 'suitable for use' approach underlies these objectives, and is based on the principles of risk assessment, including the concept of the 'pollutant linkage'.

In the event that there are unacceptable levels of risk posed by a site, a remediation notice can be served under the contaminated land regime introduced under Part IIA of the Environmental Protection Act 1990.

Voluntary remediation action on contamination resulting from historical activities can often anticipate future remediation requirements, especially where the site is not being assessed under Part IIA.

1.5 Voluntary Remediation

The remediation works proposed within this document constitute voluntary remediation and cover contamination legacies associated with historic tar distillation activities at the site. They do not cover the current on-site operations by Tradebe that are covered by permitted operations (i.e. the Tradebe Solvent Recovery operations)permit, as that effectively regulate contamination impacts arising from these processes and future remediation of such impacts, which are subject to legislation requirements associated with the Environmental Permitting Regulations (EPR, 2010).

An additional localised area of shallow historic contamination associated with the former aggregates coating and batching operations by CEMEX is also to undergo voluntary remediation within the former CEMEX site.

1.6 Regulatory Role and Liaison

The Environment Agency has taken on the lead regulatory role with regard to this site and has kept other regulatory parties advised where necessary. They have been involved in detailed review of the site conceptual model; the proposed clean up strategy discussions, the proposed end points of the remediation and the likely residual risk levels. A summary of these discussions has been prepared in the form of a Joint Position Statement, which sets out a jointly agreed remedial philosophy and strategy and is presented in full for reference as **Appendix D**.

1.7 Stakeholders

The following roles and responsibilities specific to and limited to remediation activities are anticipated for the remediation works:

Table 2 Roles and Responsibilities

Party	Responsibility
Client **Croda Distillates Limited**	■ Responsible party for ensuring that remediation works are carried out to address historic tar contamination ■ Appointment of appropriate parties with suitable qualifications and experience to undertake the works
Remediation Design and Implementation **WSP Remediation**	■ Provide a remediation design which meets the objectives of the remediation strategy ■ Provide a remediation design which can be implemented in a safe and controlled manner with due regard for the presence of existing infrastructure and the safety of the contractor and site users. ■ Design of Remediation verification strategy ■ Control of all remediation related site activities including subcontractors ■ Integration of remediation works with on-going operations ■ Preparation and implementation of the Environmental Management Plan (EMP) ■ Preparation of the detailed Method Statements for remediation activities ■ Deployment of specialist permits and licences ■ Preparation of a programme for the remediation works ■ Undertaking the remediation works ■ Sampling and analysis to meet the verification requirements ■ Remediation Verification Reporting
Site Operator **Tradebe**	■ Liaison with the remediation contractor with regard to programme and progress ■ Liaison with the remediation contractor with regard to health and safety responsibilities.
Regulatory Authority **Environment Agency**	■ Review and agreement of the Remedial Action Plan ■ Consultative party over the duration of remediation works. ■ Review and approval of Remediation Verification Report.
Former Site Operator **CEMEX**	■ Have agreed terms with the landlord to deal with residual contamination associated with their occupancy; ■ Have no further part in the discussions

1.8 Document Structure

This document is structured in the following way:

Table 3 Document Structure

Section 2	Presents a background to the site setting and findings from the site assessments undertaken to date.
Section 3	Presents the philosophy for the remediation strategy in light of the findings from the previous site assessments, the developed CSM and the Joint Position Statement (JPS).
Section 4	Presents the proposed remediation works.
Section 5	Presents proposals for verification of the remediation works and how quantification of the remediation objectives will be achieved. Presents proposals for groundwater monitoring during and after the remediation works.
Appendix B	Presents a detailed assessment of the remediation options for achieving the remedial objectives (Remedial Options Appraisal, ROA).

2 Site Background Information

2.1 Introduction

The WSP Document; 'Former Tar Distillery, Knottingley, Updated Conceptual Model, December 2011, ref: 2824.003 presents a detailed account of available background information pertaining to the site history, the contamination conditions and environmental setting of the site together with an appraisal of the risks presented by site contamination to controlled waters. The following sections provide a summary of this information.

2.2 Site History and Processes

The Knottingley site has an extensive history of tar distillation and associated activities dating back to the 1870s. The site was originally established as the Aire Tar Works which later expanded into the Stainsby and Lyon and Robinson Brothers Tar Works. These companies later merged with further entities to form Midland Yorkshire Holdings Limited (MYHL) in the 1960s. Croda International acquired MYHL and the site in 1975, which has remained in Croda's ownership since this time, with areas of the site leased to third parties as described in **Section 1**.

Tar distillation processes have dominated the site's history since the 19th Century, with crude coal tar imported by barge to site from local gas works and coking works. The tar was offloaded at a wharf on the Knottingley to Goole Canal adjacent to the site at Bank Dole Cut. Bulk tar was understood to be stored in below ground tar wells (of which ten have been identified to exist on site). The tar wells were brick lined and extended to depths of approximately 3.5 to 4.0m bgl. From there, the primary operation within the Croda land was the distillation of coal tar to form a range of finished products including bitumens, tars, creosotes, pitches, coatings and sealants. The operations resulted in a significant infrastructure of above and below ground structures associated with the manufacture and storage of tar related products.

At one stage, coal tar distillation occupied the majority of the site, however since the 1980s, these activities diversified to include aggregates coating (CEMEX Land) and solvent recovery (Tradebe Land). Section 5 within the CSM Report provides a summary of the known bulk storage facilities at the site.

2.3 Ground Conditions and Geological Setting

2.3.1 Geological Sequence

Several phases of intrusive ground investigation have been carried out at the site. These investigations have identified a geological sequence at the site which can be summarised as follows:

Table 4 Summary of Local Geological Succession

Strata	Description
Made Ground	Anthropogenic hard standing and reworked granular and cohesive soils associated with the construction of the tar operations. Made Ground was generally encountered to depths of around 2-3m bgl however this was locally deeper in areas of former tar wells and tar settling lagoons, extending to maximum recorded depths in excess of 4m bgl.
Recent Fluvial Deposits	Generally recorded in the northern portion of the site, comprising soft grey and green sandy clay. The average thickness was 1.2m however this was locally variable and extended up to a maximum of 2.8m thickness.
Vale of York Drift Deposits	*Alluvial Clay* - recorded as a stiff laminated grey/brown firm to stiff laminated orange brown sandy clay at an average thickness of 1.5m. This stratum was encountered at depths of between 1.4 and 4.1m bgl.

	Middle Deposits – recorded as a grey clayey medium to coarse sand. This grades to a silty fine sand toward the base of the unit. This has been shown to generally decrease in elevation and thicken toward the east and north-east, where maximum thicknesses of 5.9m have been identified. The average thickness of this unit is circa 1.8m. *Middle Clay* – recorded as a firm red brown slightly sandy clay, with an average thickness of 0.4m. This unit was notably absent in areas of the site, including an area in the north of the former tar distillation site. The Middle Clay is observed to thicken toward the north of the site and the River Aire and greater thicknesses were also observed in the southern, eastern and north-eastern areas of the site. *Deep Deposits* - grey sandy gravel and sands and gravels with a coarse sand and gravel content encountered to maximum thicknesses of 7.6m, generally thickening toward the east and decreasing in elevation. The base of this unit ranges from 4.35mAOD in the south-west to -5.307mAOD in the north-east.
Roxby Formation	Identified at depths between 6.5 and 13.8m bgl and recorded as a stiff to very stiff red clay. Limited penetration and investigation of this stratum has taken place due to its function as an aquitard.
Brotherton Limestone	Identified in one historical location only (ERM MW1), at 17.5m bgl described as a medium strong to strong limestone with thin interbeds of siltstone and mudstone.

2.3.2 Geological Interaction of Knottingley to Goole Canal

The Bank Dole Cut of the Knottingley to Goole Canal is located immediately to the north of the site and has existed since prior to the commencement of coal tar distillation at the site. A review of the construction and sheet piling records held by British Waterways suggests that various sections of the canal were sheet-piled at stages between the 1940s and the 1980s.

Records and in situ testing of these piles indicate that these piles extend to depths ranging from 5m up to 11m bgl on both the southern and northern banks of the canal, suggesting physical barriers may exist within the Middle Deposits within this area of the site.

Hydraulic assessment and time series data monitoring undertaken during the CSM indicates that groundwater within the Middle Deposits is hydraulically isolated by the canal, with no evidence of a link or pathway between groundwater to the north and south of the canal.

Groundwater within the Deep Deposits has been demonstrated to be unaffected by the presence of the Bank Dole Cut and sheet piling

Further detail is presented within **Section 2** of the CSM Report.

2.4 Groundwater Regime

Three discrete groundwater units, referred to as ‘Shallow’ ‘Middle’ and ‘Deep’ are present beneath the site. These units are distinct and generally separated by confining layers of clay and cohesive deposits within the stratified geology.

Shallow groundwater has been identified within made ground, trapped within former tar distillation structures and shallow granular soils. It is discontinuous in its extent and influenced by the presence of remnant features and former below ground structures such as tar wells. Monitoring, dewatering and trial pumping of this groundwater unit has confirmed the highly discontinuous nature of the groundwater and the way in which it behaves. The majority of shallow groundwater is located within the CEMEX and former tar distillation site and is analogous with areas of deeper made ground and former structures associated with the former tar distillery.

Groundwater within the Middle Deposits flows in a generally easterly to north-easterly direction. In the main portion of the site, the hydrogeological assessment concluded that groundwater will generally flow parallel to the River Aire and the canal. In the east, an element of groundwater may discharge to deeper groundwater and the River Aire although the majority of groundwater is likely to continue to flow toward the north-east where it is most likely to continue off-site and ultimately is likely to converge with the Deep Deposits. In areas where the Middle Clay is absent, groundwater flow may occur directly from the Middle to the Deep Deposits.

Groundwater within the Deep Deposits flows broadly parallel to the River Aire within the main and southern portions of the site, with a distinct northerly component of flow toward the River Aire. Northerly flow direction is observed in proximity of the Bank Dole Cut and in the eastern portion of the site, where a potential discharge zone has been identified approximately 70-80m east of the lock structure and within the northern portion of the site in the vicinity of the Bank Dole Lock. The elevation of the deep deposits and pump tests indicate that this unit is likely to be in continuity with the River Aire in this area.

2.5 Summary of Contamination

2.5.1 Soil Contamination

Soil and groundwater contamination has been identified to exist across the former tar distillation facilities. Soil contamination is generally restricted to Made Ground in proximity to bulk storage and process facilities. Heavy tar and hydrocarbon contamination has been identified within shallow soils and is evident at surface across the former tar storage and processing areas, in the form of saturated soils and tar residues.

Coal tar based hydrocarbons are the primary Contaminants of Concern (CoC) identified at the site, including:

- Naphthalene
- Benzene
- Xylene
- C6-C8 Aliphatic Hydrocarbons
- C10-C12 Aromatic Hydrocarbons
- C12-C16 Aromatic Hydrocarbons
- C16-C21 Aromatic Hydrocarbons

Assessment of the constituent components of the coal tar contaminants suggest that the coal tar is broadly characteristic of a low temperature coal tar derived from coking works and former gas works known to supply the site with raw coal tar.

In addition to the primary CoC above, it is acknowledged that further poly-cyclic aromatic hydrocarbon (PAH) and phenolic compounds are likely to be present within impacted soils and groundwater at the site.

2.5.2 Non Aqueous Phase Liquids (NAPL)

NAPL has been recorded within the Shallow Deposits, Middle Deposits and to a much lesser extent Deep Deposits, the majority of which is contained within the Middle Deposits. NAPL within the Middle Deposits has been identified to comprise a mixture of a more buoyant ‘creosote’ type product, with a density slightly greater than that of water and a more dense tar that has been identified as settled thicknesses toward the base of more permeable water-bearing strata. The mobile NAPL is not measured directly during monitoring works and is inferred from field observations, dissolved phase concentrations and the baseline recovery of NAPL throughout the remediation trials.

The mobile NAPL is considered more susceptible to lateral migration driven by groundwater flow. NAPL flow has occurred within the Middle Deposits, with evidence of NAPL identified away from the principal source areas (i.e. former tar wells).

The identified area of NAPL impact is presented within **Figure 3**.

NAPL has previously been recorded in three isolated locations within the Deep Deposits, one of which is located on the Bank Dole promontory to the north of the canal.

With the WSP Detailed Quantitative Risk Assessment (DQRA) (Ref: 2824.005 R02), characterisation of a number of NAPL samples was undertaken to establish the variance and distribution of contaminants within these NAPL samples. The results of this assessment indicated that the NAPL was broadly similar in nature across the site, with the exception of a sample collected in proximity of a former tar well, where the NAPL was recorded as a denser, viscous tar with a larger proportion of long chain hydrocarbons.

It was noted that the more short chain and soluble compounds such as benzene, toluene, ethyl benzene and xylene (BTEX) together with phenolics were recorded at low concentrations within the NAPL, suggesting that substantial dissolution of these compounds may have already occurred.

Simulation of theoretical dissolution of contaminants from the NAPL source identified six key contaminants and these were carried forward to detailed fate and transport simulation discussed within Section 2.5.5. These contaminants were:

- Total Petroleum Hydrocarbon (TPH) Aromatic EC10-12
- TPH Aromatic EC12-16
- Benzene
- Naphthalene
- Total cresols
- Total xylenol

2.5.3 Shallow Hydrocarbon Contamination at former CEMEX site

An additional minor area of shallow free phase hydrocarbons has been identified on the former CEMEX site. The signature of this contamination is clearly different to the bulk of the hydrocarbon contamination elsewhere at the site. It is characterised by the following differences:

- The TPH fractions recorded within the product are typically within the aliphatic C12-C21 range, with a lower proportion of aromatic hydrocarbons identified elsewhere at the site;
- the product is relatively unweathered, is lighter in density than water, and is present only in the shallow units;
- The contamination seems laterally hydraulically isolated with limited pathways for lateral migration.
- There appears little evidence for downwards migration or dissolution of this contamination at present.

Based on the forensic evidence from product sampling and typing, the former lessees CEMEX have agreed that this type of contamination was likely to be associated with their activities during the period of the lease from Croda. The previous lessors have also agreed that they should remove this contamination under the conditions of the lease relinquishment, and have reached an agreement with Croda so that the works can be undertaken alongside the other remedial works described herein. All primary sources and operations have been removed and demolished on this facility.

2.5.4 Groundwater Contamination

Baseline assessment has recorded dissolved phase contamination associated with the historic contamination principally within the Middle Deposits. The concentrations of the CoC are elevated, frequently above the theoretical solubility limit. The distribution of dissolved phase impacts broadly mirrors the NAPL impacted areas with significant reductions in dissolved phase concentrations outside of these NAPL impacted areas. The exception to this is phenol, which has been recorded in the southern portion of the site, outside of these zones. Dissolved phase contamination has been identified within the former tar distillation site, on the northern boundary of the Tradebe operated area and also to the north of the Bank Dole Cut Canal.

Dissolved phase contamination has also been identified within the Deep Deposits, albeit at greatly reduced concentrations compared to the Middle Deposits. Contamination has been identified in the northern portion of the site, down-gradient of the inferred area where the Middle Clay is absent, suggesting that dissolved phase contamination could be emanating from this area and migrating within the Deep Deposits.

On the basis of the CSM and groundwater regime (discussed below), the Deep Deposits is considered to be the critical groundwater unit for the historic contamination assessment.

3 Remediation Philosophy and Objectives

3.1 Conceptual Site Model and Drivers

The proposed remediation works are proceeding on a voluntary basis and in this respect Croda has acted proactively in pursuing a technically robust site investigation and risk assessment. WSP has, on behalf of Croda, liaised with relevant regulators in this respect. The Environment Agency (EA), who have agreed on the definition of pathways and receptors.

The agreed pollutant linkage which is to be addressed by the Land Remediation Programme and associated Clean up works is as follows:

- Ongoing migration of NAPL from the middle deposits to the deep deposits and the subsequent dissolution of contaminants from NAPL into the dissolved phase followed by migration and discharge in to the River Aire.

The agreement of the pollutant linkages to be addressed is only in the context of the ongoing use of site areas as defined above as chemical works, whether under lease or if purchased.

Additional refinement work has been undertaken with regard to very specific aspects of the CSM and includes:

- Modelling the risks from a declining source of contamination given that there is unlikely to be any further 'on-going release' into the soils. This is to evaluate the long term effects of residual contamination and the likely impact of these on the River Aire post remediation;
- Documenting the lines of evidence that relate to degradation of dissolved phase contamination, providing supporting quantitative inputs to the above.

The historic contamination comprises contaminants demonstrably different to those contained in the permit operated by Tradebe, and as the Tradebe site does not currently have an agreed baseline for its operations, it is suggested that the Conceptual Site Model which documents historical site contamination and the post remediation validation reports should act as a baseline for this operation to define its state of contamination including historic contamination attributable to Croda and its predecessors period of operation at the site.

This RAP primarily addresses a remediation strategy for active remediation for the agreed pollutant linkage above. For pollutant linkages concerned with the migration of dissolved phase contamination, reserve measures are proposed in the form of continuing assessment of significance (via monitoring and revalidation of the DQRA simulation assessment) However, no measures for the active remediation of dissolved phase contamination are proposed.

3.2 Planned use of the Site

It is assumed that the site will remain broadly within its current configuration with areas of vacant land remaining either vacant or utilised for industrial activities.

The different land areas and phases of the site are discussed within the JPS (**Appendix D**). It is anticipated that whilst the majority of the site is intended for continued industrial use, peripheral areas of the site may undergo separate divestment or consideration in the future.

With regard to the main portion of the site, continued industrial land use is the only end state for the site currently considered viable. It is therefore assumed that the only access and exposure to contamination on the site will be through on-site activities of the industrial workforce or unauthorised third party access.

3.3 Stakeholder Objectives

As part of the process to understand the individual stakeholder objectives, WSP has held a number of detailed stakeholder workshops with Croda, and a number of meetings with the Environment Agency. In addition, both Croda and WSP have engaged with Tradebe (the current site tenant).

The table below records the current understanding of all the stakeholder positions and objectives with respect to the project.

Table 6 Project Stakeholders

Party	Objectives	Confidence in Position
Croda Distillates Limited	■ Remediate land parcels with respect to Controlled Waters on a voluntary basis to the satisfaction of the Environment Agency.	High
Regulatory Authorities **Environment Agency**	■ Remediation of site on a voluntary basis to mitigate risks to controlled waters from identified Priority Pollutant Linkage.	High
Remediation Design and Implementation **WSP**	■ Design remediation objectives and criteria which meet the objectives of all stakeholders and allow a clear end point to the project. ■ Undertake a remediation project which can be implemented in a safe and controlled manner with due regard for the presence of existing infrastructure and the safety of the contractor and site users. ■ Design a remediation project which is sustainable, balancing environmental, social and economic benefits and impacts in the context of the project objectives.	High
Site Operator **Tradebe**	■ Minimise disruption to operations.	Medium

3.4 Remediation Philosophy

3.4.1 Philosophy

The CSM and DQRA (Ref. 1) have identified the priority pollutant linkage considered to require direct intervention (for NAPL contamination) as part of the land remediation programme together with additional verification and monitoring (for dissolved phase contamination). While the following strategy is proposed as far as is practicably possible to satisfy the statutory requirements with respect to land contamination, the strategy will focus on the delivery of a remediation approach that will ensure overall environmental protection within the context of practicability, reasonableness and sustainability and on that basis will adopt an iterative approach considering the cost and benefit of remediation works as the remediation programme progresses.

WSP completed a detailed remedial cost benefit assessment (CBA) as detailed within **Ref 9** which set out the objectives for proposed remediation and comprised a balanced assessment of a number of difference remediation scenarios. This CBA was supported by a remediation options appraisal (ROA) that examined the technologically practicable methods for the recovery of coal tar NAPL and the betterment of the site.

The current situation arises from a significant historical legacy of coal tar distillation and manufacturing, and is a direct consequence of historical practices in the industry. The current situation can be described in term of risk as follows:

- There is a significant volume of potentially mobile NAPL which is able to migrate towards the main receptor (River Aire) presenting a significant risk (**Primary Risk**);
- There is a significant volume of residual NAPL which is unlikely to migrate towards the main receptor (River Aire) but will act as a long term secondary source of groundwater contamination, which can then migrate towards the main receptor (**Secondary Risk**).

These risks are summarised formally in terms of pollutant linkages in the CSM and DQRA and in Section 2 of this RAP.

The philosophy recognises that there will be an end point, beyond which, it is not sustainable to deliver further betterment or NAPL recovery. In line with the latest guidance on the verification of remediation works (**Refs 2, 3 and 4**), this will be specifically recognised as the point where the net environmental, social and economic impacts of the ongoing product recovery outweigh any environmental, social and economic benefits of continuing the remediation activities.

This philosophy is proposed as a flexible, open and transparent framework whereby all stakeholders can buy into the end point decision for the remediation.

3.4.2 Objectives

In addition to the stakeholder views highlighted above, the land remediation programme has been appraised around a defined set of remediation objectives. This sets both technical and wider objectives for the remediation, allowing a structured appraisal process, which is both objective and transparent.

In the context of overall betterment, the primary remediation objective is reduction of recoverable and mobile NAPL which has been identified to act as a potential source of ongoing dissolved phase contamination and potential migration toward the River Aire. This primary objective of the remediation works will deliver mass removal and long term risk reduction to the primary receptor. Criteria to assess recoverability are developed further below. For the primary objective, it is recognised that it there will be an end point, beyond which, it is not sustainable to deliver further product recovery. Criteria for this are discussed in section 3.5 below.

Secondary remediation objectives are set as follows:

- To monitor and assess the potential significance from dissolved phase contamination, recognising the contribution of natural attenuation within groundwater. These will include assessing the mobility and risks from residual contamination following the mass recovery phase and the validation and refinement of the fate and transport simulation.

These objectives will reduce and control the potential risks associated with the identified pollutant linkages. Mass recovery has been shown to be practical and technically effective for this site, and remediation trials (**Ref 5**) have demonstrated that mass recovery is a flexible and viable approach.

3.4.3 Remediation Options Appraisal

A remedial options appraisal has been completed and is presented in **Appendix B**. Based on site conditions and constraints and the technical objectives presented above, the appraisal has identified a number of potential remediation technologies that could be employed at the site. Each method/technology has been rated using a qualitative scoring system against the headings below, in order to develop a total score and identify the most suitable remediation technology for the site.

- Cost
- Risk
- Timescale
- Applicability
- Technical Feasibility
- Effectiveness
- Sustainability

The conclusions of this options appraisal have been used to inform the remediation approach outlined in Section 5.

3.5 Remediation Criteria

3.5.1 Introduction

In light of the philosophy and objectives outlined in this section a set of technical and wider criteria have been developed to measure the performance of the remediation works within the realms of what is reasonable, practicable and sustainable. This section therefore lists the measures by which the success of the remediation will be judged.

3.5.2 NAPL (Contaminant Mass) Recovery - Baseline Criteria

Commencing in February 2010, WSP have undertaken a series of remediation trials to establish the rate of recoverable mobile NAPL from a trial cell (Cell 1) and assess the suitability of a series of NAPL recovery enhancements in accelerating the rate of mobile NAPL recovery and managing waste effluent streams (Ref 5). The trials have provided a baseline of information on groundwater pumping yields, groundwater reinjection rates, NAPL recovery rates, energy consumption, physical separation of NAPL once extracted from the ground and activated carbon consumption rates. During 2011, the trial area was extended to include a second trial cell area. (Cell 2)

The baseline trial has demonstrated that, with enhancements and hydraulic management through injection, it is technically effective and practicable to recover mobile NAPL from the Middle Deposits at a rate of between 0.07% and 0.15% per m3 of groundwater recovered.

The findings of the remedial trials indicate that to establish a recovery cell, an expected operational period to optimise development of permeability and porosity to allow efficient recovery of NAPL is expected to be in the order of 6 months.

3.5.3 NAPL (Contaminant Mass Recovery) Remediation Performance Targets

In light of the extended trial and evidence base, the following specific remediation criteria are proposed to inform the end point of remediation activities at the site:

Table 7 Proposed Lines of Evidence

Remediation Objective	**Target**	**Detail**
Mass Reduction	Line of Evidence 1: Recover mobile NAPL mass to an asymptotic recovery level defined as 10% of the baseline yield per cell.	The primary technical criteria for closure will be met when NAPL yields drop to below 10% of the baseline yield, for a period of 3 months. Remediation recovery will be set up in cells and each installed cell will be treated separately. As ground conditions vary greatly across the site, further evidence collected on yield for each individual cell will be used to inform the actual asymptote and hence closure point for each cell.
	Line of Evidence 2: Measure recovered NAPL on a cumulative basis per remediation cell.	The cumulative recording of recovered NAPL presents a secondary line of evidence that will be used to demonstrate where on-going NAPL recovery has reached an asymptote.
	Line of Evidence 3: Measure the mass of contaminant recovered in terms of NAPL and	The estimation of contaminant mass recovered will provide a secondary measure of the effectiveness of remediation activities and will be achieved through direct

Remediation Objective	Target	Detail
	dissolved phase contamination.	measurement of the mass of NAPL recovered by the system and through the estimation of mass of dissolved phase contamination recovered through groundwater abstracted and contaminant concentrations recorded in the effluent following NAPL separation.
	Line of Evidence 4: Measure settled NAPL thickness to establish that NAPL thickness is demonstrating stable or decreasing trends.	Baseline NAPL thickness monitoring will be undertaken within each remediation cell to benchmark settled NAPL thickness and provide an estimate of initial NAPL mass within each cell. Following demonstration of Lines of Evidence 1 and 2, rebound monitoring will be undertaken to confirm that NAPL (immobile) thicknesses are stable and not increasing.
Flexibility & Risk Reduction	Manage isolated occurrences of rebound within individual wells within a defined recovery cell on completion of NAPL recovery by assessing mobility and recoverability.	After closure of a NAPL recovery cell there is the potential for rebound of measurable NAPL within individual wells in a cell. Recovery tests on these individual wells will be undertaken to assess the potential for locally meaningful NAPL recovery to take place within the previously outlined parameters of practicability, cost and sustainability. This will include an assessment of the significance of NAPL contamination within the rebounding well to determine whether the NAPL is likely to be mobile and consider the overall risk reduction achieved in the cell.

3.5.4 Sustainability Criteria

In order to assess the sustainability of the remedial options and inform the ongoing consideration of cost vs. benefit (and to assist in defining the end point of the remediation system) a set of sustainability indicators are proposed by which the potential impact of remedial options and decisions can be considered against the definable benefit delivered by the remediation project. The philosophy follows that developed in work such as Eurodemo (**Ref 7**), where we compare the on-going benefit of the system (betterment), against the impact of the system as it is operational.

Work undertaken on this and other remediation projects recently has shown that indicators can be used to show quantitatively, where the activity of undertaking the remediation starts to dramatically outweigh the actual impact of the remediation system. This is where the remediation system is effectively running into diminishing returns and no longer sustainable. Indicators, in line with the sets proposed by SURF-UK (**Ref 4**), have been selected as follows:

Table 8 Summary of Sustainability Indicators

Group		Considerations/Applicability to Project
Environmental (E)		
E1	Air	Emissions from plant Emission as a result of energy consumption at effluent treatment plant (sewage treatment works) Emissions as a result of energy consumption and fuel use for vehicle movements associated with staff, waste

Group		Considerations/Applicability to Project
		movement (NAPL) and suppliers CO2 impact of overall project
E2	Soil and Ground	Suitability of ground for redevelopment and building – changes in geotechnical properties of site soils.
E3	Groundwater and Surface Water	Improvement to groundwater quality, improvement to River Water Quality
E4	Ecology	Not relevant
E5	Natural Resources and Waste	Impact on water resources
E6	Intrusiveness	Effluent generation
Social (S)		
S1	Human Health & Safety	Risk Management of site during remediation operations
S2	Ethical and equity	Polluter pays principle being upheld
S3	Neighbourhoods	Impact to neighbourhood during remediation operations
S4	Community Involvement	Not relevant
S5	Compliance with policy objectives and Strategies	Remediation is voluntary and in line with CLR11
S6	Uncertainty and Evidence	Sustainability data and long term monitoring data
Economic (EC)		
EC1	Direct Economic costs and benefits	Directly considered through cost benefit of project
EC2	Indirect Economic costs and benefits	Indirectly considered through value of land
EC3	Employment	Continued industrial use of the land
EC4	Gearing	Ability of project to unlock land for use in industrial context
EC5	Life span and project risks	Ability of project to meet long term risk management goals
EC6	Project flexibility	Ability of project to meet different land sale scenarios

Of the above, discussions with the stakeholder groups have highlighted the yellow areas which are considered to be key sustainability areas for this project, and therefore sustainability indicators will be set for each of these as follows:

Table 9 Summary of Sustainability Metrics to be measured during the Works

Affected Media		Quantitative Indicators to be measured for sustainability assessment
E1	Air	Impact - kg CO2 emitted (direct and indirect emissions)
E3	Groundwater and Surface Water	Impact - water abstracted from aquifer (m3)
		Benefit - Water reinjected to aquifer (m3)
		Benefit - Kg NAPL recovered from aquifer
E5	Natural Resources and Waste	Benefit - amount of recovered NAPL recycled (kg)
		Impact - volume of effluent discharged to sewer (m3)
		Impact – waste materials and soils disposed to landfill

Affected Media		Quantitative Indicators to be measured for sustainability assessment
		(tonnes)
S1	Human Health & Safety	Impact - Accident records and statistics of project
S2	Ethical and equity	No quantitative indicators set
S5	Compliance with policy objectives and Strategies	No quantitative indicators set
S6	Uncertainty and Evidence	No quantitative indicators set
EC1	Direct Economic costs and benefits	Impact - Direct Cost of Project
		Benefit - betterment delivered
		Benefit – revenue for suppliers
EC6	Project flexibility	No quantitative indicators set

The technology trial has established that a base yield of mobile NAPL measured as a percentage recovered /per m3 of groundwater abstracted can be measured.

For this level of defined benefit, it is proposed to measure the impact and benefits achieved by the system. The mass yield can be directly assessed against the impact of abstracting groundwater, direct costs, CO2 generation, waste generation, and activated carbon usage. The secondary benefits such as the proportion of NAPL recycled, and the amount of water re-injected into the aquifer will be directly compared with the impacts such as costs. Recording and presentation of this information will allow a transparent assessment of where the impacts of remedial action start to outweigh the benefits delivered and assist stakeholders reaching a transparent justification for system closure, in addition to the mass recovery based criteria presented above.

Direct cost benefit assessment will be used in conjunction with the above indicators to quantify the net environmental benefit of the project.

4 Proposed Remediation Work

4.1 Introduction

Based upon statutory requirements and the remediation philosophy outlined in Section 3, the strategy for the remediation of the main Knottingley site is the following key remediation objective:

- Remove recoverable mobile NAPL from the Middle Deposits.

Alongside the remediation objectives described above, it is proposed that groundwater monitoring from key wells will occur over the duration of the remediation works, both to measure the general performance of the remediation and to ensure that mobilisation of site contaminants is not occurring at unacceptable concentrations and/or presenting a risk to the River Aire; these are detailed within Section 5 of this report.

A further remediation activity to be carried out is the recovery of shallow LNAPL contamination within the former CEMEX site. Whilst this contamination has not been identified as an area of concern within the CSM, Croda wish to carry out remedial works to reduce the risk associated with this contamination.

4.2 Middle Deposits Groundwater Remediation

Following the remediation options appraisal and the Stage 1 Technology Trial (**Ref 5**), the remediation technology selected as the most appropriate for the recovery of mobile NAPL from the Middle Deposits for the site is concluded to be total fluids removal and hydraulic management through both the abstraction and re-injection of groundwater via a well-field installed across the areas of the site identified to be impacted with coal tar NAPL contamination.

The use of combined abstraction and hydraulic management has been proven to successfully recover mobile NAPL (coal tar and creosote) at the site and the use of both abstraction and re-injection enables the aquifer to be put under increased “stress” than abstraction alone enhancing migration of mobile NAPL toward abstraction wells. Furthermore at the point where NAPL recovery approaches asymptotic conditions and recovery operations are ceased, retardation forces upon the NAPL will exceed acceleration forces resulting in a stable residual NAPL plume.

The area of the site where groundwater remediation is proposed as part of the contaminant mass reduction works is summarised on **Figure 3**, which focuses on the previously identified areas of NAPL.

Wells will be installed within areas identified to be grossly contaminated with mobile NAPL with spacing dictated by access and below ground obstructions but installed nominally on a 12m grid basis. Wells will be screened across the full thickness of the Middle Deposits.

Each well is to be installed using 100mm nominal bore (NB) HDPE well screen and riser. The annulus around each well will be a minimum of 50mm and constructed using washed sand or filter media. Each well will be sealed across the clay layer separating the upper perched water bearing unit and the Middle Deposits with a bentonite seal to prevent any downward migration of perched groundwater.

The well field will be split into a number of cells surrounding known contaminative sources or identified impacts to allow a more accurate picture of quantities of fluids and hence contaminant mass recovered from defined areas of the site. Larger areas of NAPL impact will be subdivided with each operational cell typically comprising 20-30 no. recovery wells. The proposed well field layout incorporating the difference recovery cells is presented within **Figure 4**.

Groundwater will be abstracted from wells using pneumatically driven pumps capable of pumping fine silts, groundwater and entrained NAPL. The pumps comprise a cylinder with float activated discharge valve; the pumps are filled by gravitational forces and can be set to allow fluid ingress from the top of the pump, base of the pump or a combination of both. When the pump cylinder is full a float activated valve allows the ingress of compressed air to expel the water through an outlet pipe. This method of operation means that the pumps are both low shear and self-controlling.

Abstracted fluids will be transferred from the well field to the treatment plant via polyethylene header pipes, the pipe specification will be chosen so that the pipe burst pressure exceeds the maximum pressure attainable by the abstraction pumps.

4.3 CEMEX Site LNAPL Remediation

Investigation and characterisation of this area of the site within the CSM report identified the presence of shallow LNAPL contamination resulting from historic use of gas oil within the aggregates coating activities in this area.

LNAPL recorded within shallow perched groundwater beneath the hardstanding in the southern portion of the site will be addressed using a shallow fluid recovery system installed and operated as a standalone operation to the Middle Deposits recovery system

The installation of the remediation system in this area will comprise the formation of a number of shallow groundwater recovery sumps installed within shallow soils beneath the concrete slab. Hardstanding will be broken out in each location to allow the collection of perched groundwater and the installation of recovery pipework and pumps.

LNAPL and contaminated groundwater will be abstracted via the use of air powered top-loading pneumatic pumps.

Abstracted fluids will be transferred from the well field to a standalone treatment plant via polyethylene header pipes, the pipe specification will be chosen so that the pipe burst pressure exceeds the maximum pressure attainable by the abstraction pumps.

4.4 Treatment and Discharge of Contaminated Groundwater

Groundwater treatment will employ a number of processes sequentially prior to discharge to the aquifer and/or sewer:

- Gravity separation of Dense NAPL and silts
- Gravity separation of Light and buoyant NAPL (including the CEMEX site)
- Particulate filtration and carbon adsorption (as required)

Operation of the system to date has indicated that the majority (>95%) of the NAPL exists as DNAPL following gravity separation.

To enable quantification of recovered DNAPL from up to six consecutively operated cells the initial gravity separation will be undertaken by six lamella plate separators. DNAPL and silts collected in the hopper of these separators will be transferred in a batch wise operation from individual separators to corresponding gauging tanks prior to quantification and storage for disposal. The quantity of DNAPL collected in the gauging tank will be assessed after each batch of DNAPL is transferred allowing quantification of contaminant mass recovered from each cell as NAPL.

Effluent from the lamella plate separators will be transferred under gravity and combined at the inlet to the Oil Water Separator (OWS). Individual effluent sampling points will be provided on lamella outlets to allow sampling, analysis and quantification of contaminant mass exiting this first stage of the treatment process.

Within the OWS, a dissolved air flotation (DAF) system will be employed to encourage the flotation of oils and NAPLs hung in suspension within the separator. Effluent from the LNAPL separator will be transferred by gravity to a buffer tank prior to filtration.

Clarified waters will be pumped from the OWS to a UV inoculation tank. This is intended to reduce the microbial content of the effluent stream, the growth of which will have been encouraged by the DAF plant. From the UV tanks, the effluent will be passed through suitable particulate filters and granular activated carbon filters as required and dependent upon its destination (foul sewer or aquifer re-injection). The filtration flow-rate(s) will be controlled to match influent rates, ensuring maximum efficiency is attained, particularly from the activated carbon.

Water to be re-injected to the aquifer will be passed through both particulate and GAC filtration to ensure that injection wells do not become blocked and contaminant mass is not returned to the aquifer. Injection lines will be run in polyethylene and well heads will be equipped with automatic flotation cut-offs to ensure overtopping does not occur. The pipe specification will be chosen so that the pipe burst pressure exceeds the maximum pressure attainable by the injection pump. Injection flows to the wells will be proportionally controlled with feedback from either simple level controls installed in wells or the measurement of back pressure.

Water disposed to sewer will be treated to a sufficient level to meet discharge criteria as supplied by Yorkshire Water. Flow meters will be installed to monitor volumes discharged to both sewer and aquifer. The discharge instrumentation system will be MCerts accredited as part of the commissioning phase.

The process system will be contained in a bunded area capable of retaining at least 110% of the largest vessel. The system will be fully automated and safeguarded by suitable instrumentation including fail-safe interlocks should a fault condition occur that poses as risk to the operators, third parties or the environment.

Recovered NAPLs and oily sludges will be transferred from the process portion of the system to a NAPL handling area. The first stage of this is a silty NAPL handling tank. From this point, effluent will be pumped to a filter press to reduce the sediment content. From here it is pumped to a backwash filter plant which also handles backwash from the particulate filter.

Processed coal tar NAPL will be stored within IBCs within the NAPL handling area prior to disposal for recycling under suitable duty of care.

Due to the likely long-term installation and operation (>3years) of the system it will be designed to use efficient and energy saving devices and operational algorithms where possible to minimise its impact to the wider environment.

A schematic for the water treatment process is presented as **Figure 5** (process) and **Figure 6** (NAPL Handling).

4.5 Verification and Monitoring

In order to support the remediation strategy a verification plan has been prepared and is presented in detail in Section 5 of this strategy.

4.6 Further Contamination

During the remediation works there is potential for further contamination to be encountered. If such contamination is encountered, it will require delineation and characterisation. Furthermore, consideration should be given to whether the identified impacts warrant either further investigation works or remediation.

Any areas of contamination identified during the remediation programme will require reporting to the regulatory authorities with a clear record of the decisions made and the actions taken.

4.7 Permitting and Licensing

Where applicable, all necessary consents and licenses will be obtained from the appropriate regulatory body, prior to commencement of remediation works. The permit required will depend on the final design of the remediation and specific consents/licenses which may be required are:

Table 10 Anticipated Permitting Requirements.

Licence/Permit	**Details**
Environmental Permit	Issuing authority Environment Agency, application by Remediation Contractor through the client. Required under the Environmental Permitting Regulations to govern the water treatment process and the discharge of treated groundwater to aquifer.

Groundwater Abstraction License (Section 32)	Issuing authority Environment Agency, application by Groundwater Remediation Contractor through the client.
Sewer Discharge Consent	Issuing authority Yorkshire Water, application by Groundwater Remediation Contractor through the client.

5 Verification of Remediation Works

5.1 General Approach

The aim of the remediation works is to gain regulatory acceptance that the identified risks to controlled waters in the context of the land remediation programme have been satisfactorily reduced in line with the agreed remediation philosophy and JPS. The goal of this RAP provides one of several lines of evidence which may allow this conclusion to be reached.

The following provides a summary of the considerations for assessing the adequacy of remediation works. Some of these have been informed following consultations with the Environment Agency during the preparation of this document:

- The degree to which mass reduction through the removal of NAPL and groundwater containing entrained NAPL within the Middle Deposits has been achieved.
- The degree of contaminant rebound (if any) over an agreed period of post remediation monitoring following remediation works.
- Groundwater conditions within agreed remediation monitoring wells confirm that assumptions made as part of the DQRA are being met.
- Evidence has been gathered to demonstrate that natural attenuation within the aquifer is sufficient to deal with residual contaminant concentrations.
- Requirements for further remediation works to achieve increased environmental improvement have been discounted on the grounds of pollutant linkage assessment, cost, technical achievability/practicability or sustainability versus the benefit that will be gained.

5.2 Groundwater Remediation Criteria

In order to assess the success of the groundwater remediation, the following technical remediation criteria (RC) are proposed:

- The recovery of non-aqueous phase liquids from the Middle Deposits reaches its asymptote which will be defined as recovery reducing to 10% of the baseline yield.
- The mass of contaminant recovered in terms of dissolved phase and NAPL is deemed to represent an acceptable proportion of the overall contaminant mass within each recovery cell, as characterised at the baseline stage.
- Post remediation monitoring demonstrates that the plume remains stable or is declining i.e. there is no evidence of NAPL migration beyond the areas of treatment.
- The observed concentrations of contamination within the Deep Deposits are broadly in line with the parameters simulated within the DQRA and that no significant outbreak of contamination has taken place.

A proposed procedure for acceptance of the remediation works and closure of the land remediation programme is presented in Section 5.7.

5.3 Measuring Contaminant Mass Recovery

Contaminant mass yield will be measured using the following procedures:

- Through measurement of NAPL recovered on a cell by cell basis (to be transferred to a clarifying tank for measurement on a batch by batch basis) against groundwater abstraction rates measured through dedicated flow meters.

- Through dissolved phase concentrations recorded following the removal of NAPL from groundwater effluent streams against groundwater abstraction rates measured through flow meters.

5.4 Measurement of NAPL Recovery

5.4.1 Pre-Commencement of NAPL Recovery

Following the design and installation of the treatment cells, a baseline round of groundwater level and NAPL monitoring will be carried out within the NAPL source areas. The data will be used to benchmark initial source conditions and support the outline derivation of source area contaminant mass.

The results of this monitoring exercise will support the production of a baseline NAPL condition report, which will be used to benchmark the on-going performance of the recovery works. Further detail on this approach is presented within **Table 14** below.

5.4.2 During Remediation

Operation of the trial remediation system within Cell 1 and 2 demonstrated that monitoring of wells during operation required a substantial duration of downtime of pumping operations. In order to sustain improved performance and NAPL recovery, the monthly monitoring of individual wells is not proposed to be undertaken.

5.4.3 Post Remediation

Once the system recovery data within each remediation cell indicates that the primary remediation goal has been met, the remediation works will move into the validation stage. During this first phase of verification, groundwater remediation infrastructure will be retained at the site in case of further requirements for use based upon the verification results.

It is proposed that monthly monitoring of each remediation cell is undertaken to determine rebound conditions and the recharge nature of any residual NAPL entering the recovery well network. This will be undertaken for 3 months before a review is carried out to assess the case for cessation, recommencement of the NAPL recovery works or corrective action. These works will be carried out on a cell by cell basis with validation of each area being undertaken to close out that particular cell.

In the event of any significant rebound following the validation period, corrective action will be undertaken as detailed in **Table 14**.

5.5 Dissolved Phase Monitoring

5.5.1 Objectives of the Dissolved Phase Contamination Monitoring Plan

The pollutant linkage assessment and CSM identified key pathways and areas of the site where the migration of dissolved phase contamination has been calculated based upon ground characterisation and groundwater flow modelling. This is associated with the dissolution from NAPL source and subsequent migration via transport within groundwater flow.

DQRA was undertaken to determine the level of risk from residual contamination following the removal of recoverable and mobile NAPL and identified theoretical breakout concentrations in excess of water quality standards at the River Aire.

There is a requirement to continue to evaluate dissolved phase concentrations and review the significance of possible impacts and natural processes that mitigate these impacts and ensure that the assumptions and parameters adopted within the CSM and DQRA remain valid.

Groundwater monitoring will be carried out throughout the remedial works at the site; the objectives of which are as follows:

- Support and ratify the conclusions of the controlled waters DQRA, with emphasis on the critical pollutant pathways and providing verification that the DQRA parameters are valid;
- Demonstrate that the primary remediation objectives detailed within Section 4 are being met and groundwater quality within the Middle Deposits throughout the remediation and post remediation programme demonstrates that dissolved phase contamination remains acceptable within the framework of the DQRA and the CSM;
- Provide on-going information on groundwater quality in the Deep Deposits throughout the remediation and post remediation programme to demonstrate that the critical pathways within this unit remain of low impact;
- Gather supporting lines of evidence to demonstrate that natural attenuation is likely to be taking place within the Deep Deposits and contaminant plumes are stable, such that residual contamination remaining within the aquifer following the removal of recoverable NAPL will diminish in line with the DQRA conclusions.

The following section details the proposed approach to implementing this monitoring.

5.5.2 Proposed Groundwater Monitoring Network

Monitoring will be carried out across a network of wells established during the site characterisation works. The primary focus of the monitoring wells is to provide information on site groundwater condition and not to verify the performance of the source area remediation works.

The groundwater monitoring network will be focused on a series wells directly surrounding and down gradient of the key source areas; relative to the NAPL sources and remediation cells, and includes monitoring wells installed within the Deep Deposits only. The proposed network of Deep Deposits monitoring wells is presented in **Table 11** below and illustrated in **Figure 7**:

Table 11 Proposed Groundwater Monitoring Wells

Site Area	**Included Wells**	**Rationale**
Background	BH02/05A, BH07/05A, WSP309, WSP310, WSP320	Background general water quality from peripheral wells outside of the main remediation work area.
General Site Coverage (including Background)	WSP316, BH03/07D, BH09/07D, BH10/07D, BH11/07/D, WSP301, WSP302, WSP303, WSP304, WSP305, WSP306, WSP307, WSP308, WSP311, WSP312, WSP313, WSP316, WSP320, WSP323, BHD	Provide comprehensive information on the quality of the groundwater within the Deep Deposits during the remediation programme.
Down-Gradient Monitoring Wells	WSP314, WSP318, WSP321, WSP322, WSP324, WSP325, BHA, BHE	In addition to the existing wells in the down-gradient area, three further wells to be installed and included within monitoring network to verify and support the groundwater flow model and DQRA contaminant modelling. The additional wells to be installed toward the theoretical groundwater to river discharge zone to act as site boundary ‘sentinel’ wells.

5.5.3 Monitoring Programme

Prior to the commencement of groundwater remediation works, baseline groundwater data will be gathered from the proposed network of monitoring wells and will then be carried out on a quarterly basis during

remediation works. The results of the monitoring will be reported in line with the reporting programmes outlined in **Table 13** below:

5.5.4 Proposed Scope of Groundwater Monitoring

The wells detailed in **Table 11** above will be monitored and sampled for the following contaminants and determinants, based upon the contaminants of concern defined within DQRA.

Table 12 Proposed Scope of Groundwater Analysis

Purpose	Analysis
Contaminants of Concern	TPH Criteria Working Group (CWG), naphthalene, speciated phenols
Groundwater Conditions	Temperature, conductivity, pH, Oxidation-Reduction Potential (ORP), Dissolved Oxygen (DO).
Natural Attenuation Parameters	Alkalinity, Nitrate, Nitrite, Iron (II), Iron (III), Sulphate, Sulphide, Manganese, Dissolved Methane.

Sampling will be undertaken using low-flow methods (such as BS EN ISO 5667) using dedicated LDPE or Nylon sampling tubes installed within each monitoring well. In-line multi-parameter data will be gathered from the sample stream and samples taken only when groundwater parameters have stabilised.

5.5.5 Proposed Surface Water Monitoring

In addition to the proposed groundwater monitoring, surface water samples from the River Aire will be gathered during each sampling event throughout the remediation process and during the post remediation validation period. Selected locations will be sampled up-gradient of the site, at the theoretical discharge zone and down-gradient of the site.

Surface water samples will be analysed for the CoC defined within the CSM, and the results used to support the findings of the DQRA and provide information upon the presence or otherwise of any dissolved phase impacts to the River Aire. The locations of the proposed sampling points are presented on **Figure 7.**

5.5.6 Post Remediation Groundwater Monitoring

Running concurrent to the validation of the NAPL recovery works, monitoring will continue to support the long term assessment of dissolved phase impacts and the effects of natural attenuation.

The duration of post remediation groundwater monitoring will be established upon completion of the active NAPL recovery works but it is anticipated that monitoring will be undertaken on an annual basis.

5.6 Completion Reporting

A series of planned remediation and validation activities have been defined within this RAP document that will require reporting. Factual and where required interpretive update reports will be prepared and available for inspection by the regulatory authorities following each stage of the remediation works. **Table 13** summarises the proposed consultation stages with the Environment Agency, a checklist for reporting requirements is included as **Appendix C.**

Table 13 Summary of Proposed Regulatory Consultation

Milestone / Time period	**Information**	**Purpose**
Remedial Action Plan	This Document	Provide the remediation philosophy, overall aims and proposed

Milestone / Time period	Information	Purpose
		remediation methods
Remediation Method Statements *Issued not less than two weeks prior to remediation works commencing.*	■ Provision of the detailed groundwater remediation design. ■ Specific details of all permitting relevant to the remediation design. ■ Detailed health and safety information and requirements. ■ Detailed information and method statements for environmental controls during the remediation works.	Provide details and design/method statements relevant to all aspects of the proposed remediation works.
Groundwater Baseline Document *Issued following the installation of treatment wells and baseline sampling of the Deep Deposits monitoring wells.*	■ Surveyed location plan of all newly installed wells. ■ Baseline NAPL thickness. ■ Baseline aquifer geochemistry. ■ Identification of findings which significantly diverge from the current site understanding. ■ Baseline estimation of NAPL Mass.	Provides a document detailing the baseline conditions and from which the performance of the NAPL recovery works and the conclusions of the DQRA can be assessed.
Provision of Bi-Annual NAPL Recovery Reports	■ Report the mass of NAPL recovery during the reporting period ■ Report against environmental intensity and sustainability metrics. ■ Measure the performance of the remediation works. ■ Provide opportunity to review the efficacy of the remediation works and monitor when remediation asymptote may be met.	Allow on-going consultation with the regulators with the view to presenting the lines of evidence related to remediation performance and demonstration of continued performance of the remediation works.
Provision of Quarterly Groundwater Quality Reports	■ Report aquifer geochemistry & dissolved phase contaminant concentrations. ■ Provide update on hydrogeological regime.	Provide an update on the current aquifer conditions and compare against the baseline to assess DQRA conclusions and determine the requirement for a review of remediation objectives.
Single Event Reports	■ As built details ■ Factual information ■ Results of performance testing or validation data	Provide a record of any single event activities that were carried out during the remediation works e.g. those outside of the Middle Deposits NAPL recovery works.
Final Validation Document.	■ Provide factual account of all remediation works ■ Provide summaries of all groundwater monitoring data. ■ Provide interpretive assessment on NAPL recovery works, single event	To provide a summary of all works to date will allow the regulators to provide final comment on the success of the remediation works as a whole.

Milestone / Time period	Information	Purpose
	activities and natural attenuation and on-going protection of controlled waters	

This process of reporting will allow an open exchange of information throughout the duration of the project such that where potential issues are raised with any aspect of the works these can be resolved as the project progresses. The nature of this staged consultation will mean that little new information will be given within the final validation document and that broad agreement will have been reached on the success of the remediation works well in advance of the final validation report being issued.

5.7 Decision Process for Remediation Closure (RC)

Completion of groundwater remediation works will require supporting documentary evidence to demonstrate that suitable decisions have been taken over the duration of the remediation and validation works. These should demonstrate sufficient evidence to support the completion of the works and demonstrate that risks to controlled waters have been reduced in line with the agreed remediation objectives.

It is intended that closure will be sought on a “cell” by “cell” basis in accordance with the cells described in **Figure 4.**

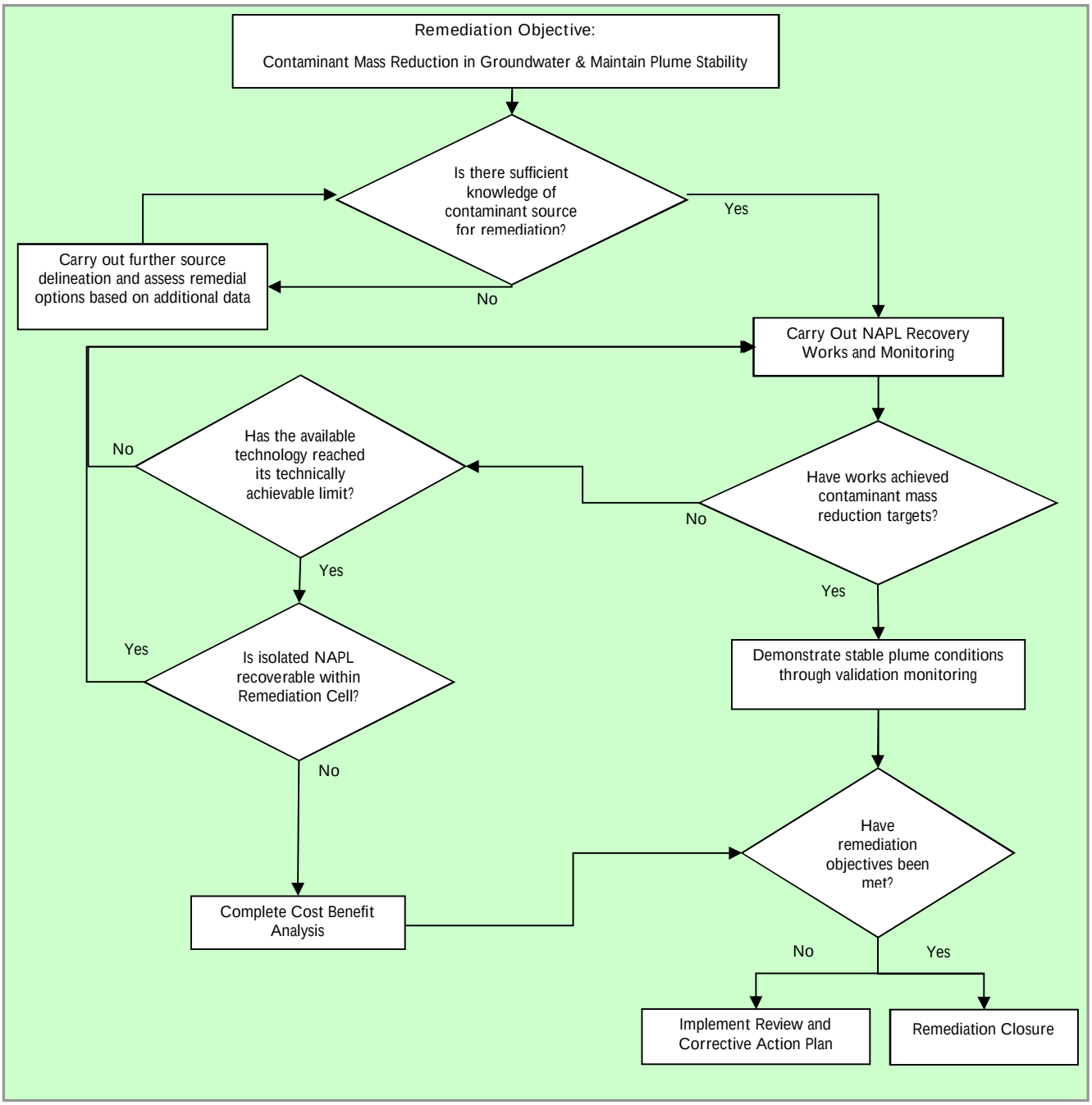
Where remediation works are progressing in areas of the site that are hydraulically up-gradient of the area submitted for remediation closure, such proposals will consider the requirement for prevention of future re-contamination with mobile NAPL.

The following decision process is suggested for demonstration that remedial objectives have been met and to facilitate acceptance of the works by the Environment Agency. Remediation works will progress until the following conditions apply:

- The remediation criteria (RC) are achieved.
- Where the RC are not met, a process of assessment and cost benefit review is carried out.
- Following completion of the remediation works, a review of the post remediation monitoring data confirms that the residual plume is stable and the residual risks to controlled waters are reduced to the satisfaction of the Environment Agency.

Plate 1 overleaf provides a decision matrix and process that will be used to plot the closure of remediation works or, in the event that the RC have not been substantively met, the actions that will be implemented.

Plate 1 Decision Process for Completion of Groundwater Remediation Works



5.8 NAPL Recovery Performance

On the basis of the operation of the trial remediation system, the operation of each recovery cell is anticipated to last for no longer than four years. Throughout the operational period, continuous assessment of the efficacy of the NAPL recovery will be measured against the established remediation criteria.

Following the establishment of a baseline yield within each cell, the following sequential hierarchy will be considered to support the objectives of the programme. NAPL recovery will continue until such point as:

1. NAPL recovery reaches the target of 10% of the baseline yield per cell;
2. suspected NAPL migration influence from neighbouring cells and hydraulic isolation is not maintained;
3. the evolution of NAPL characteristics has changed to a position where recovered NAPL becomes more viscous and less of a 'mobile' NAPL. Viscous tars could lead to difficulty in recovery and fouling of the treatment system;
4. if groundwater chemistry undergoes a significant change from an external influence that causes significant treatment issues over that currently designed for; and
5. an ongoing sustainability basis where costs exceed benefits of time of operation.

As part of the cost benefit and sustainability appraisal, a NAPL transmissivity (i.e. yield) assessment will be undertaken for a period to be agreed between Croda and the Environment Agency to assess the presence of residual mobile NAPL within each cell and define the assessment of whether further action or cessation of works is recommended. Reference will be made to standards adopted within the USA (Ref:11).

5.9 Corrective Action Procedures

A matrix of corrective actions has been developed and is summarised in Table 14:

Table 14 Correction Action Measures

Occurrence	**Corrective Action**	**Reporting /Notification Process**
NAPL is recorded at measureable thickness in monitoring wells outwith of defined remediation cells.	■ Assess spatial extent based on existing borehole network (monitor from other surrounding wells if not included within current monitoring network). ■ Where insufficient information exists implement further characterisation works. ■ Conduct product recovery tests. ■ Where recoverable product is measured during tests establish remediation cell in the defined area.	■ Progress Reports
NAPL rebound is recorded within remediation cells following cessation of NAPL recovery works.	■ Undertake product recovery tests on selected wells within a remediation cell. ■ Target NAPL recovery from isolated wells where NAPL yields exceed cell baseline vol/m^3 of groundwater abstracted.	■ Progress Reports

Occurrence	Corrective Action	Reporting /Notification Process
	■ Operate until the defined asymptotic conditions are achieved or cost benefit determines no further works required.	
Isolated increase in dissolved phase contamination.	■ Continue to Monitor	■ Monitoring Event Reports (quarterly)
Significant increase in dissolved phase contamination within monitoring well network.	■ Continue to monitor quality on a quarterly basis. ■ Continue for a period of no more than 6 months before programme is reviewed.	■ Notify EA in writing

At all stages, it is the aim of WSP to provide sufficient information to the Environment Agency to allow detailed discussion on the most appropriate site response.

5.10 Cost Benefit Assessment

Any cost benefit assessment carried out according to standard methodology to review remedial options and techniques that could be applied or considered at the site will be done so considering the following criteria:

- Estimated extent of contamination remaining;
- Estimated extent of contaminant mass that is recoverable;
- Risks presented by remaining contaminant mass;
- Technologies available to achieve contaminant mass removal;
- Constraints and limitations associated with continued NAPL recovery;
- Remedial objective;
- Timescales to achieve future objective;
- Impacts during the implementation of the remedial works; and
- Estimate of costs to achieve remedial objectives (to be compared against current costs incurred and contaminant mass removed at that point).

5.11 Regulatory Acceptance

Following submission of the final validation report for each area of the site (as per Table 1) and subject to the remediation objectives having been met, either directly or through evidence based assessment which can demonstrate that the site no longer poses a risk to controlled waters (in the context of the current land use), WSP and Croda would seek to gain written confirmation from the regulatory authorities that they accept this conclusion and that there would be no further action based on a continued use of the site.

Any such closure may be contingent on the continued monitoring of water quality within the Deep Deposits in line with the agreed post remediation approach.

5.12 Borehole Retention and Decommissioning

All available site boreholes will be retained within each remediation cell until the completion of the post remediation validation. Following the submission of the final validation report and acceptance of this report for

each cell consultations with the client and their advisors and the Environment Agency will be made over the decommissioning of some or all of the monitoring and injection wells.

Following agreement of all parties on monitoring wells which are no longer required, these wells will be decommissioned in accordance with Environment Agency guidelines.

WSP Remediation Limited

References

1) Updated Conceptual Site Model: Croda Distillates, Knottingley, WSP, 2011 ref: (2824.003)

2) Verification of Remediation of Land Contamination, Environment Agency, 2010 Ref: (SCO30114)

3) Model Procedures for the Management of Contaminated Land, CLR11, Environment Agency, 2004

4) A Framework for Assessing the Sustainability of Soil and Groundwater Remediation, Sustainable Remediation Forum UK, 2010

5) Stage 1 Technology Report: Former Croda Tar Distillery Knottingley, WSP, 2011 Ref: (2824-001 R001)

6) Framework for Sustainable Land Remediation and Management, D5-3, EURODEMO, 2007

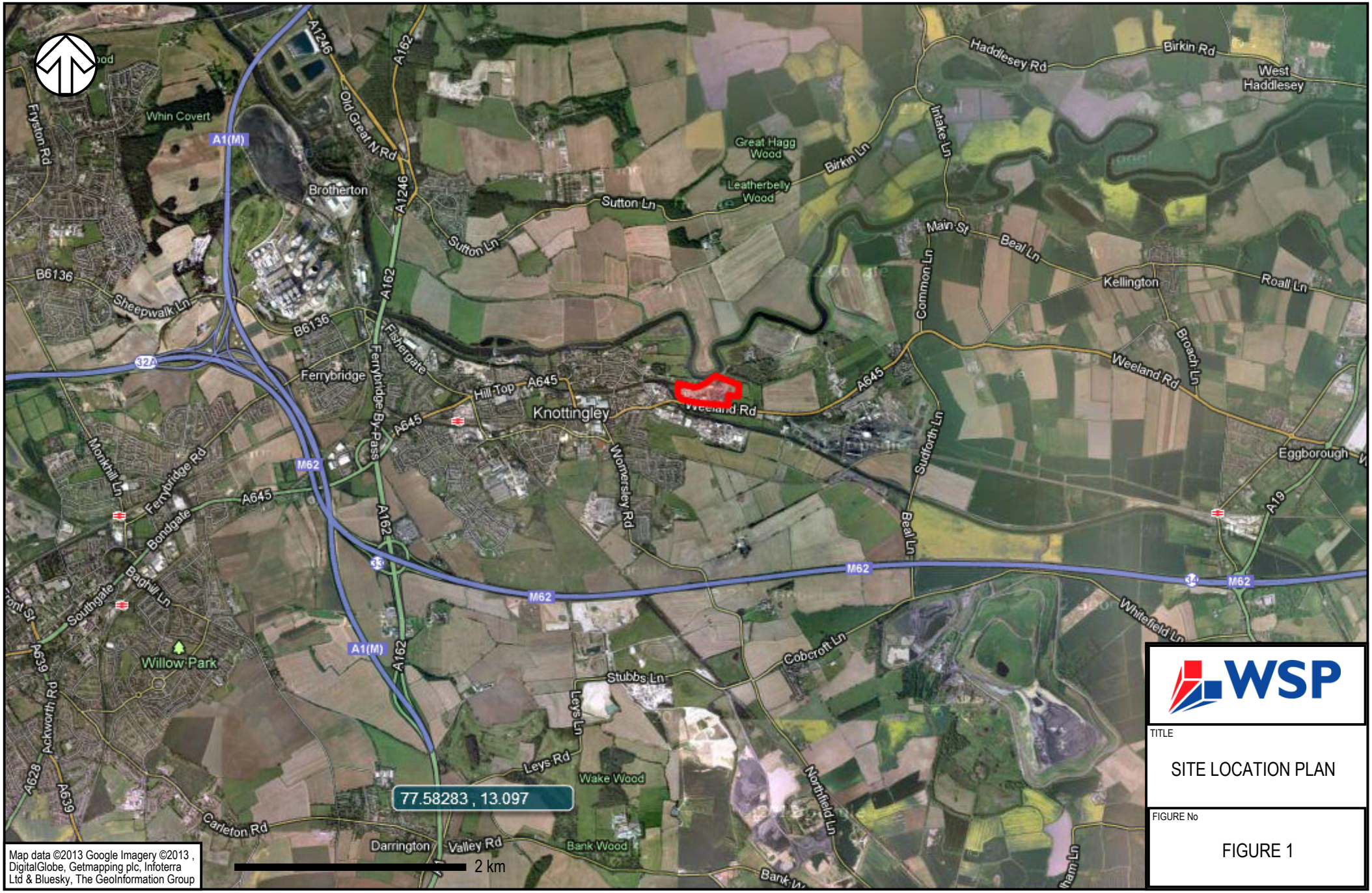
7) Environmental Efficiency Criteria, Report on Case Studies, D5-2, EURODEMO, 2007

8) Former Tar Distillery, Knottingley, Detailed Quantitative Risk Assessment, August 2012, Ref: (2824.005 R02)

9) Croda Distillates, Knottingley, Remedial Cost Benefit Analysis, WSP, January 2012, Ref: (2824.004)

10) Joint Position Statement (August 2012), EA + Croda International PLC).

11) ASTM E2856 - 12 Standard Guide for Estimation of LNAPL Transmissivity



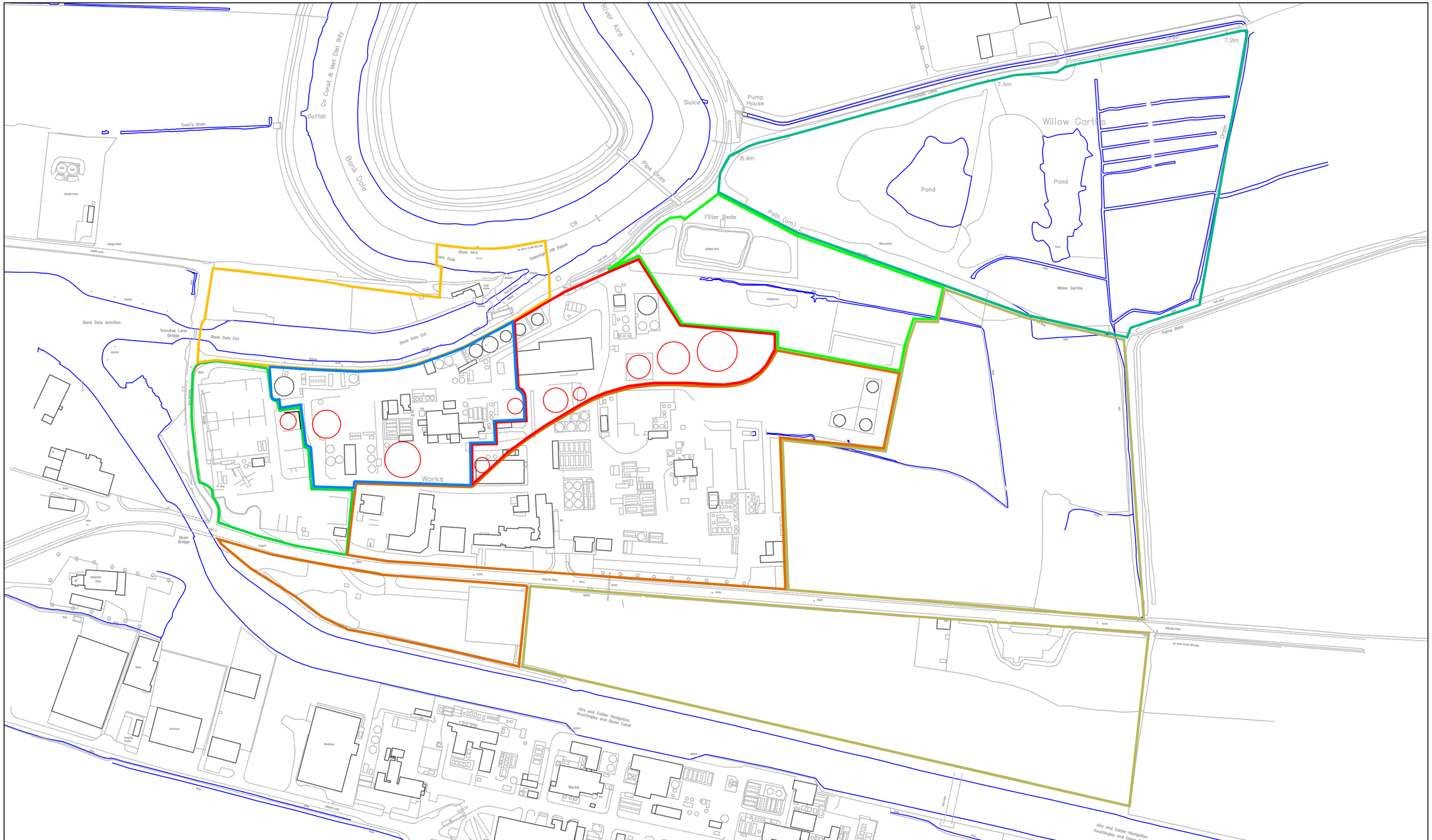
WSP

TITLE

SITE LOCATION PLAN

FIGURE No

FIGURE 1



DO NOT SCALE

- CEMEX Site
- CaRT Land
- Vacant Land
- Tradebe Operational Area
- Tradebe Tar Legacy Area
- North - East Land
- Willow Garth
- Agricultural Land

REV	DATE	BY	DESCRIPTION	CHK	APD

CLIENT: CRODA

PROJECT: CRODA, KNOTTINGLEY REMEDIAL ACTION PLAN

TITLE: GENERAL SITE LAYOUT AND BOUNDARIES

DRAWING STATUS: FINAL

SCALE@SIZE:	CHECKED:	APPROVED:
SMcK	RC	RC
CAD FILE:	**DESIGN/DRAWN:**	**DATE:**
002	RL	MARCH 2013

PROJECT NUMBER:	DRAWING NUMBER:	REV:
2824.012	Figure 2	1

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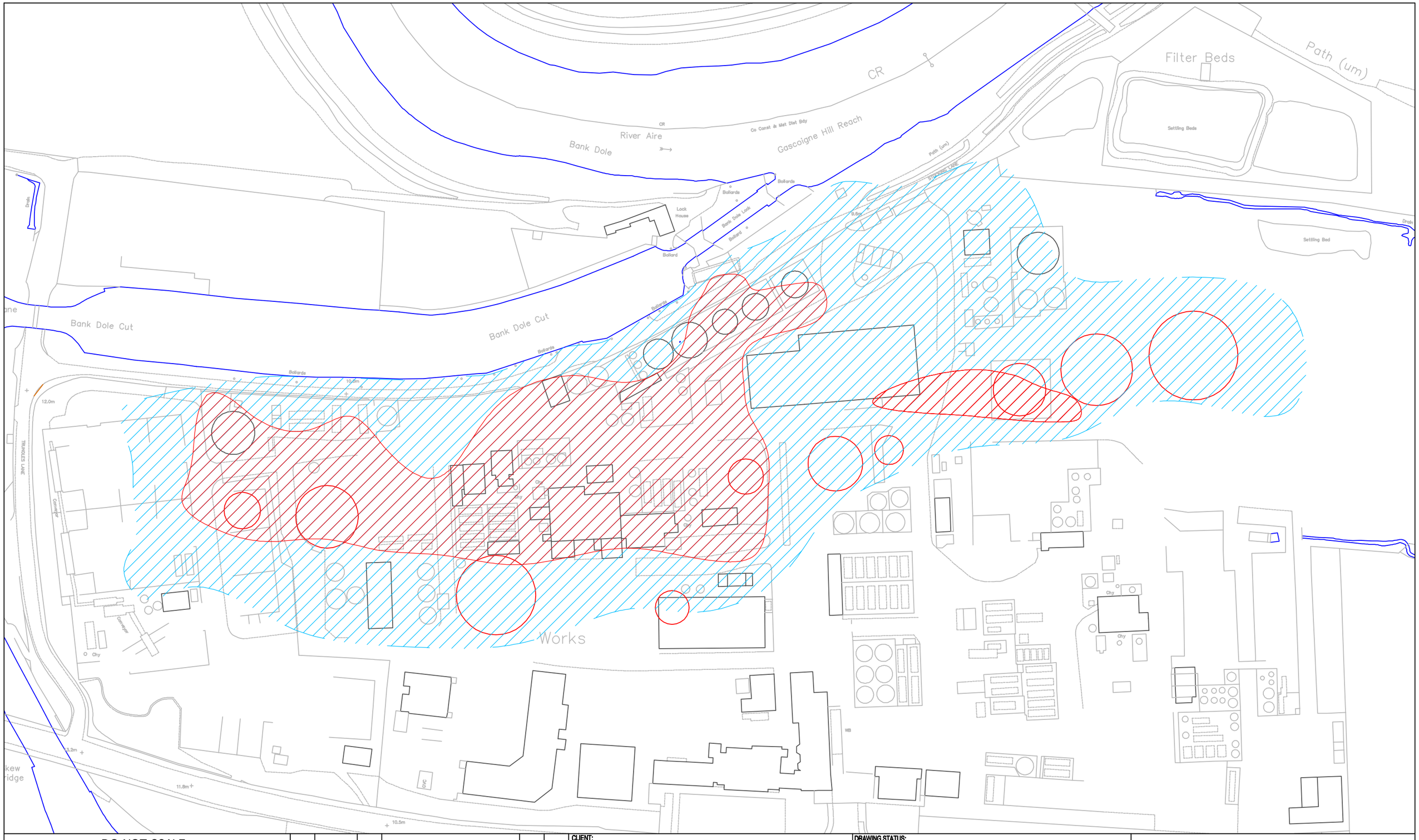

DO NOT SCALE

Identified NAPL Extent

Anticipated NAPL Extent based upon investigation data

REV	DATE	BY	DESCRIPTION	CHK	APD

CLIENT: CRODA

PROJECT: CRODA, KNOTTINGLEY REMEDIAL ACTION PLAN

TITLE: IDENTIFIED AND ANTICIPATED EXTENT OF NAPL IMPACT

DRAWING STATUS: FINAL

SCALE@SIZE:	CHECKED:	APPROVED:
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CAD FILE:	**DESIGN/DRAWN:**	**DATE:**
003	RL	MARCH 2013
PROJECT NUMBER:	**DRAWING NUMBER:**	**REV:**
2824.012	Figure 3	1

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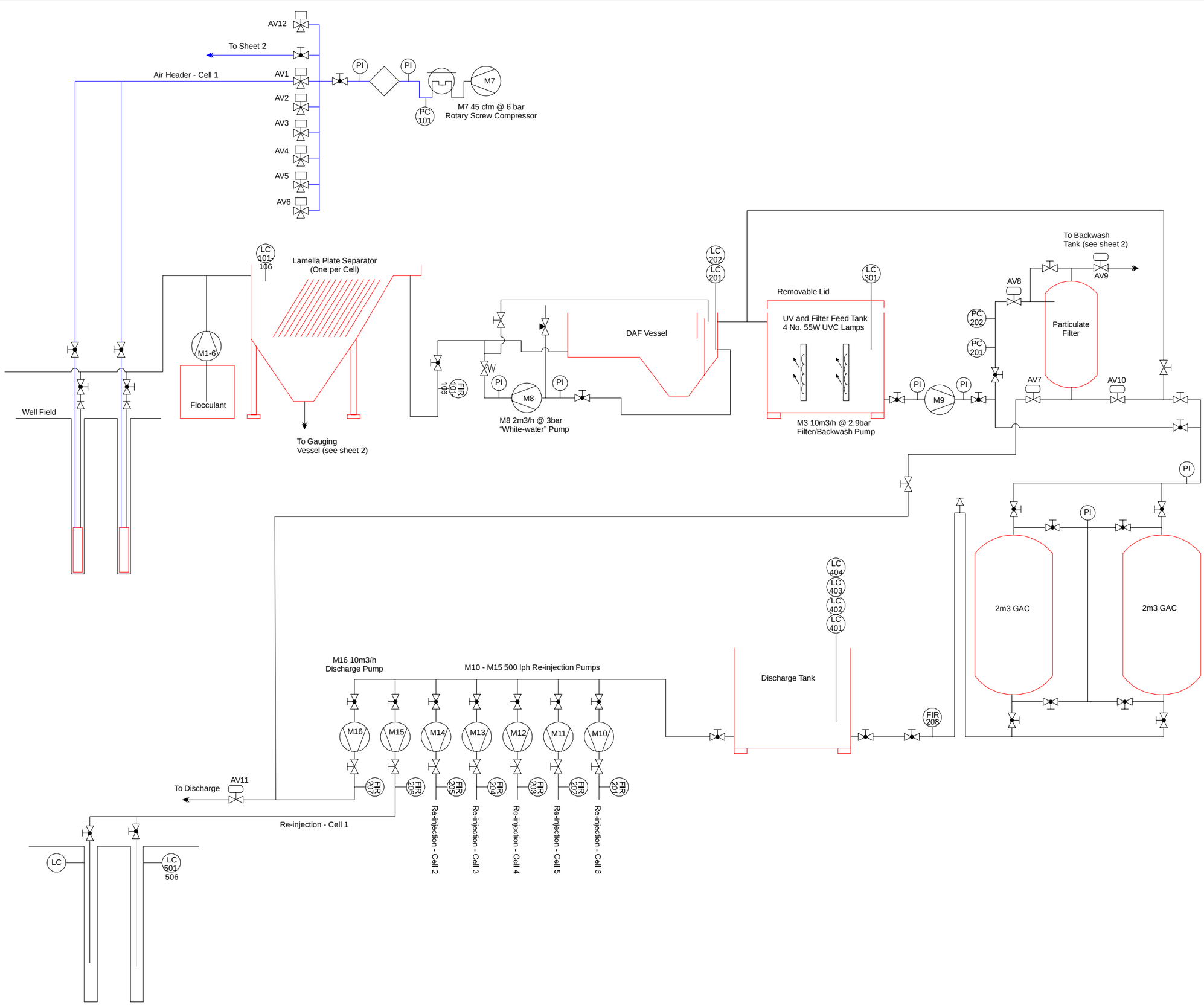

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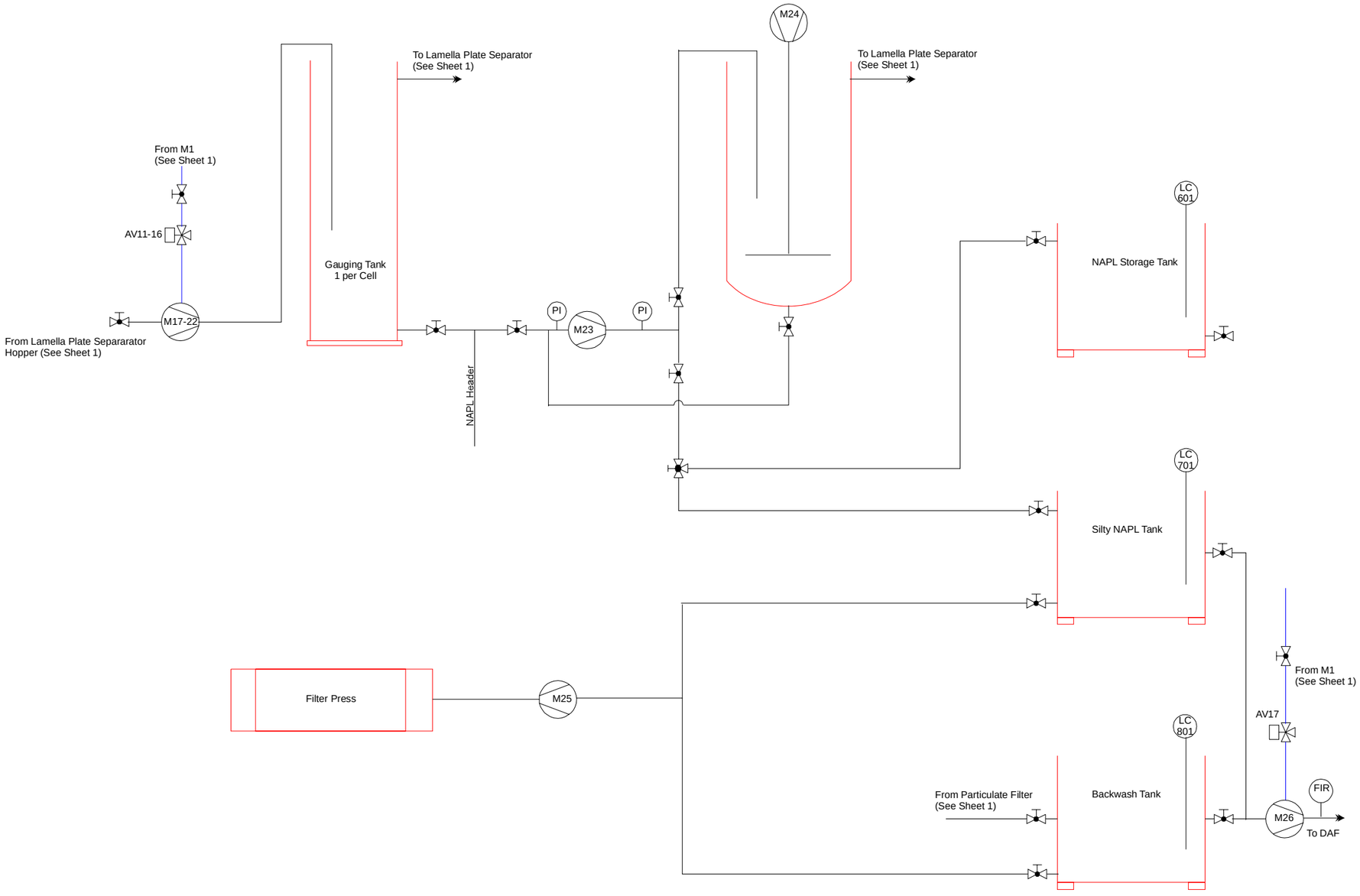

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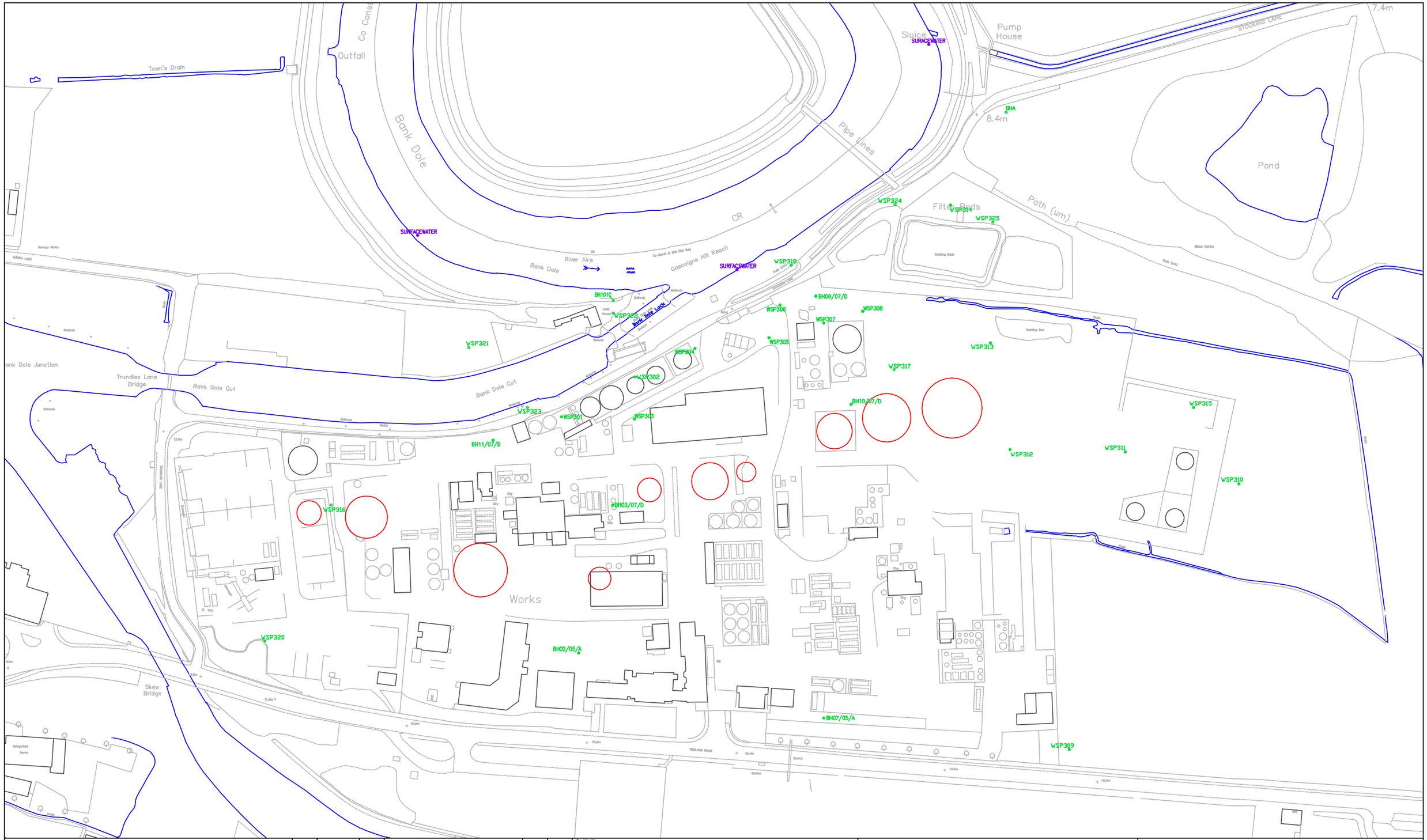

DO NOT SCALE

WSP320 Deep Deposits Location

SURFACEWATER River Aire Surfacewater Location

REV	DATE	BY	DESCRIPTION	CHK	APD

CLIENT: CRODA

PROJECT: TAR DISTILLERY, KNOTTINGLEY REMEDIAL ACTION PLAN

TITLE: PROPOSED GROUNDWATER MONITORING LOCATIONS

DRAWING STATUS: FINAL

SCALE@SIZE:	CHECKED:	APPROVED:
NTS	SMCK	RC
CAD FILE:	**DESIGN/DRAWN:**	**DATE:**
007	RL	MARCH 2013

PROJECT NUMBER:	DRAWING NUMBER:	REV:
2824.012	FIGURE 7	1

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Appendices

Appendix A Regulatory Correspondence

Our Ref:

Sent via email to:

Mr Terry Thistlewaite

Dear Terry

Date: 5th October 2012

Purpose: Review of Joint Position Statement and Detailed Quantative Risk Assessment at Croda, Knottingley

Further to our meeting with WSP on the 4th October we are writing to confirm that the Environment Agency have no further comments on the draft joint position statement and would be happy for this to be finalized.

In respect to the quantitative risk assessment we agree with the overall approach detailed in this report. However, we have asked WSP to expand the final conclusions section to include a discussion on the groundwater monitoring frequency and duration during and post remediation. Specifically post remediation monitoring is likely to be influence, to some degree, by the data obtained from monitoring during active remediation.

We also had a discussion about appropriate targets for TPH. In the absence of any viable alternative WSP have opted to use the WHO Drinking Water value of 10µg/l. The use of this value is typical and acceptable. However, this value represents a total TPH concentration and as such when considering individual TPH fractions it is generally expected that the total allowable concentration would be proportioned between the fractions present. The WSP risk assessment applies the whole 10µg/l to each individual fraction, effectively increasing the allowable target by a factor of ten.

In the Corda risk assessment the individual compounds usually identified as indicators for TPH fractions have also been considered in their own right which provides a more robust evaluation of the risk of TPH. Therefore it is our view that, in this instance, using a proportioned approach for TPH fractions would not alter the overall outcome. We have therefore not asked WSP to consider this further within the context of this site.

As a more general point the status update on the lagoon area and the Canals and Rivers Trust land was encouraging and we look forward to receiveing site summaries and scopes of work in the near future.

If you have any questions in relation to the above, please contact the undersigned.

Yours Sincerely

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Appendix B Remediation Options Appraisal

C.1 Introduction

A series of priority pollution linkages have been derived from the Conceptual Site Model (CSM (Ref:1) and Detailed Quantitative Risk Assessment (DQRA) (Ref 8), which consider routes for potential NAPL and dissolved phase contaminant impacts to the River Aire (considered to be the primary receptor). Based on the identified pollutant linkage it has been determined that the primary remediation objective will be the reduction of recoverable and mobile NAPL that has the potential to migrate towards the River Aire via dissolution and transport within the Deep Deposits.

This options appraisal will only focus on techniques and technologies that can successfully deliver the above objectives. Each identified method/technology will then be assessed using a qualitative rating system against the headings below, in order to develop a total score and identify the most suitable remediation technology for the site.

- Cost
- Cost Management
- Timescale
- Applicability
- Technical Feasibility
- Effectiveness
- Sustainability

The options appraisal forms a key piece of the cost vs benefit appraisal that has been applied to the design of this remedial action plan and will form a reference for future consideration during the evolution of the remediation works.

C.2 Groundwater Remediation Options Appraisal

C.2.1 Introduction

The selection of appropriate options for NAPL recovery in the Middle Deposits have been made with benefit of the findings from a comprehensive technology study (Ref: 5) conducted by WSP Remediation in 2010. The study evaluated pump and treat, vacuum enhanced pumping in the form of Dual Phase Vacuum Extraction (DPVE), surfactant flushing and thermal enhanced remediation. The study compared the performance of each technique (especially the yield ratio of recovered NAPL to groundwater abstracted) against cost and select sustainability drivers. It was found that DPVE did not significantly increase the yield of NAPL, but was significantly more expensive and energy intensive to operate. Similarly, although a laboratory study demonstrated that surfactant flushing could increase NAPL recovery, it was identified as a very expensive approach and probably unfeasible at site scale. Therefore, in terms of applicability, technical feasibility and cost neither of these options has been considered further.

The conclusion of the technology trial indicated that a pump and treat based option would be an effective means of recovering mobile NAPL. It was also identified as being more sustainable and deliverable when compared to enhanced pumping options. Pump and treat is however a relatively long-term option, requiring an estimated 3 to 4 years to meet the remedial goals proposed. On this basis, other options have been considered that may provide time and performance advantages, whilst possibly achieving similar levels of deliverability and sustainability.

One option that will increase performance and reduce timeframes is thermal enhanced remediation and as such has been more closely appraised below. The technology study also evaluated thermal enhancement options, albeit on a limited scale. The results were inconclusive, although it was noted that there was some

evidence of NAPL mobilisation. It can therefore be viewed that thermal enhanced remediation may potentially offer a viable option to expedite remediation if so required in select areas of the site.

To complete the options appraisal, consideration has been given to other methods that can achieve NAPL mass removal and/or prevent further contaminant impact to the River Aire. No ex-situ (mass excavation) options have been considered on applicability and cost reasons, noting that costs would likely exceed £12m depending on what treatment options were used. In-situ stabilisation is also ruled out on poor applicability, technical feasibility and cost. Therefore the only other possible solution is the use of impermeable barriers, designed to break the migratory pathways of contamination to the River Aire. Permeable treatment barriers have not been considered, as NAPL flow is so slow that this option becomes effectively redundant.

Remedial options are summarised and rated in Tables C3 and C4.

C.2.2 NAPL Recovery using 'Pump and Treat'

The findings of the technology trials would need to be used to determine the most appropriate 'pump and treat' system at full-scale. However, the system would likely comprise pumping from 100 mm diameter wells, designed to house low flow/low shear borehole pumps. The pumps would feed back to a central treatment plant, which will comprise NAPL separation and dissolved phase contaminant filtration. The system would also comprise some form of flow-path management, which was shown to increase NAPL recover yields.

Operational timeframes will be dependent on the intensity of the final design. A higher number wells, positioned in a tighter field array, will decrease the treatment timeframe. The key, however, will be efficient management of the system to maintain high NAPL yields. This can be done through careful control of total fluids abstraction rates and flow path management, which can be achieved by re-injecting groundwater around abstraction zones to induce NAPL flow towards recovery wells. This will increase infrastructure costs and therefore an exercise will be required to determine a balance between the two. One limiting constraint will be the volume of abstracting groundwater that can be discharge to sewer under license as this is currently limited to 8m3/hr; although flow-path management and reinjection into the aquifer will allow for an overall increased rate of abstraction.

The technology trial report indicates the treatment will require between 3 to 4 years to reach the remedial objectives. A number of other parameters were also estimated, based on different rates of NAPL recovery. A pump and treat system would consume between 85 and 716 MWh of power and use between 25 and 205 tonnes of GAC filtration media. Costs will be dependent upon the final design, agreed target areas and the remedial objectives but are likely to range between £1.5m and £3m.

C.2.3 Thermal Enhancement

There are three established methods of thermal enhancement that can be used to heat the aquifer and potentially increase the mobility of NAPL. These are conductive heating, resistive heating and steam/hot water injection. The hot water injection trial was limited and results inconclusive, but post trial testing did show an increase in NAPL recharge of monitoring wells indicating possible increase in NAPL mobility. In general terms it would be expected that a properly applied thermal enhanced remediation project will increase NAPL yields by 400 to 2,000%.

Conductive heating is likely to best suit the lower permeability conditions in the Middle Deposits and offers a simple and robust means of heating the target formation. The concept of conductive heating relies on heat transfer from elements place in the ground that is heated to greater than 300oC. Conductive heating methods can be slow in comparison to steam injection and require significant capital investment. To allow heat build-up and transfer, the conductive elements would need to be installed into the lower permeability clay layer at the base of the Middle Deposit. To avoid excessive temperature gradients and ensure the targeted zone reaches temperature within the practical timeframe elements would need to be spaced at 6.0m centres. This would mean locating 1,000no. 3.5 kW heater elements across the 12,600m2 target, which would be prohibitively expensive and impractical as local mains power is unlikely to support such a high power demand.

In addition to the limitations relating to practicality, cost and power supply, there are a number of health and safety and environmental control issues to consider. It would not be recommended that thermal enhancement is undertaken within 15 metres of the River as mobilised NAPL or increased dissolved phase contamination

could escape outside the recovery system capture zone. Additionally, ensuring suitable monitoring, control and optimisation of the system becomes harder if the heating area increases. On this basis it would normally be recommended that the active heating zone does not extend beyond 3,500 m2.

If a scenario arises that requires a smaller section of the site (ideally less than 3,500m2) to be cleaned to a higher standard and/or more quickly, conductive heating might prove to be suitable. A budget cost for using conductive heating methods for the treatment of 1,500m2 of the Middle Deposit would be c. £0.7m to £0.9m. Cost estimates for treating the full 12,600m2 area would be circa £5.5m to £6m based on reusing key plant in a phased approach over a period of approximately 2.5 years.

C.2.4 Impermeable Barriers

Impermeable barrier systems have been considered as a means of containing NAPL contamination within the middle aquifer. A number of different options are available, including interlocking sheet piles and Bentonite clay barriers. To ensure an effective seal, the barrier would need to be keyed into the top of the Roxby Formation, which is described as a stiff to very stiff red clay. The effects of installing a barrier would need to be modelled, as they will impact on the hydrogeological regime. The modelling would need to establish a water balance flowing in and out of the site and also look at the sensitivities of downstream (off-site) discharge points.

The most robust barrier option would be to enclose the whole site or areas of known gross NAPL impact. Complete enclosure of the site would also require extensive drainage and infiltration protection to ensure flood management inside and around the containment barrier. Costs for this option, including design, management, enabling works and barrier installation (based on interlocking steel sheet piles) will exceed £3.5m. Works required to improve site drainage could add a similar sum if excavation and disposal of contaminated soil was required. The cost of managing the logistical constraints of installing a barrier would also need to be carefully considered.

The potential negative effects on the local hydrology are significant, including both on-site and off-site flooding and increased contaminant mass transfer into the Deep Aquifer. Based on these risks impermeable barriers are not considered a viable option.

C.2.5 Remediation of Middle Deposits Options Review Summary and Rating Assessment

Table C3 Groundwater Remediation Options Review

Remediation Method	Principal	Engineering Requirements	Anticipated Operational Period	Effectiveness	Disadvantages	Relative Cost
Pump and Treat	The principle of pump and treat draw contamination from the subsurface via total fluids abstraction. Abstracted contaminants, including NAPL, are treated at surface via bespoke treatment plant prior to being suitably disposed	The design/spacing of wells and selection of pumping equipment will need to satisfy hydrogeological and contaminant physiochemical limitations. Additionally treatment plant needs to ensure contaminated influent streams are effectively processed prior to discharge	3 to 4 years	A recent long-term technology trial has determined that pump and treat can recover and sustain recovery of NAPL at the Site.	Pump and Treat is a relatively long-term solution, which can only recover the mobile fraction of NAPL in the subsurface	Pump and treat systems are generally cost effective to install but carry a long term operational and maintenance liability.
Thermal Enhanced Pump and Treat	There are three established methods of thermal enhancement that can be used; conductive heating, resistive heating and steam/hot water injection. The objective of these technologies is to efficiently heat up contamination in	The spacing and positioning of wells/heater elements needs careful consideration to ensure efficient and uniform heating. Recovery wells also need to be placed so that mobilised contaminants are effectively	Between 12 and 18 months, depending upon how works are sequenced, what thermal enhancement technique is used and how that technique is designed.	Thermal enhancement can increase NAPL recovery by a factor of 4 to 20. NAPL as a high percentage of residual NAPL will become mobile upon heating to temperatures >50oC. The overall effectiveness might be limited by the		

Remediation Method	Principal	Engineering Requirements	Anticipated Operational Period	Effectiveness	Disadvantages	Relative Cost
	the subsurface, improving their mobility and recoverability.	captured. Recovery plant needs to take into account high temperatures and treatment of volatilised contamination.		low soil permeability encountered in the target aquifer.		
	To ensure control of mobilised NAPL the technology should only be used to actively heat a maximum area of 3,000m2 at any one time. The technology is designed to significantly enhance the mobility of NAPL, therefore consideration needs to be given to protecting sensitive receptors (River Aire)	Operational costs will be higher than conventional pump and treat, mainly due to much higher power and filter media consumption. Capital costs will also be high due to additional plant (e.g. heat exchangers) and infrastructure (e.g steam well) requirements. There will however be some offset due to the reduced timescales for treatment in comparison to non-enhanced options				

Table C4 Scoring of Potential Groundwater Remediation Techniques

Technique	Relative Cost	Cost Management	Timescale (out of 5)	Applicability	Technical Feasibility	Effectiveness	Sustainability	Total Score
Pump and Treat	7 Treatment plant cost can be minimised by using a central treatment system linked to hubs. System will require a large number of wells and the treatment duration will be extended	7 The duration of treatment and demand on consumables (e.g. filter media) introduce some uncertainty. Remedial goals however	2 The recovery of NAPL will be an attrition process based on the findings of trial works on site. It is anticipated sufficient NAPL recovery will require 2 to 4 years depending on the design of the recovery system	5 Some consideration would need to be given to sequencing the treatment of remote NAPL plumes. The discharge limit of 8m3/hr represents a potential constraint to the application of the technology at full scale although this could be addressed through rotation of recovery from remediation “cells”.	7 A long-term technology trial using pump and treat has demonstrated that it is an effective method for recovering NAPL, which satisfy the remedial objectives	6 Pump and treat will be limited to the recovery of mobile NAPL only and grossly contaminated groundwater.	7 Long operational periods represent a long term requirement for power consumption. Would require the disposal of water treatment media such as activated carbon.	41

Thermal Enhancement Pump and Treat	3 Power consumption will be high. Additional infrastructure costs will also be high.	5 Running period would be the main unknown variable; however, overrun costs would be low compared to overall installation costs.	4 Would operate for 1-2 years	5 It is considered that the dense nature of the underlying deposits and variable presence of lower permeability strata would make this technology less effective.	7 While the installation of this type of system is not anticipated to be problematic, constraining factors related to the site geology are unlikely to make this technology feasible	8 Unlikely to be 100% effective within the identified geology, but will increase the NAPL recovery rate and total NAPL mass recovered.	4 Thermal enhanced pump and treat will use significant power to heat the target area (estimated power consumption is approximately 5,000 MWhr compared to 300 to 700 MWhr using conventional pump and treat). A higher amount of filter media will also be used.	36
Impermeable Barrier	4 Installation costs would be considerable. There would be a long term maintenance cost liability.	2 The impact on costs associated with design and installation of flood management system and the management of logical issues to enable installation of the barrier	1 Quickly removes liability to River Aire, but will require long-term monitoring to ensure it doesn't negatively after local hydrogeology	2 The considerable engineering requirements needed for the installation of such a structure would limit its applicability on an operational facility.	4 It will stop contaminant migration, but may have a negative effect upon local hydrogeology	8 It will stop further migration of NAPL off-site into the River Aire	7 The installation of the flood management system will generate waste soil that may need off-site disposal. The installation of the barrier will require use of heavy plant, however once installed the	28

		could have a major impact upon costs					solution is passive	

C.2.6 Conclusions for Middle Deposits Remediation Options

Overall, the appraisal falls in line with the conclusions drawn from the remediation technology study and confirms pump and treat as the most appropriate solution. The results indicate that pump and treat will offer the most cost effective and sustainable solution for the remediation of NAPL impact within the Middle Deposits.

Thermal enhanced remediation offers a potentially effective and quicker solution, providing the area being targeted is less than 3,500 m2. If thermal enhancement was to be used to target a wider reaching area it would offer less programme advantage, as its application will need to be sequenced.

The option of using an impermeable barrier is considered to represent the least appropriate remedial solution for the Middle Deposits.

Appendix C Reporting Requirements

Groundwater Remediation Reports
■ Copies of relevant environmental permits and licences.
■ Copies of registered waste carrier certificates.
■ Records of any consents, permits authorisation and/or licences held or obtained by the Contractor (and sub-contractors) relevant to the Works.
■ System operation and performance summaries.
■ Borehole and monitoring well records.
■ Validation sample records.
■ Records from specialist remediation processes.
■ Waste disposal records, including the following, as applicable:
■ – Liquid waste disposal summary
■ – A sample of waste consignment notes
■ – A sample of liquid waste transfer notes.
■ Analytical results.
■ Air quality monitoring results for dust and organic vapours, including laboratory test results, record of odour and organic vapour monitoring by PID and visual/olfactory observations; organic vapour monitoring data for site personal (PID print outs/data); records of hire and calibration of personnel organic vapour monitors as required by the RMS.
■ Final 'As built' drawings.
■ Records of any site investigations carried out during the Works, including trial pit and borehole logs.
■ Laboratory QA/QC data report.
■ Any other information requested.

Appendix D Joint Position Statement

Croda Knottingley Land Remediation Programme

Joint Position Statement

Without Prejudice

Commercial in confidence

Purpose

The overall objective for Croda in establishing a Land Remediation Programme is to establish clean-up works which are deemed appropriate by the Environment Agency to address historic contamination at the site in the context of continued use of the site in an industrial context. This is to satisfy Croda's corporate objectives, and, potentially, to support the sale of the site to the current occupier (Tradebe). This document seeks to establish the framework and objectives for clean –up works which are appropriate to bring the land into a condition that is suitable for use, and that the Environment Agency can agree is no longer causing significant environmental risk.

Context

Croda has been undertaking a voluntary Land Remediation Programme at part of the Knottingley site to meet with its corporate objectives and to support decisions relating to the future of the site. It is Croda's ultimate intention to sell the Knottingley site and in doing so address historic contamination liabilities associated with Croda's former operation of part of the site as a tar distillation plant.

Most of the site will remain in industrial use for the foreseeable future, operated as a permitted solvent recovery facility, under lease currently to Tradebe (formerly SRM). Other parts of the site have other intended uses – as described below. The transfer of land parcels, and therefore the clean-up works, is likely to take place in phases.

Croda has been undertaking investigative works at the site dating back to 1978, with the majority of works taking place since 1997. A list of relevant site reports is appended.

Site Areas

The site is divided into a number of areas relating to historic ownership and contemporary operations. For the purposes of this statement and the Land Remediation Programme, areas of the site have been determined as follows (as illustrated in Figure 1):

'CEMEX' Site – located in the western portion of the site that formerly housed tar settling beds and below ground tar storage associated with a tar distillation plant. In recent years the site operated as an aggregates coating business operated by Hargreaves, RMC and latterly CEMEX. The site has now been decommissioned and is currently redundant. This area requires clean-up works under the Land Remediation Programme.

'Vacant Land' - housed the majority of the historical tar distillery activities dating back to the commencement of operations at the site. Processes within this area included above and below ground tar storage, tar distillation and intermediate product storage and handling. This area was decommissioned in the late 1990s and demolished during the early 2000s. This area requires clean up works under the Land Remediation Programme.

'Tradebe Site' – plant on this portion of the site is currently operated by Tradebe (formerly SRM) under an Environmental Permit. It houses a solvent recovery facility which utilises a large portion of the former infrastructure from Croda's historical operations. Also included is a car park which is to the south of Weeland Road Of these two separate areas, the area to the north of Weeland Road requires clean-up works under the Land Remediation Programme.

It is intended that the Site Areas are to be continued to be used as a chemical works by Tradebe.

'North East Land' – a small portion of land in the north-east of the site. This area abuts Stocking Lane to the north and Willow Garth to the east and is situated outside of the operational area of the Tradebe site. This area will either be transferred to Yorkshire Wildlife trust, or remain secure and vacant under Croda's ownership and therefore sits outside the Land Remediation programme described in this document. However two redundant tar settling beds remain in this area associated with former operations. This area of land is thought to not require clean-up works as currently, there is no evidence for the land contributing to the identified pollutant linkages. However, some additional confirmatory sampling, and some physical enabling works may be undertaken to enhance the long term security of the area.

Willow Garth - This comprises a nature reserve that has existed at the site for over 100 years. The site is currently stewarded by Yorkshire Wildlife Trust and has not previously housed any industrial activities. This area of land does not require clean-up works under the Land Remediation Programme.

Agricultural Land – Land to the east of the Tradebe Site and the south of Weeland Road is currently leased to local farmers. This area of land does not require clean-up works under the Land Remediation Programme.

The above three areas are not operational areas, and the intention is to lease the North East Land and Willow Garth to the Yorkshire Wildlife trust, and to sell the Agricultural land for agricultural use.

Conceptual Site Model

Following extensive investigations by Croda, the site has been characterised in depth. A Conceptual Site Model (CSM) has been developed and shared with the Environment Agency (EA), who have agreed on the definition of pathways and receptors. The main sources have been identified and characterised as historic.

Additional refinement work is being undertaken at the moment which relates to very specific aspects of the CSM and includes:

- Modelling the risks from a declining source of contamination given that there is unlikely to be any further 'on-going release' into the soils. This is to evaluate the long term effects of residual contamination and the likely impact of these on the River Aire post remediation;
- Documenting the lines of evidence that relate to degradation of dissolved phase contamination, providing supporting quantitative inputs to the above.

The historic contamination comprises contaminants demonstrably different to those contained in the permit operated by Tradebe, and as the Tradebe site does not currently have an agreed baseline for its operations, it is suggested that the Conceptual Site Model which documents historical site contamination and the post remediation validation reports should act as a baseline for this operation to define its state of contamination including historic contamination attributable to Croda's period of operation at the site.

The agreed pollutant linkage which is to be addressed by the Land Remediation Programme and associated Clean up works is as follows:

- Ongoing migration of NAPL from the middle deposits to the deep deposits and the subsequent dissolution of contaminants from NAPL into the dissolved phase followed by migration and discharge in to the River Aire.

The agreement of the pollutant linkages to be addressed is only in the context of the ongoing use of site areas as defined above as chemical works, whether under lease or if purchased.

Aims and Objectives of the Land Remediation Programme

The overall objective for Croda in establishing a Land Remediation Programme is to satisfy its corporate objectives and establish clean-up works which are deemed appropriate by the Environment Agency to address historic contamination at the site in the context of continued use of the site in an industrial context. This document seeks to establish the particular clean –up works which are appropriate to meet these objectives, and that the Environment Agency can agree are appropriate in the context. On the basis of the on-going use of the site as a chemical works, and on the conceptual site model, and the risk, cost, benefit and sustainability assessments undertaken to date, the most appropriate objective for the clean-up works is:

- To remove recoverable mobile NAPL from the middle aquifer.

This is to limit further migration of NAPL from the middle to the deep.

On the basis of the objective above, the clean-up works will comprise:

- Physical removal of mobile recoverable NAPL from the middle aquifer, and;
- Monitoring of the dissolved phase contamination in the deep aquifer.

The end point for the clean-up works are therefore defined on the basis of multiple lines of evidence, both from the recovery of NAPL in the middle aquifer, and from the evolving situation in the deep aquifer. Further technical details of the end-point are presented in Appendix 1.

This end point for the product recovery clean-up works will be decided on the cell by cell performance characteristics of the product recovery system, so that when the recovery of remaining mobile NAPL becomes technically reasonably impracticable and the costs and energy consumption outweigh the benefits, recovery will cease.

Whilst clean up works or direct intervention in the deep aquifer has been ruled out at present on cost benefit and sustainability grounds, Croda recognises that the situation requires on-going monitoring and review, and proposes to put in place reserve mitigation plans as part of the overall Land Remediation Programme.

As part of the Land Remediation Programme, a monitoring plan will be developed and put into place alongside the clean-up works which seeks to:

- Monitor the continued evolution of the dissolved phase components in the deeper aquifer and confirms understanding of the residual risks posed by this;
- Provide sentinel wells with definition of significant concentration changes over defined time periods that will trigger reserve mitigation plans.

The trigger levels for commencement of reserve mitigation plans will be developed following completion of the current refinements to the conceptual site model. Reserve mitigation measures are not yet defined and are pathway dependent. On the basis of the current information, such measures could include one-off treatments in the deep deposits, or other pathway management measures such as grouting of the clay in specific areas of the site where there is demonstrable downward migration of residual product from middle deposits to deep deposits.

Statement of Works

Croda propose to implement clean-up works at the site to address the historic contamination impacts at the site.

The focus of the clean-up works will be the removal of mobile recoverable NAPL from the Middle Deposits together with the monitoring of the identified direct pollutant migration pathways (as identified in the agreed CSM). This will be achieved primarily via total fluids abstraction and hydraulic management via reinjection and recirculation of treated groundwater.

This presents an overview of the concept. Detailed design of cells will be presented and agreed prior to implementation.

However, overall, the remediation implementation is anticipated to comprise the following activities:

System Design and Installation

1. Installation of a remediation well field across the area of identified NAPL impact within the middle deposits. The full extent of the anticipated remediation well field is based upon the conclusions of the CSM report (Ref:20). The well field will be subdivided into remediation 'cells' with wells installed and screened within the Middle Deposits. The detailed design of each cell including the number of wells and well spacing will be defined on a cell by cell basis and will be influenced by the presence of site obstructions and access constraints, As cell

designs are finalised, they can be agreed with all stakeholders and will be appended to this document.

2. The installation of systems will be phased based upon access and timescale conditions and is anticipated that in order to be able to be running at full capacity it will take in the order of 12 months to scale up. It is anticipated that NAPL recovery operations will commence in the west of the site (Cemex Land) and extend eastwards along the line of groundwater flow.

System Operations and Performance

3. Based on early data from cell 1 and assuming that other cells show a similar performance, and that Tradebe allow access to site areas when required, a provisional programme will be developed, based on the following milestones:
    a. Completion of cell 1 operations
    b. Installation of cell 3 on western end of site
    c. Commissioning of cell 3 to run in parallel with cell 2
    d. Scale up of treatment system and commissioning
    e. Completion of cell 2 operations
    f. Installation of cells 4 – 6 according to access constraints
    g. Completion of NAPL recovery in remaining cells
    h. Validation works
4. At the commencement of NAPL recovery operations within each cell, a baseline NAPL recovery rate will be determined as a benchmark to measure the performance of the system. This would be undertaken on a cell by cell basis to account for local variation within the NAPL recoverability in each zone.
5. Groundwater and entrained/suspended NAPL will be abstracted from the Middle Deposits using low-shear pneumatically driven bottom loading pumps driven by compressed air. Abstracted fluids will be transferred to the remediation treatment system via header lines.
6. Each remediation system will undertake water treatment via a process of gravity separation, particulate filtration and carbon adsorption. It is anticipated that the majority of the NAPL removal will take place within the physical separation phases.
7. Separated NAPL will be transferred under waste duty of care to be recycled by a permitted facility for use as incinerator fuel.
8. Following treatment and filtration of the effluent stream, this will be stored within buffer tanks prior to reinjection or disposal to sewer under a licensed discharge consent from Yorkshire Water. The use of groundwater reinjection within each remediation cell will support the manipulation of hydraulic gradients to promote increased NAPL recovery. This also has the benefit of reducing effluent disposal to sewer.

Performance Monitoring

9. Monthly monitoring of the performance, fluid volumes and intensity indicators will be undertaken to understand the efficiency of the recovery system.
10. Data from the product recovery system will be used to assess the performance of the recovery operations to inform the decision making. An agreed programme of post-shutdown monitoring and verification will be implemented to determine the final condition of each remediation cell. NAPL transmissivity assessment will be undertaken for an agreed period to

assess the presence of residual mobile NAPL within each cell and define the assessment of whether further action or cessation of works is recommended. This will be reviewed along with other lines of evidence as to the progression of the remediation as outlined in appendix B.

11. A corrective action procedure will be implemented and used to address unexpected conditions identified during the operational phase.

Groundwater Monitoring of the Deep Deposits

12. An interim monitoring plan will be implemented during the clean-up works. The plan will enable the collection of data to verify the conclusions of baseline plume conditions and any fluctuation during NAPL recovery operations.
13. Data from down-gradient wells will be used to correlate against the conclusions of risk assessment and modelling and also determine the need for localised mitigation in the event of unexpected contamination or rebound.
14. The duration of groundwater monitoring will extend beyond the completion of NAPL recovery works and will be used to support the conclusions the clean-up works.

Joint position statement

Whilst both parties (the Environment Agency and Croda) recognise there will be residual contamination and residual risks associated with the scheme described above, the approach has been developed in light of cost benefit and sustainability, as required by UK and EU guidance when dealing with land contamination risks.

As such, both The Environment Agency and Croda have jointly agreed that under a voluntary remediation agreement, the above scope of works represents the most appropriate and sustainable way of reducing risks to controlled waters receptors associated with the historical contamination at the site in the current state of the land.

The Environment Agency acknowledges that Croda have embarked upon a Land Remediation Programme and that the clean-up works described above represent an appropriate plan to address Historic Contamination at the site, given the on-going use of the site as a chemical facility under a permitted regime.

Croda acknowledges that the EA cannot provide any guarantee, or certainty, that regulation of the site will never be needed in the future, for example if significant pollution of controlled waters is identified (for example if future works on the site cause additional sources or pathways), or if a more sensitive land use is proposed in the future.

Appendix A -References

Site Specific Reports

(1) Report on Groundwater Pollution of River Aire, Knottingley – Croda Hydrocarbons Ltd, Knottingley Site, West Yorkshire. Prepared by Binnie and Partners. June 1978; [1]

(2) Investigation into Hydrocarbon Contamination in the Area of Bank Dole Cut, Knottingley – British Waterways. Report Reference: A71135, dated June 1997; [2]

(3) Site Investigation Report – Croda Hydrocarbon Ltd, Knottingley Site, West Yorkshire. Prepared by Golder Associates. Report Reference: 98528230, dated February 1999; [3]

(4) Site Investigation Report – Croda Hydrocarbon Ltd, Knottingley Site, West Yorkshire. Prepared by Golder Associates. Report Reference: 00525427, dated June 2001; [4]

(5) Phase I Report – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated December 2003; [5]

(6) Phase IIA Screening Report – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated March 2004; [6]

(7) Phase I/II Baseline Condition Survey Report - Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated May 2004; [7]

(8) Phase IIB Initial Characterisation report - Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED24481, dated September 2004; [8]

(9) Phase III Groundwater Investigation Report - Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by AEA Technology. Report Reference: ED48362, dated June 2005; [9]

(10) Outline Remediation Design – Interpretative Report – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by Atkins. Report Reference: 5040854, dated June 2006; [10]

(11) Site Investigation and Preliminary Environmental Risk Assessment – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by Atkins. Report Reference: 5040854_077_31635, dated October 2007; [11]

(12) Detailed Quantitative Risk Assessment (DQRA), Controlled Waters – Croda International Ltd, Knottingley Site, West Yorkshire. Prepared by Atkins. Report Reference: 5040854_077_31946, dated November 2007; [12]

(13) Technology Evaluation Report – Weeland Road, Knottingley. Prepared by QDS. Report Reference: 3447-01, dated January 2008; [13]

(14) Remediation Action Plan – Croda PLC, Former Coal Tar Distillery, Knottingley. Prepared by Atkins. Report Reference: 5040854_077_32250, dated February 2008. [14]

(15) Updated Conceptual Site Model: Croda Distillates, Knottingley, WSP, 2010 (Ref 2824.002)

(16) Stage 1 Technology Report: Former Croda Tar Distillery Knottingley, WSP, 2011 (Ref 2824-001 R001)

(17) Draft Remedial Action Plan, Former Tar Distillery, Knottingley, WSP, 2011 (Ref 2824.003.draft)

(18) Conceptual Site Model; Croda Distillates, Knottingley, WSP, 2011 (Ref: 2824.003)

(19) Cost Benefit Assessment: Croda Distillates, Knottingley, WSP. 2012 (Ref: 2824.004)

Appendix B – End Point of the clean-up works.

In the context of overall betterment, the primary remediation objective is reduction of recoverable and mobile NAPL which is free to migrate towards the primary receptor. This primary objective will deliver mass removal and long term risk reduction to the primary receptor. Criteria to assess recoverability are summarised below. For the primary objective, it is recognised that there will be an end point, beyond which, it is not sustainable to deliver further product recovery. Criteria for this are also presented below. A Secondary remediation objectives will be to monitor and assess the potential significance of dissolved phase contamination, recognising the contribution of natural attenuation within groundwater. These will include assessing the mobility and risks from residual contamination following the mass recovery phase.

These objectives will reduce and control the potential risks associated with the identified Priority Pollutant Linkages. Mass recovery has been shown to be practical and technically effective for this site, and remediation trials have demonstrated that mass recovery is a flexible and viable approach.

REMEDIATION CRITERIA

In light of the philosophy and objectives outlined above, a set of technical and wider criteria have been developed to measure the performance of the remediation works within the realms of what is reasonable, practicable and sustainable. This section therefore lists the measures by which the success of the remediation will be judged. This section summarises the criteria developed and presented in the RAP (reference 17)

Since February 2010, WSP have undertaken a series of remediation trials to establish the baseline of recoverable mobile NAPL from a trial cell and assess the suitability of a series of NAPL recovery enhancements in accelerating the rate of mobile NAPL recovery and managing waste effluent streams (Ref 5). The trials have provided a baseline of information on groundwater pumping yields, groundwater reinjection rates, NAPL recovery rates, energy consumption, physical separation of NAPL once extracted from the ground and activated carbon consumption rates. The baseline trial has demonstrated that, with enhancements and hydraulic management through injection, it is technically effective and practicable to recover mobile NAPL from the Middle Deposits at a rate of up to 0.15% per m3 of groundwater recovered, over an extended time frame.

NAPL (Contaminant Mass Recovery) Remediation Performance Targets

In light of the extended trial and evidence base, the following specific remediation criteria are proposed to inform the end point of remediation activities at the site:

Table 1 - Remediation Targets

Objective	Target	Detail
Mass Reduction	Line of Evidence 1: Recover mobile NAPL mass to an asymptotic recovery level defined as 10% of the proposed baseline recovery rate (established by the technology trial).	The primary technical criteria for closure will be met when NAPL recovery rates drop to below 10% of 0.15% mobile NAPL per m3 of groundwater abstracted, for a period of 3 months (i.e 0.015%). Remediation recovery will be set up in cells and each installed cell will be treated separately. As ground conditions vary greatly across the site, further evidence collected on recovery rates for each individual cell will be used to inform the actual asymptote and hence closure point for each cell.
	Line of Evidence 2: Measure recovered NAPL on a cumulative basis per remediation	The cumulative recording of recovered NAPL presents a secondary line of evidence that will be used to demonstrate where on-going NAPL recovery has reached its asymptote (i.e. the product recovery curve becomes near horizontal) over a

Objective	Target	Detail
	cell.	period of operation.
	Line of Evidence 3: Measure the mass of contaminant recovered in terms of NAPL and dissolved phase contamination.	The estimation of contaminant mass recovered will provide a secondary measure of the effectiveness of remediation activities and will be achieved through direct measurement of the mass of NAPL recovered by the system and through the estimation of mass of dissolved phase contamination recovered through groundwater abstracted and contaminant concentrations recorded in the effluent following NAPL separation.
	Line of Evidence 4: Measure dissolved phase concentrations in deep aquifer to confirm DQRA conclusions.	Dissolved phase monitoring of the deep aquifer will be undertaken at a periodic interval (to be determined on the basis of the DQRA) to confirm that dissolved phase concentrations are evolving in line with the expectations of the DQRA.
	Line of Evidence 5: Measure settled NAPL thickness to establish that NAPL thickness is demonstrating stable or decreasing trends.	Baseline NAPL thickness monitoring will be undertaken within each remediation cell to benchmark settled NAPL thickness. Following demonstration of Lines of Evidence 1 and 2, rebound monitoring will be undertaken to confirm that NAPL (immobile) thicknesses are stable and not increasing.
Flexibility & Risk Reduction	Manage isolated occurrences of rebound within individual wells within a defined recovery cell on completion of NAPL recovery by assessing mobility and recoverability.	After closure of a NAPL recovery cell there is the potential for rebound of measurable NAPL within individual wells in a cell. Recovery tests on these individual wells will be undertaken to assess the potential for locally meaningful NAPL recovery to take place within the previously outlined parameters of practicability, cost and sustainability. This will include an assessment of the significance of NAPL contamination within the rebounding well to determine whether the NAPL is likely to be mobile and consider the overall risk reduction achieved in the cell.

The above set of criteria reinforces the concepts of risk reduction in line with the predictive simulations associated with the DQRA modelling. In particular, multiple lines of evidence associated with 4 will be used to assess whether the plume behaviour in the deep is in line with the conceptual site model, and thus represents an acceptable level of risk reduction in the deep aquifer associated with the residual contamination following removal of the recoverable mobile NAPL in the middle aquifer.

Sustainability Criteria

In addition to the above, sustainable criteria are presented in order to assess the sustainability of the remedial options and inform the ongoing consideration of cost vs benefit (and to assist in defining the end point of the remediation system). A set of sustainability indicators are proposed by which the potential impact of remedial options and decisions can be considered against the definable benefit delivered by the remediation project. Discussions with the stakeholder groups have highlighted the following which are considered to be key sustainability areas for this project, and therefore sustainability indicators will be set for each of these as follows:

Table 2 – Finalised Set of Sustainability Indicators

Affected Media		Indicators to be recorded for sustainability assessment
E1	Air	Carbon Dioxide emissions associated with energy consumption from project activities
E3	Groundwater and Surface Water	Mass reduction in mobile NAPL
E5	Natural Resources and Waste	Amount of Water re-injected to aquifer % of Recovered NAPL recycled Volume of Effluent discharged to Sewer
S1	Human Health & Safety	Accident records and statistics of project
S2	Ethical and equity	None set but uphold polluter pays principle
S5	Compliance with policy objectives and Strategies	EA approval sought for project
S6	Uncertainty and Evidence	Sustainability data and robustness of sustainability data set Uncertainty in long term dissolved phase prediction
EC1	Direct Economic costs and benefits	Direct Costs of Project Environmental Benefit delivered – to be measured with E1, E3, E5, S1
EC6	Project flexibility	Uphold ability of project to meet a number of land sale and management scenarios

Of the wider indicator set above, we propose to use a sub-set of directly measurable indicators to monitor the on-going sustainability of the remediation system using quantitative analysis as follows:

Table 3 – Summary of Sustainability Metrics to be Measured during the Works

Affected Media		Quantitative Indicators to be measured for sustainability assessment
E1	Air	Impact - kg CO2 emitted (direct and indirect emissions)
E3	Groundwater and Surface Water	Impact - water abstracted from aquifer (m3)
		Benefit - Water reinjected to aquifer (m3)
		Benefit - Kg NAPL recovered from aquifer
E5	Natural Resources and Waste	Benefit - amount of recovered NAPL recycled (kg)
		Impact - volume of effluent discharged to sewer (m3)
		Impact – waste materials and soils disposed to landfill (tonnes)
S1	Human Health & Safety	Impact - Accident records and statistics of project
S2	Ethical and equity	No quantitative indicators set
S5	Compliance with policy objectives and Strategies	No quantitative indicators set
S6	Uncertainty and Evidence	No quantitative indicators set
EC1	Direct Economic costs and benefits	Impact - Direct Cost of Project
		Benefit - betterment delivered

Affected Media		Quantitative Indicators to be measured for sustainability assessment
		Benefit – revenue for suppliers
EC6	Project flexibility	No quantitative indicators set

The technology trial has established that a base recovery rate of 0.15% mobile NAPL per m3 of groundwater abstracted will be achievable, with enhancement trials confirming this is achievable over a sustained period.

For this level of defined benefit, we propose to measure the impact and benefits achieved by the system. The mass recovery rate can be directly assessed against the impact of abstracting groundwater, direct costs, CO_2 generation, waste generation, and activated carbon useage. The secondary benefits such as the proportion of NAPL recycled, and the amount of water re-injected into the aquifer will be directly compared with the impacts such as costs. Recording and presentation of this information will allow a transparent assessment of where the impacts of remedial action start to outweigh the benefits delivered and assist stakeholders reaching a transparent justification for system closure, in addition to the mass recovery based criteria presented above.

Direct cost benefit assessment will be used in conjunction with the above indicators to quantify the net environmental benefit of the project.

Appendix C – Detailed Cell Designs – To be issued upon finalisation

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APPENDIX 3

2023 Annual Groundwater Monitoring Report, Former Knottingley Tar Works

Geosyntec consultants

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Certificate Number 14638

2023 Annual Groundwater Monitoring Report, Former Knottingley Tar Works

Prepared for

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Project Number: GCU0309002

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Final Report

Geosyntec consultants

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LIMITATION

Geosyntec Consultants Ltd (Geosyntec) has prepared this report for the sole use of FCC Environment (FCC) in accordance with the Agreement under which our services were performed. No other warranty, express or implied, is made as to the professional advice included in this report or any other services provided by us. This report may not be relied upon by any other party without the prior and express written agreement of Geosyntec, which will not be unreasonably withheld.

Unless otherwise stated in this report, the assessments made assume that the site and facilities will continue to be used for their current purpose without significant change. The conclusions and recommendations contained in this report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested. Information obtained from third parties has not been independently verified by Geosyntec, unless otherwise stated in the report.

Where assessments of works or costs required to reduce or mitigate any environmental liability identified in this report are made, such assessments are based upon the information available at the time and may be subject to further investigations or information which may become available. It is therefore possible that cost estimates, where provided, may vary outside stated ranges. Where assessments of works or costs necessary to achieve compliance have been made these are based upon measures which, in Geosyntec's experience could normally be negotiated with the relevant authorities under present legislation and enforcement practice, assuming a pro-active and reasonable approach by site management.

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1 GENERAL INTRODUCTION

1.1 Introduction

Geosyntec Consultants Ltd ("Geosyntec") have been appointed by FCC Environment (FCC) to undertake a deep groundwater quality monitoring programme in support of the on-going Non-Aqueous Phase Liquid (NAPL) recovery remediation program at the FCC Solvent Recovery Site situated off Weeland Road, Knottingley, WF11 8DZ (**Figure 1**). The purpose of the deep groundwater monitoring programme is to assess evidence as to whether the groundwater concentrations are stable or are declining as a result of implementing the ongoing remediation programme at the site. This report summarises results from three groundwater monitoring rounds undertaken in January, May and September 2023 and provides a comparison of the results against longer-term trends.

1.2 Site History and Project Background

The FCC Knottingley site was historically the location of a tar distillation works. The site was previously owned by Croda and latterly Tradebe. The eastern three quarters of the Knottingley site was purchased by FCC from Tradebe in 2022. The distillation works included 10 below ground tar wells (tanks) (see red circles on **Figure 2**) and multiple above ground processing/storage tanks and distillation plants. These were located across the central and western sections of the northern half of the current FCC property. It is understood that the tar wells had been decommissioned by the 1980s and were infilled with clean imported fill. Other above ground elements of the Tar Distillation plant have also been removed from site.

Various phases of intrusive site investigation undertaken on behalf of Croda in the 2000s identified shallow hydrocarbon contamination of soil and groundwater beneath the subject site and on adjoining land to the west, not purchased by FCC. These impacts included Light Non-Aqueous Phase Liquid (LNAPL) (in land to the west only) and, more frequently, Dense Non-Aqueous Phase Liquid (DNAPL) contamination. Dissolved phase and buoyant free phase emulsified hydrocarbons were also detected.

WS Atkins undertook initial risk assessment and remedial design works at the site on behalf of Croda and developed a Remedial Acton Plan (RAP) in 2008. WSP took over as consultants to Croda for contamination issues at the site in 2010. By 2011 further site investigation works had been completed which characterised widespread DNAPL impacts within the shallow Made Ground and underlying 'middle sand' deposits. These strata make up the "shallow aquifer" beneath the site. They are designated by the British Geological Survey as the 'Breighton Sand Formation' (formerly known as Vale of York Deposits) and are classified by the Environment Agency as a Secondary 'A' Aquifer.

Deeper sandy gravels of the Breighton Sand Formation, the "deep aquifer", are generally separated from the shallower deposits by an intermittent "middle clay" layer. The deep aquifer was demonstrated to be impacted by more localised and limited free and dissolved phase hydrocarbon impacts. Following the development of a detailed Conceptual Site Model (CSM) for the site in 2011, WSP identified potential risks to water quality in the adjacent River Aire from NAPL in the shallow

Made Ground and upper sand deposits via contaminant dissolution and migration to the river. The key contaminant migration pathway for the shallow contamination was via gaps in the middle clay and migration through the deeper aquifer.

WSP concluded that once mobile NAPL was removed from the site, significant risks to water quality in the River Aire from the site would be reduced. An initial remediation pilot trial comprising NAPL recovery took place between 2010 and 2013 in the western and northern section of the current FCC site in an area designated as "Cell 1" and "Cell 2". The pilot remediation works involved the extraction and separation of contaminated groundwater and NAPL from the Made Ground and middle sand deposits.

WSP prepared an updated RAP in 2013 that focused on removal of NAPL from the Made Ground and shallow aquifer across the affected area of the site. This was divided into 9 separate remediation cells (7 and a half of which were located on the current FCC site), comprising a total of 268 remediation wells. They also recommended that quarterly monitoring of surface water in the River Aire and deep groundwater quality take place to ensure that natural attenuation of residual contaminant mass along the migration pathway from the shallow source areas to the river was taking place.

An initial phase of remediation works at full-scale took place between June 2013 and June 2017, with a final WSP quarterly groundwater monitoring round undertaken in July 2017. Following this, NAPL rebound monitoring was undertaken across the remediation cell network in July 2018, November 2018 and January to April 2019. The rebound monitoring demonstrated the need for continued operation of the full-scale remedial works to address localised areas of potentially recoverable NAPL that remained in all 9 cells. Subsequently, the second phase of full-scale remedial works has resulted in the Environment Agency accepting that the RAP objectives being achieved in Cells 1, 2, 3, 4, 5 and 7. Cells 1, 2, 5, 7 and half 4 being within the current FCC boundary. Remediation of these areas has ceased with on-going NAPL recovery focused on wells in the remaining 3 cells. Deep groundwater monitoring has taken place at the site since June 2013, with groundwater monitoring data of some individual wells being available from as early as 2007. The groundwater quality in the deep deposits is well characterised. From 2021 onwards, deep groundwater monitoring at the Site has taken place every 6 months, with monitoring undertaken at this frequency considered adequate to identify significant changes that may occur in this groundwater horizon than the quarterly interval set out in the RAP (Ref. GCU0255007/ GB/JDWW). Following sale of the site to FCC in 2022, deep groundwater monitoring well WSP316 was removed from the monitoring network. Groundwater quality at this well has never shown any impact by contamination and the well is located hydraulically up-gradient of the remaining active remediation cells at the site.

This document sets out the results from three monitoring rounds undertaken in January, May, and September 2023 in the "deep aquifer" including groundwater quality and NAPL accumulation monitoring. A discussion of current site conditions compared to the baseline conditions and previous monitoring results obtained by both WSP and Geosyntec is also provided as are recommendations for further monitoring works.

2 GROUND WATER SAMPLING

2.1 Sampling Methods

Groundwater sampling of selected deep monitoring wells located across the FCC site at Knottingley and land to the north and east (see **Figure 2**) was undertaken between:

- 11th and 13th of January,
- 10th and 12th of May 2023, and
- 19th and 21st of September 2023.

Permission was obtained by Geosyntec on behalf of FCC from Croda to access their retained land to sample monitoring wells WSP309, WSP310, WSP314, WSP315 and WSP325. The network of wells and surface water sampling locations selected for sampling, aimed to mirror that utilised by WSP up to 2017. This sampling programme is also set out in the WSP RAP of 2013. The monitoring works comprised:

- Prior to sampling each monitoring well, the depth to groundwater was measured using an oil-water interface meter. This meter was also used to evaluate the presence and thickness of accumulations of dense or light non-aqueous phase liquids (DNAPL or LNAPL) within each groundwater monitoring well. The groundwater and NAPL elevation data for the January, May and September 2023 monitoring events are included in **Tables 1a - 1c** respectively.
- The purging and sampling of 26 No. (January 2023), 25 No. (May 2023) and 27 No. (September 2023) monitoring wells (WSP301-304, WSP306-315, WSP317-318, WSP323 & WSP325, WSP330 & WSP332, BH02/05/A, BH03/07/D, BH07/05/A, BH09-11/07/D and MW1A) and the sampling of 3 No. surface water points. Groundwater samples were collected by Geosyntec engineers using low flow/minimal disturbance sampling techniques. Peristaltic pumps and lengths of well dedicated 6 mm internal diameter polyethylene tubing were used to purge wells at low-flow rates (typically ≤ 250 ml/minute). Field measurements of hydrochemical parameters (temperature, pH, specific electrical conductance, dissolved oxygen and oxidation-reduction potential) were recorded during purging (collected every 5 minutes) using a pre-calibrated YSI Professional Plus Multi-Parameter Instrument until the readings were stable. Stabilisation of hydrochemical parameters was taken to indicate pumping of groundwater representative of in-situ conditions and therefore a representative groundwater sample could be collected. Purge volumes were commonly in the region of 5 to 10 litres.
- Records were made of notable visual/olfactory observations of contamination in the extracted groundwater during the purging and sampling works. These are summarised in **Tables 1a, 1b** and **1c** for the three monitoring rounds reported herein.
- In wells where NAPL or heavily impacted groundwater quality has previously been identified, there is the potential for contamination to damage the YSI Professional Plus Multi-Parameter Instrument. In these wells, as detailed in **Tables 1a, 1b** and **1c**, the Multi-Parameter Instrument

was not used. Instead, at these locations, groundwater was purged for 3 well volumes prior to sampling.

- An additional 8 monitoring wells were included in the original WSP monitoring programme, but these have either been damaged or are no longer relevant to the monitoring programme for the FCC site (see **Table 2**). WSP331 has been blocked since August 2020, with groundwater sampling from this installation no longer possible. In May 2023 it was not possible to access BH02/05/A due to location being buried under recently laid rubble. The well was dug out and found prior to the September monitoring round. WSP323 was buried beneath rubble prior to the January 2023 monitoring round and could not be sampled. This monitoring well was subsequently located and reinstated with a lockable flush cover as part of the April 2023 Headworks Improvement works (Ref GCU0309002/06/BC/GB).

Surface water samples were collected adjacent to the southern bank of the River Aire at three locations designated as Surface Water sampling points 1-3. Sampling at these locations involved:

- Attaching a weight to the polyethylene sample collection tubing and lowering it into the River Aire at the locations utilised by previous WSP/Geosyntec monitoring events.
- The sampling of river water via the tubing using a peristaltic pump. The samples were collected after recording field measurements with a YSI Professional Multi-Parameter Instrument, as described above.

2.2 Site Specific Health and Safety Measures

All Geosyntec field staff were provided with a FCC site safety induction prior to starting work. All site activities were covered by the FCC permit to work system and were supported by Geosyntec Health, Safety and Environment Plan, which included method statements, risk assessments and mitigation measures for all Geosyntec activities. Health and safety information for work undertaken on Croda owned land was additionally verified by Croda.

A basic level of PPE was used throughout the duration of the groundwater purging and sampling. This included safety boots, nitrile gloves, protective eyewear, hard hats and hi-vis reflective clothing. Disposable polyethylene Tyvek suits and Sundstrom half-face respirators with appropriate filters were brought to site as a precautionary measure (to be used in the event of gross free phase product being encountered).

Furthermore, life jackets were worn whilst working along the river channel during the collection of Surface Water Samples 1 to 3. In these isolated locations, Geosyntec employees worked in teams of two as an additional precaution so that the alarm could be raised in the event of an incident.

2.3 Waste management

General waste including gloves, tissues and tubing were disposed of into appropriate designated waste bins on-site as directed by FCC.

For all wells the purged groundwater was collected in 25 L plastic jerry cans before being transported to the on-site treatment plant for disposal.

The locations and methods for waste disposal was agreed in advance with FCC.

2.4 Laboratory Analysis

During all three groundwater monitoring rounds, once collected the samples were stored and chilled in a refrigerator. Upon the conclusion of each monitoring round the samples were securely packed and taken by courier to Element Deeside laboratory in a single batch under chain of custody procedures.

Water samples were analysed for the following suite of determinants:

- Electrical conductivity.
- Hydrocarbons, including benzene, toluene, ethylbenzene, xylenes, methyl tertiary butyl ether, naphthalene, speciated phenols and total petroleum hydrocarbon criteria working group fractions.
- Inorganic substances including sulphate (expressed as SO_4), nitrate (as NO_3), nitrite (as NO_2), sulphide, total alkalinity as $CaCO_3$ and dissolved methane; and,
- Metals including dissolved iron II, dissolved iron III and dissolved manganese.

See **Tables 3a** and **3b** for full sample inventories.

3 MONITORING RESULTS AND INTERPRETATION

3.1 Visual and Olfactory Evidence of Contamination in Deep Wells

The locations where observations were recorded of visual and/or olfactory evidence of contamination in the groundwater samples from the deep aquifer, during the January, May and September 2023 monitoring events, are shown in shown in **Figure 3.** Visual and/or olfactory evidence of contamination observed in the deep aquifer included:

- Micro emulsified buoyant NAPL[1] entrained in groundwater. This was noted to be prevalent in the samples from wells close to and down-gradient of areas where the overlying clay is believed, from previous drilling records, to be absent and therefore where NAPL has been able to migrate into the deep aquifer from the overlying shallow aquifer. The inferred lateral distribution of the emulsion relative to the clay layer breaches and deep groundwater flow regime is illustrated by **Figure 3**.

[1] Buoyant micro emulsified NAPL can result in the migration of free phase low solubility hydrocarbon mixtures of similar density to water

- Trace accumulations[2] of DNAPL were recorded during the sampling of deep monitoring wells MW1A, WSP330 and BH10/07/D (locations shown on **Figure 3**).
- DNAPL accumulations of 1.2-2.3m were consistently measured in well BH10/07/D during the baseline monitoring period that took place between January 2010 to October 2011. Since March 2020, DNAPL has periodically been absent from the well and has not exceeded 0.45m. However, iridescent sheens and hydrocarbon odours continue to be observed in the sampled groundwater at this location. BH10/07/D is located very near to an area where the middle clay is believed to be absent, and this has the potential to represent a past direct NAPL migration route from the shallow to the deep aquifer.
- DNAPL accumulation was measured in the MW1A monitoring well 0.4 m thick during the October 2010 baseline monitoring. Since then, observations of micro emulsified buoyant NAPL have frequently been made in the groundwater extracted during purging of this well. However, no accumulations of separate phase DNAPL has been detected using the interface probe at the base of the well. It is noted that this well is not screened across the whole depth of the deep aquifer and DNAPL accumulations may be present in the deep deposits below the base of the well screen at this location.
- Since Geosyntec commenced monitoring of WSP330 in April 2019, DNAPL accumulation has been occasionally identified, specifically in March 2020 (0.485 m) and February 2021 (0.290 m). In all other monitoring events either only trace levels or no DNAPL was identified. WSP330 is situated directly down-gradient of MW1A but was not part of the baseline monitoring scope.
- The locations where micro emulsified buoyant NAPL have been observed are inferred to be part of a broader area where visual and olfactory evidence of contamination have been noted (NAPL coatings on dip meter probes, hydrocarbon odours and dark coloured waters are observed in the deep groundwater). This area is illustrated by **Figure 3**.

Overall, the data indicates that DNAPL has been present at BH10/07/D from before 2010 but that this has reduced in thickness over the period of the remediation works on site. Similarly, DNAPL thickness has also reduced over time at MW1A. However, observations of NAPL coatings on probes and hydrocarbon odours along the northern boundary of the site down-gradient of the holes in the middle clay have been consistent since Geosyntec commenced groundwater monitoring in 2019.

[2] 'Trace accumulations' of DNAPL refers to the presence of a small amount of NAPL on the interface probe end but not a substantial enough volume to trigger a detection from the interface probe. Nominally <1cm of NAPL.

3.2 Groundwater Levels

Measured deep groundwater elevations from the January, May and September 2023 monitoring events are presented in **Tables 1a, 1b** and **1c** respectively. Inferred groundwater flow regimes are displayed for January, May and September 2023 in **Figures 4a, 4b** and **4c** respectively.

Deep groundwater flow at the site is generally towards the River Aire, in a northeasterly direction in the west of the site and a northwest direction in the east of the site . Groundwater recharge mounds are inferred to be present in the Deep Groundwater where the middle clay is absent, allowing groundwater to flow from the shallow aquifer into the deep aquifer. Previous real time groundwater level monitoring has shown that the deep aquifer is in continuity with the River Aire, with groundwater discharge to the River Aire likely occurring between WSP330 and WSP332 at times of normal or low river levels. At times of high river level surface water from the River Aire likely discharges to deep groundwater beneath the site in this area.

The inferred groundwater flow regime from May 2023 is consistent with that observed over the majority of previous groundwater monitoring events at the site when levels in the River Aire have been low or around normal. Groundwater levels decrease from between 7 to 8 m AOD in the south of the site and around the groundwater recharge mounds to around 6.1 m AOD near to the River Aire. Flow is towards the north with discharge occurring to the river.

The January 2023 monitoring round coincided with extremely heavy rainfall that led to the River Aire bursting its banks in the vicinity of the site in the days following the monitoring round. Shallow groundwater flow in the south of the site is generally northwards to the River Aire and recharge mounds are visible where gaps are present in the middle clay. However, within 50 m of the bank of the River Aire between WSP330 and WSP332 groundwater flow is into the site from the River Aire, i.e. the River Aire is losing water. Groundwater levels were measured at 7.7 m AOD or greater across the entire site during this monitoring round.

The September 2023 monitoring round coincided with heavy rainfall immediately prior to Storm Agnes, which caused water levels in the River Aire to rise. Between within 50 m of the bank of the River Aire between WSP330 and WSP332 groundwater flow is again into the site from the River Aire.

3.3 Current Deep Aquifer Groundwater Quality Compared Against Baseline

Graphs of water quality data over time for deep groundwater monitoring wells are presented in **Appendix A.** The inferred extent of TPH impacts to deep groundwater quality and trends (plotted on consistent scales so that the relative degrees of impact are better illustrated) over time for selected wells are presented in **Figure 5a**. **Figure 5b** has trend plots with varying scales so the full trend for individual wells can be observed.

From the analysis presented as **Figures 5A & B** it is inferred that the there are two broad areas of high total petroleum hydrocarbon (TPH) concentrations in deep groundwater. These are generally consistent with the areas in which the micro emulsified NAPL has been identified in the deep aquifer as shown in **Figure 3**. These two areas relate to contamination having migrated down from the shallow

aquifer to the deep aquifer through holes in the middle clay and identified DNAPL in the deep aquifer at BH10/07/D and MW1A.

The following trends can be inferred in the water quality data over the 13-year period from baseline conditions to the present:

- A TPH plume is inferred to be present down-gradient of a hole in the middle clay centred around WSP323 and WSP303 in the west of the site near to Bank Dole Cut.
    - At WSP323 total TPH concentrations are shown to be relatively stable over the last 6 years with measured concentrations of 4,990 and 10,053 µg/l in May and September 2023 respectively (the well could not be sampled during the January monitoring round). These results are within the range previously measured at this location of 245 – 24,100 µg/l detected in groundwater samples collected at this location.
    - WSP303 has displayed a long-term decreasing trend in TPH concentrations, with measured concentrations decreasing from 10,500 µg/l in January 2014 to 282 µg/l in September 2021. Concentrations have since partially rebounded but have remained stable between 1,200 – 2,000 µg/l since February 2022.
    - TPH concentrations at WSP301 (directly down-gradient of the area with higher concentrations) have shown a stable or slightly decreasing trends since January 2015 and have remained less than the laboratory detection limit of 10 µg/l since May 2017.
    - A modest rise in the TPH concentration was measured in WSP302 throughout 2023, with measured concentrations rising from <10 µg/l (January 2023) to 220 µg/l and 649 µg/l in May and September 2023 respectively. WSP302 is situated immediately downgradient of WSP303. The measured TPH concentrations in WSP302 are within the range of concentrations measured at WSP303 since the start of monitoring in 2013.
- Localised DNAPL has been measured historically at MW1A in the central northern section of the Site (See **Figures 5A&B**). DNAPL in this area is likely dissolving in groundwater causing the measured higher TPH concentrations at the MW1A and WSP330 monitoring wells, in a thin (less than 20m wide) zone. TPH concentrations at WSP330 and MW1a were measured between 20,764 µg/l and 131,343 µg/l in 2023 respectively. These results are within the range of concentrations previously measured at these locations. Within 25 m of MW1A and WSP330 bordering wells, WSP304 and WSP306, continue to record total TPH of less than 15 µg/l.
- A TPH plume is present centred around BH10/07/D in the east of the site near the location of an inferred hole in the middle clay. DNAPL was previously measured in this well. Between July 2013 and April 2020 TPH concentrations were relatively stable between 15,000 – 50,000 µg/l. Since April 2020, concentrations trends have been sporadic, with higher TPH concentrations exceeding 100,000 µg/l measured in September 2021 (279,159 µg/l), February 2022 (112,231 µg/l) and September 2023 (146,611 µg/l) respectively. These more elevated concentrations are above some of the hydrocarbon compound solubility limits and indicate the

presence of emulsified product within the samples. However, decreasing DNAPL thicknesses measured at this location suggest that conditions are improving as a result of remediation in the shallow strata feeding this impact.

- TPH concentrations at WSP317, located to approximately 30 m east of BH10/07/D, have been largely stable since baseline conditions were recorded in 2013. TPH concentrations of 4,670 µg/l, 9,024 µg/l and 6,784 µg/l were measured in January, May and September 2023 respectively. All results are within the TPH range historically measured at this location (517 – 14,733 µg/l).
- Down-gradient to the north of the TPH plume centred at BH10/07/D, a decrease of TPH concentrations was measured at WSP306, WSP307 and WSP308 since the start of remediation, suggesting that contaminant migration into the deep aquifer is also reducing in this area. A maximum TPH concentration of 34,500 µg/l was measured in WSP307 in January and April 2015. Since May 2017 TPH concentrations have been measured at 1,006 µg/l or less. BH09/07/D, also situated down-gradient of BH10/07/D, has displayed a consistent decrease in measured TPH concentrations of nearly an order of magnitude from 11,500 µg/l in July 2015 to 1,894 µg/l in September 2023.
- WSP318, is located in the riverbank area. Measured TPH concentrations in WSP318 have been less than detection limits in 8 out of the last 10 groundwater monitoring rounds. However, an uncharacteristic elevated TPH concentration of 889 µg/l was recorded in February 2022, which was attributed to the short-term alterations in the local groundwater flow regime resulting from the high surface and groundwater elevations arising as the result of Storm Dudley. Throughout 2023, TPH concentrations in WSP318 have remained less than detection limits and therefore the February 2022 result is considered an anomaly, not an indicator of migrating contamination.
- WSP313 has shown a steady decreasing trend in measured TPH concentrations from 2,980 µg/l in April 2016 to 695 µg/l in September 2023. This suggests a decrease of contaminant flux to the deep aquifer at this location.
- BH02/05/A is located in the south of the Site up-gradient of identified sources of on-site contamination. Throughout 2023 TPH concentrations have been measured at baseline levels (10 – 700 µg/l), following elevated results in February 2021 (1,240 µg/l). The February 2021 anomalous result may have been due to the sample incorporating impacted sediment from the base of the well.
- A low concentration of TPH (33 µg/l) was measured at WSP311 in September 2023. This well is located at the periphery of the site where usually the TPH analysis results are less than the laboratory detection limit. TPH measured was made of low chain length aliphatic hydrocarbons which typically biodegrade quickly.

In conclusion, the groundwater quality in the deep aquifer is similar to baseline conditions with longer term improvements observed in some areas. The shallow groundwater remediation programme appears to have resulted in some sustained improvements in the deep aquifer groundwater quality.

3.4 Current Surface Water Quality in River Aire Compared Against Baseline

Graphs of water quality data over time for surface water sampling locations are presented in **Appendix A.**

At the River Sampling point mid-steam (Surface Water 2 – **Figure 2**) to the site, dissolved phased hydrocarbons have been measured at very low or trace levels in the majority of samples taken between July 2013 and September 2023. Dissolved TPH concentrations have only been measured above the laboratory limit of detection of 10 µg/l on 2 occasions at this location. These were in January 2015 (3,060 ug/l) and May 2017 (90 µg/l). The elevated January 2015 value coincided with high concentrations in the upstream River Aire sample and is considered likely to relate to an up-stream source.

At the down-steam River Aire sample point (Surface Water 3 – **Figure 2**) has measured dissolved Total TPH concentrations above the laboratory limit of detection of 10 µg/l have only been measured on 3 occasions. The last time being in October 2016 (222 µg/l). At the downstream sample naphthalene has been measured below its Water Framework Directive (2015) freshwater annual average EQS of 2 µg/l in 24 out of 26 occasions it has been sampled since 2013 with an average concentration of 0.55 µg/l. Phenol and toluene have not been measured above their laboratory limit of detection in the down-stream sample and benzene has not been measured above its freshwater annual average EQS of 10 µg/l in the down-stream sample.

Over the last year all TPH fractions, phenols and all BTEX compounds have been measured below their laboratory limit of detection in all surface water samples. Very low levels of polycyclic aromatic hydrocarbons were recorded albeit at similar levels in the up-stream, mid-stream and down-stream samples. As such, there remains no identifiable impact of the site upon water quality in the River Aire.

3.5 Assessment of Current Data Against Findings of Previous DQRA

3.5.1 DQRA Summary

The WSP Detailed Quantitative Risk Assessment (DQRA) presented as part of their CSM 2011 report modelled the risk to the River Aire from dissolved phase hydrocarbon contamination at the site. This approach assessed the risk to water quality in the River Aire from dissolution of NAPL within the shallow aquifer and migration as a dissolved phase via the deep deposits. The DQRA pathway considered dilution of contamination in groundwater as it entered the deep aquifer from the shallow aquifer, lateral migration of groundwater in the deep aquifer and dilution of the groundwater into the River Aire. The model did not consider further migration of the NAPL in the deep aquifer identified at BH10/07/D and MW1A. WSP concluded that "once the removal of the mobile NAPL source is undertaken, there is unlikely to be significant risks to the River Aire from the residual dissolved phase

contamination at the site". Based on evidence at the time, WSP considered there to be "no compelling evidence" to suggest the site is adversely affecting water quality in the River Aire.

The DQRA report considered there to be anaerobic degradation of dissolved phase contaminants within the deep aquifer. The 2011 CSM report identified there to be some evidence for mildly reducing microbial biodegradation processes to be occurring at the site. However, it was concluded that there were no clear trends in the data. Groundwater was estimated to flow c. 40 m/ year in the deep aquifer. The site at its closest point is 25 metres from the River Aire, leaving limited time for any microbial attenuation to take place. Dilution rather than biodegradation was suggested to be the dominant attenuation process.

3.5.2 Assessment of Data

The visual and olfactory evidence of contamination within the Deep Aquifer suggests a reduction of mobile NAPL in the deep aquifer over time (See Section 3.1).

In groundwater, electron acceptors are used sequentially by microorganisms to support the biodegradation of petroleum hydrocarbons. At the outer limits of a contamination zone dissolved phase oxygen is used as the preferential electron acceptor to break down hydrocarbons (via aerobic respiration). Dissolved oxygen in groundwater is often quickly used up by microorganisms to degrade natural and pollutant organic compounds and as a result limited or no dissolved oxygen is often present in the core of hydrocarbon impacted groundwater plumes. Within the core of contaminant plumes anaerobic reduction processes predominantly occur to break down hydrocarbons. Electron receptors, if present, are sequentially used up by microorganisms to break down the hydrocarbons as conditions become more reducing. Nitrate reduction processes occur first (dissolved phase NO_3^- converted to NO_2^- or N_2), followed by, in order, manganese reduction (MnO_2 in minerals converted to Mn^{-2}), iron reduction (Fe^{3+} in minerals converted to Fe^{3+}) and sulphate reduction (dissolved phase SO_4^{2-} converted to H_2S). Even if an electron receptor is present, reduction processes will not occur if the appropriate microorganism is not present. Other hydrochemical conditions in an aquifer may also inhibit a biodegradation process from occurring. In the centre of petroleum hydrocarbon plumes methanogenesis often occurs. At this point no electron receptors are left and methanogenic bacteria directly break down hydrocarbons through fermentation to create methane and energy. This is often a slower process than other biodegradation pathways.

Measurements of natural attenuation indicator parameters (electron receptors, methane and other indicators that conditions are suitable for degradation) from the January, May and September 2023 groundwater monitoring rounds have been assessed against guidance in Environment Agency Research and Development Document 95.

- pH and temperature are measured at a suitable range for microbial degradation to occur.
- Low Dissolved Oxygen (DO) concentrations:
    - Were measured below 1 mg/l indicative or aerobic conditions, except:

- In January 2023 at BH02/05/A (5.29 mg/l), BH07/05/A (2.32 mg/l) and WSP309 (1.68 mg/l) up-gradient of on-site contamination sources in the south of the site. Elevated oxygen concentrations may relate to influx of high volumes of oxygenated rainwater migrating into the site from up-gradient during a known period of high rainfall.
- In January 2023 at BH09/07/D (1.29 mg/l), WSP301 (1.84 mg/l), WSP302 (1.48 mg/l), WSP304 (1.41 mg/l) and WSP306 (2.11 mg/l) in the north of the site. Elevated oxygen concentrations may relate to influx of oxygenated surface water from the river air at this time.
- In January 2023 at BH11/07/D (4.39 mg/l), WSP312 (1.07 mg/l) and WSP313 (1.48 mg/l). Elevated oxygen concentrations may relate to influx of high volumes of oxygenated rainwater through nearby holes in the middle clay.
- In May 2023 at WSP313 (1.79 mg/l) cross-gradient of the main plume;
- In September 2023 at WSP310 (1.41 mg/l) up-gradient of the main plume.

Limited dissolved oxygen is detected in groundwater across the site in hydrocarbon impacted areas of the deep aquifer and therefore limited potential to support aerobic biodegradation processes. Concentrations are below 1 mg/l in more than half the samples collected at the Site suggest aerobic biodegradation of dissolved phase hydrocarbons is unlikely to be material beyond the periphery of the plume. However, there is considered to be the potential for some anaerobic degradation to be occurring in locations where the dissolved oxygen levels are measured <0.5mg/l, which includes 12%, 52% and 30% of the locations monitored in January, May and September 2023.

- Nitrate was measured above 1 mg/l at only 2 locations in January 2023 (BH09/07/D (51.4 mg/l) and WSP309 (1.2 mg/l)) and one location in May 2023 (WSP301 (1.96 mg/l), all other measurements in 2023 were <1 mg/l. Since 2019 nitrate has been reported below detection limits at most locations, with concentrations infrequently measured > 1 mg/l at WSP301, WSP306, WSP309, WSP311, WSP312, WSP332, BH09/07/D and BH10/07/D. Results suggest that either limited nitrate is present in the groundwater for biodegradation or that nitrate is rapidly consumed by nitrate reducing bacteria biodegrading hydrocarbons.
- Nitrite is periodically observed in deep groundwater in the eastern section of the site up gradient and within the contaminant plume. Nitrite can be formed through the partial reduction of nitrate during biodegradation of hydrocarbons. Nitrite has been periodically detected at low concentrations in deep groundwater samples collected at the site. In January 2023 low concentrations of nitrite were measured at BH09/07/D (1.93 mg/l) coincident with the high nitrate concentrations. In WSP309 nitrite was measured between 0.024 and 0.085 mg/l throughout the year. Concentrations may be attributed to the partial reduction of nitrate during biodegradation of hydrocarbons. Very low (<0.02 mg/l) concentrations elsewhere may

indicate that nitrite, following generation from nitrate reduction, may be reducing further to ammonium or nitric oxide.

- As outlined above, nitrate is periodically present in groundwater beneath the site, with nitrite also present at low concentrations. As such there is potential for nitrate to contributing as an electron acceptor in the biodegradation of hydrocarbons at the site.
- Dissolved Manganese concentrations were measured between 0.05 and 1.90 mg/l throughout 2023, consistent with previously measured concentrations. Dissolved iron (II) concentrations were measured up to 10.3 mg/l in September 2021 and up to 2.55 mg/l in February 2022. No clear trends in the dissolved metals data between areas impacted by dissolved phase hydrocarbons and those un-impacted are observed across the site. It is therefore unclear whether metal reducing anaerobic degradation process are taking place at the site.
- Variable sulphate concentrations (<0.5 mg/l to 354 mg/l) were observed across the site during the monitoring period, with high concentrations available as an electron acceptor for degradation. Only trace levels of sulphide (<0.35 mg/l) was identified in groundwater in 2023. Previously up to 5.71 mg/l sulphide (July 2019) has been measured in samples from BH09/07/D. Sulphide is present in groundwater as hydrogen sulphide (H_2S) which is volatile and gives off a rotten egg like or reducing odour. Observations of reducing odours are consistently measured for several wells during monitoring and may indicate that hydrogen sulphide is being formed. Reducing odours were measured in at least one of the monitoring rounds in 2023 in: BH07/05/A, WSP301, WSP302, WSP306, WSP309, WSP314, WSP318 and WSP325. The groundwater monitoring data suggests sulphate reduction maybe occurring in deep groundwater at the site, specifically in areas down-gradient of NAPL sources. It is noted that sulphate contamination may be present at the site related to the historical tar distillation works and this may be complicating any observed trends where sulphate has been depleted by anaerobic biodegradation processes.
- Dissolved methane concentrations across the site are presented on **Figure 6**. Elevated dissolved methane concentrations are typically observed in conjunction with higher dissolved hydrocarbon concentrations, with dissolved methane concentrations up to 26.7 mg/l measured at the site in 2023 consistent with the previously measured range. The high levels of methane within the centre of the hydrocarbon plumes indicate that it is likely being generated by hydrocarbon fermentation.

In summary, groundwater quality data suggests that in some areas of the site, predominantly those down-gradient of NAPL sources, anaerobic degradation processes (methanogenesis, sulphate reduction and potentially limited nitrate reduction) are occurring. The mass per litre of total petroleum hydrocarbons degraded by anaerobic processes has been estimated. For these simple calculations, petroleum hydrocarbons have been assumed to be present as benzene. In the centre of the hydrocarbon plumes c. 20 to 40 mg/l of methane is being produced. For this to be present it is estimated that between c. 26 and 52 mg/l of total petroleum hydrocarbons in groundwater is being

degraded via methanogenesis. Up to 6 mg/l of sulphide is observed in groundwater at the site in recent years. If present due to degradation of hydrocarbons via sulphate reduction this is equivalent to c. 4 mg/l of total petroleum hydrocarbons being degraded. Nitrate has been recorded up to 2 mg/l during the current monitoring period at the site. If this amount of nitrate was used to degrade hydrocarbons via nitrate reduction this is equivalent to the degradation of 0.16 mg/l of total petroleum hydrocarbons. This gives a total estimated mass of total petroleum hydrocarbons degraded in the centre of the plume of up to c. 56mg/l. In the centre of the hydrocarbon plumes the total petroleum hydrocarbon concentrations is identified to be around 10 to 100mg/l. This analysis suggests that natural degradation processes at the site in the deep aquifer are degrading a large portion (c. 30 to >75%) of the dissolved phase hydrocarbon mass entering into the deep aquifer. However, a portion of the hydrocarbon mass is still observed, at least locally, to reach the bank area of the River Aire.

During high rainfall events aerobic water flows into the site from the River Aire and from rainwater, with localised dissolved oxygen concentrations of between 1 to 5 mg/l. If all this oxygen is used via aerobic degradation it could degrade up to 1.6 mg/l of petroleum hydrocarbons.

Analysis indicates that methanogenesis is the main process by which petroleum hydrocarbons are being biodegraded at the site.

All available river data has been assessed to determine, whether the site is adversely affecting the water quality of the River Aire. No clear trends in river water quality are observed over time (Appendix B). In the January 2015 monitoring round, there was a spike detected in river water TPH concentrations. However, this was at least partly due to an influx of contamination from up-stream sources. Since that time, low surface water concentrations have been recorded. In September 2021 there was an isolated incident when Geosyntec site engineers observed an iridescent sheen on the surface of the River Aire, on the jetty north of the Bank Dole Cut near the surface water mid-stream sampling point. The iridescent sheen was not observed to be emanating from the bank and may have been due to leaks from the oil-water drainage interceptor present at this location, it is unlikely it is a result from migration of contamination from site. Despite this visual sign of contamination, from September 2021 to 2023 the TPH concentrations upstream, mid-stream and downstream of the site were all below laboratory limits of detection. As such, the site is not considered to be demonstrably adversely affecting the quality of the River Aire.

3.6 Conclusions & Recommendations

Measured concentrations of contaminants and natural attenuation parameters in groundwater are considered to be broadly supportive of the conclusions in the WSP 2011 DQRA for the site. Analysis indicates that microbial degradation in the deep aquifer has the potential to degrade 30 to 75 % of measured dissolved phase concentrations. Residual contamination is diluted to low concentrations below detection limits/ environmental quality standards as it discharges as baseflow to the River Aire. The water quality in the River Aire is not considered to be adversely affected by the site, as seen from data from all recent monitoring rounds.

No significant deterioration in groundwater quality is indicated to have occurred in the deep aquifer, with the visual and olfactory evidence of contamination remaining stable or decreasing within the aquifer over time. However buoyant mobile NAPL micro emulsion continues to be observed down-gradient of NAPL sources. DNAPL accumulation was identified to be present at trace levels (NAPL present on interface probe but not measurable as a phase separated layer) at BH10/07/D and WSP330 in the deep aquifer during this monitoring period. NAPL emulsion impacts should be considered to represent part of the contamination plume rather than representing NAPL source area migration.

The general approach of the WSP Remedial Action Plan was that remediation would remove recoverable sources of NAPL from the shallow strata and that natural attenuation (dilution and biodegradation) processes would be sufficient to reduce residual dissolved phase contamination to acceptable levels upon entering the River Aire. Current data suggests that buoyant NAPL micro emulsion may be contributing to the relatively elevated total "dissolved phase" hydrocarbon contaminant concentrations detected in WSP323 and WSP330 close to the bank of the River Aire. Groundwater monitoring data indicates that sulphate reduction and methanogenic processes within the hydrocarbon plume are contributing to the degradation of petroleum hydrocarbons in deep groundwater. This is significantly reducing the petroleum hydrocarbon flux from groundwater reaching the River Aire, although some contamination is still reaching groundwater in the riverbank area. No adverse impacts to surface water quality have been identified from samples of the River Aire itself. The data is supportive of dilution and degradation reducing residual dissolved phase contamination to acceptable levels. The data indicates that groundwater concentrations in the deep aquifer are generally stable or decreasing over time. There is considered to be sufficient data coverage of the site with the available well network and re-drilling of lost wells is not considered to be necessary.

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Geosyntec Consultants trust the information and discussion contained in this report meets all your immediate requirements. Please do not hesitate to contact the undersigned if you have any further comments or questions about any aspect of the work.

Respectfully submitted,

On behalf of Geosyntec Consultants

Bob Crabtree
Senior Staff Hydrogeologist

Gareth Barns
Project Professional

Jim Wragg
Senior Principal

Geosyntec consultants

engineers | scientists | innovators

FIGURES

Allerton Bywater
Castleford
Knottingley
Eggborough
Pontefract
Whitley

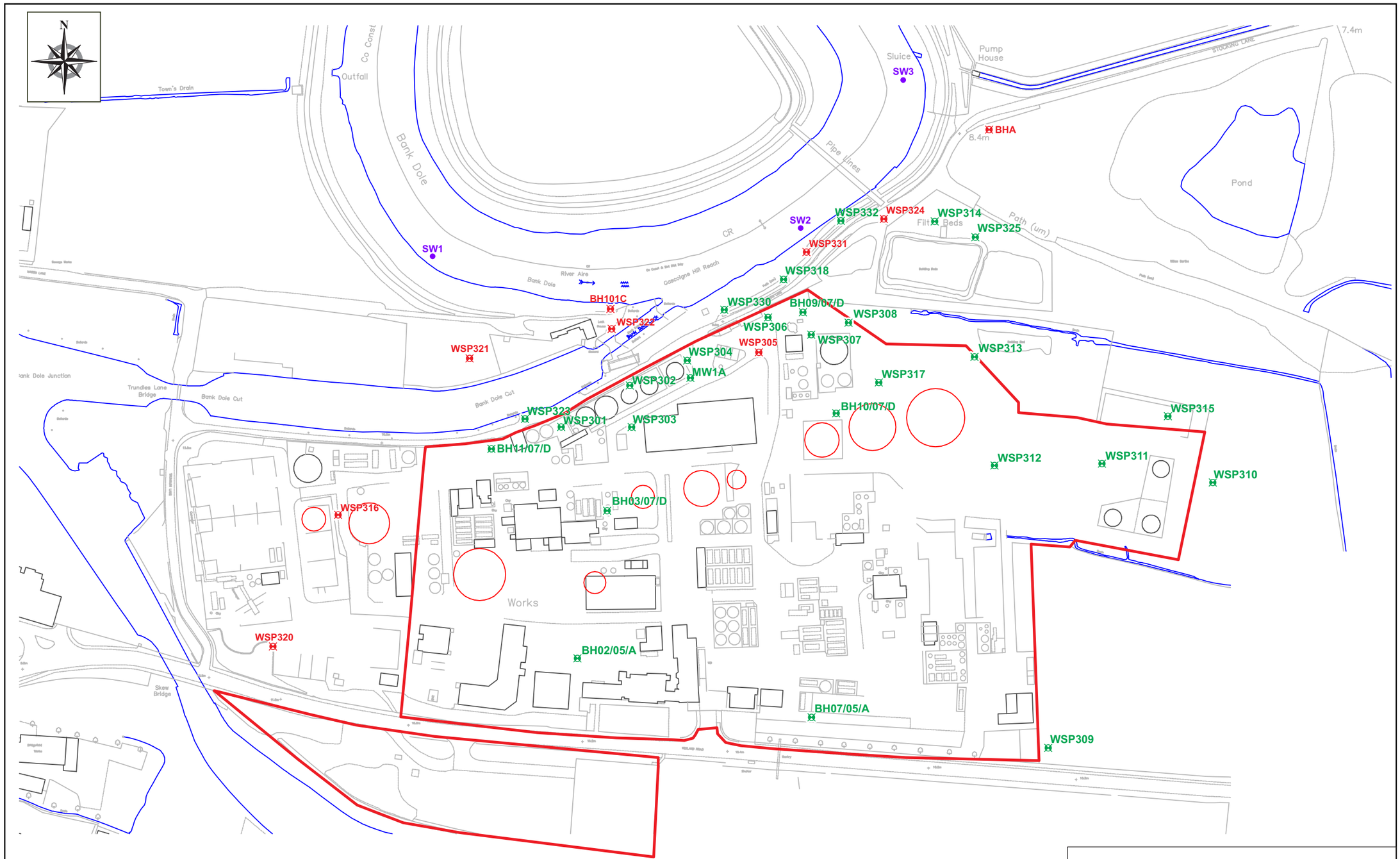
N

Approximate Scale

0m 3000m

Site Location Plan

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure 1
Delph, UK	November 2023	



KEY

Screened Lithology

- Sampled Deep Deposits Location
- Not Sampled Deep Deposits Location
- SW2 Surface Water Sampling Location

0 50 100

APPROXIMATE SCALE (m)

Quarterly Monitoring Location Plan

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure 2
Delph, UK	November 2023	

Well	MW1A
NAPL thickness (m)	
Oct-10	0.40
Aug-11	0.00
Jul-19	0.00
Mar-20	0.00
May-20	0.00
Aug-20	0.00
Nov-20	0.00
Feb-21	0.00
Sep-21	0.00
Feb-22	0.00
Jan-23	0.00
May-23	0.00
Sep-23	0.00

Well	WSP330
NAPL thickness (m)	
Aug-19	0.00
Mar-20	0.485
May-20	Trace
Aug-20	0.00
Nov-20	0.00
Feb-21	0.29
Sep-21	0.00
Feb-22	-
Jan-23	0.00
May-23	Trace
Sep-23	Trace

Well	BH10/07/D
NAPL thickness (m)	
Oct-10	2.37
Aug-11	1.72
Jan-19	1.24
Jul-19	See Note 1
Mar-20	0.16
May-20	0.38
Aug-20	Trace
Nov-20	0.45
Feb-21	0.38
Sep-21	0.00
Feb-22	-
Jan-23	0.00
May-23	Trace
Sep-23	Trace

Inferred lateral extent of Visual and Olfactory Evidence of Contamination in Deep Aquifer

WSP332 WSP314 WSP325 WSP318 WSP330 BH09/07/D WSP308 WSP306 WSP307 WSP304 MW1A WSP302 WSP313 WSP317 WSP323 WSP301 WSP303 BH10/07/D WSP315 BH11/07/D WSP312 WSP311 WSP310 BH03/07/D BH02/05/A BH07/05/A WSP309

Town's Drain · Outfall · Co Const · Bank Dole · Pump House · Sluice · Pipe Lines · Path (um) · Gascoigne Hill Road · Bank Dole Junction · Trundles Lane Bridge · Bank Dole Cut · Skew Bridge · Works · 7.4m · 8.4m

Key

- Inferred Deep Groundwater Flow Vector
- Sampled Deep Deposits Location
- DNAPL recorded in deep aquifer
- Inferred Area where the Clay Layer is Absent

Groundwater Contamination Observations

January 2023 May 2023 Setpember 2023 — **NAPL micro emulsion present**

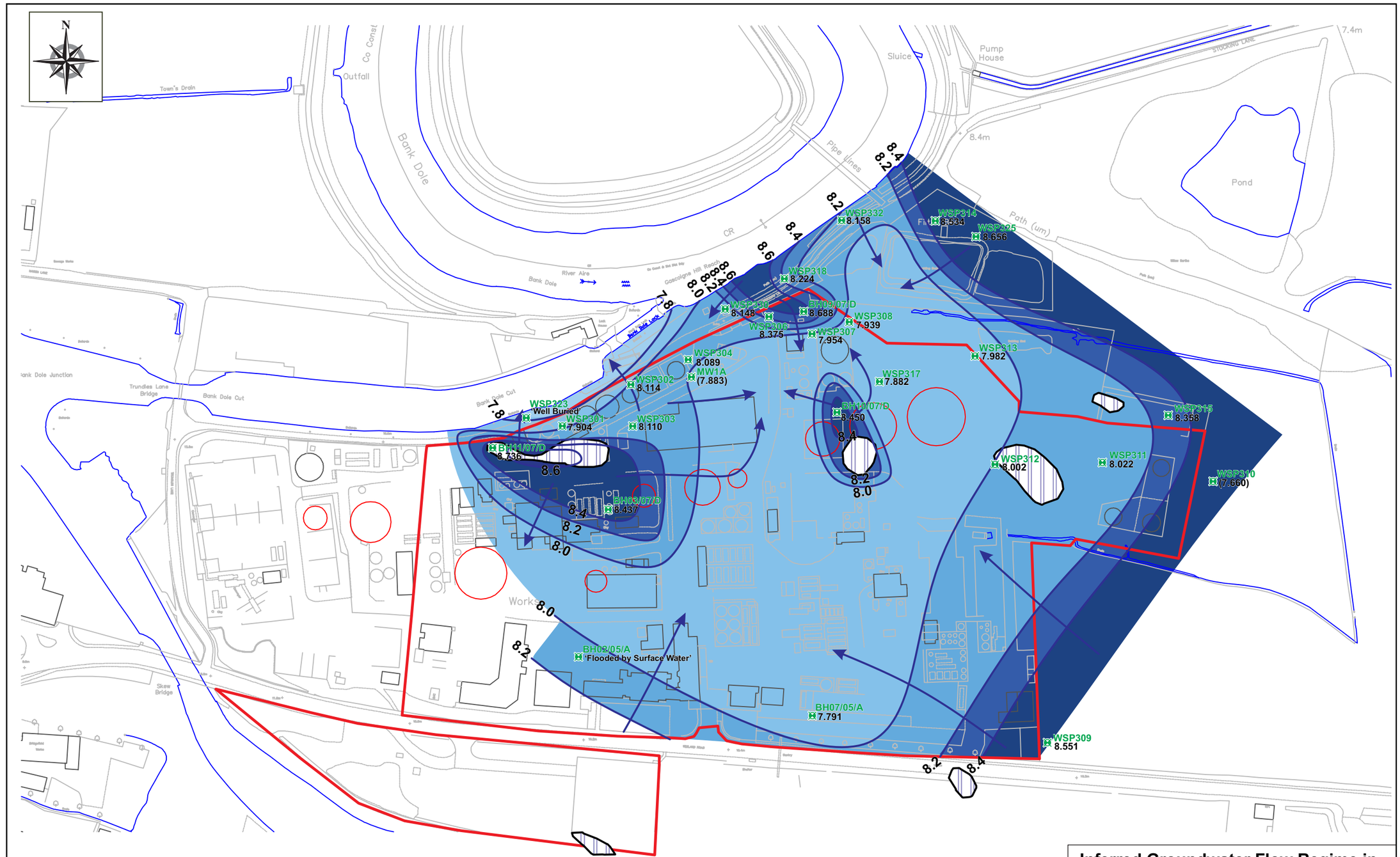
January 2023 May 2023 Setpember 2023 — **Hydrocarbon Odours**

Note:
1. DNAPL observed during monitoring, but not recorded by probe.
2. No NAPL thickness monitoring data available from WSP330 pre July 2019.
3. DNAPL thickness levels not available between August 2011 - January 2019 and February 2022

0 50 100
APPROXIMATE SCALE (m)

Inferred Extent of Deep Aquifer Contamination Observations

Knottingley, UK	GCU0309002	
Geosyntec consultants / FCC Environment		Figure 3
Delph, UK	November 2023	



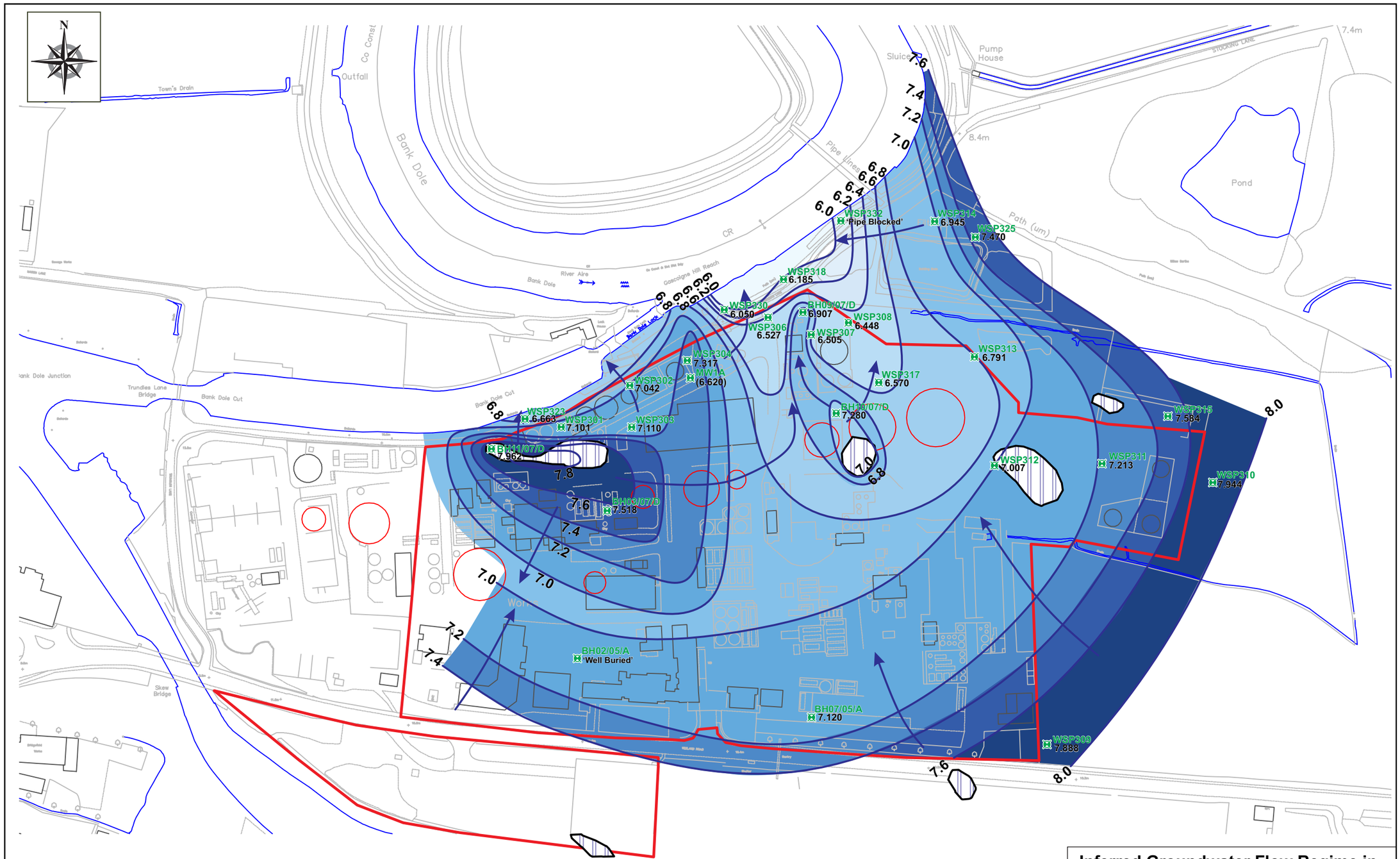
KEY

- Sampled Deep Deposits Location
- SW2 Surface Water Sampling Location
- Inferred Area where the Clay Layer is Absent
- Inferred Deep Groundwater Contour Elevation
- **7.170** Groundwater Elevation (mAOD)
- Inferred Deep Groundwater Flow Vector

0 50 100
APPROXIMATE SCALE (m)

Inferred Groundwater Flow Regime in the Deep Deposits, January 2023

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure **4a**
Delph, UK	November 2023	



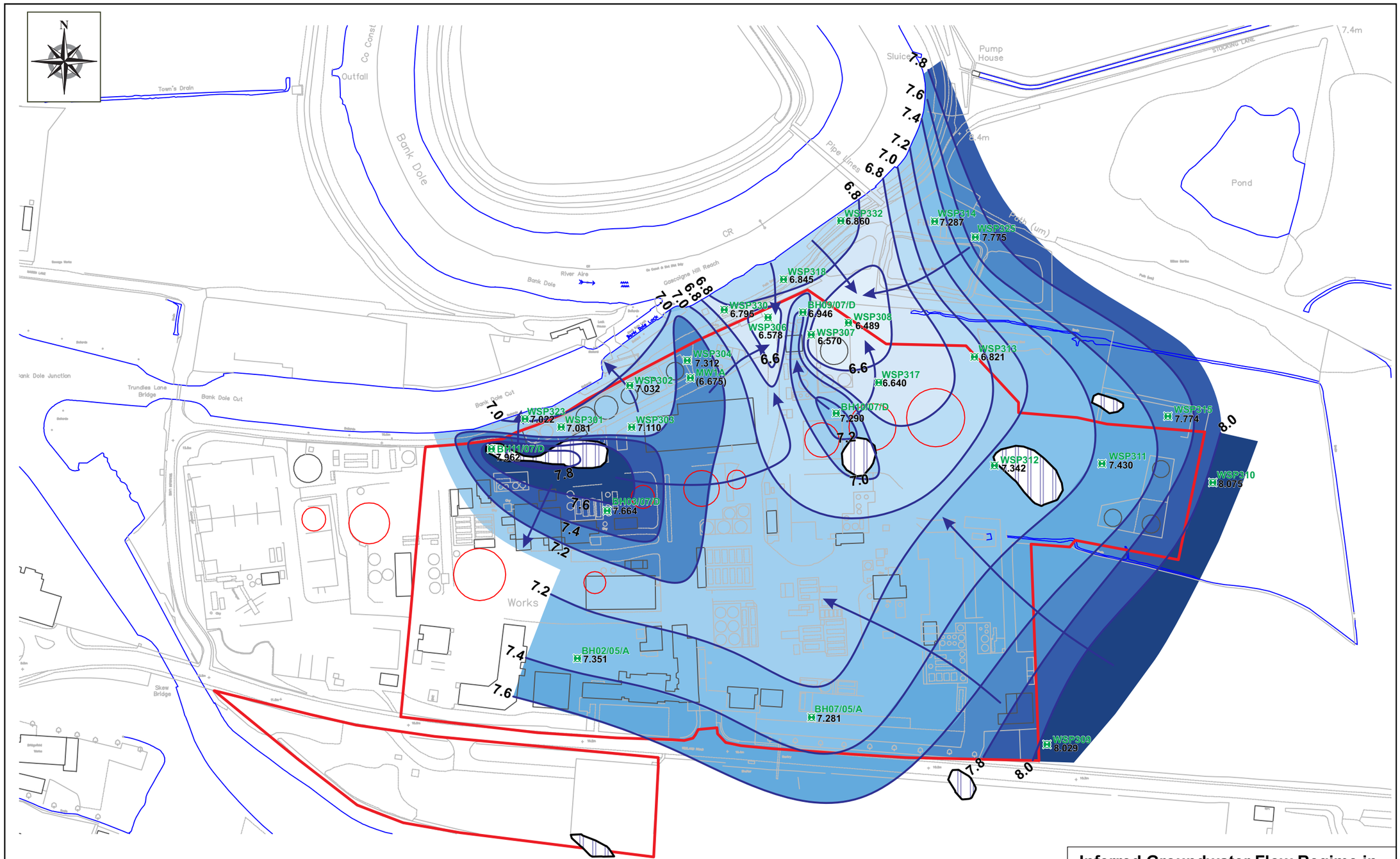
KEY

- Sampled Deep Deposits Location
- SW2 Surface Water Sampling Location
- Inferred Area where the Clay Layer is Absent
- Inferred Deep Groundwater Contour Elevation
- **7.170** Groundwater Elevation (mAOD)
- Inferred Deep Groundwater Flow Vector

0 50 100
APPROXIMATE SCALE (m)

Inferred Groundwater Flow Regime in the Deep Deposits, May 2023

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure **4b**
Delph, UK	November 2023	



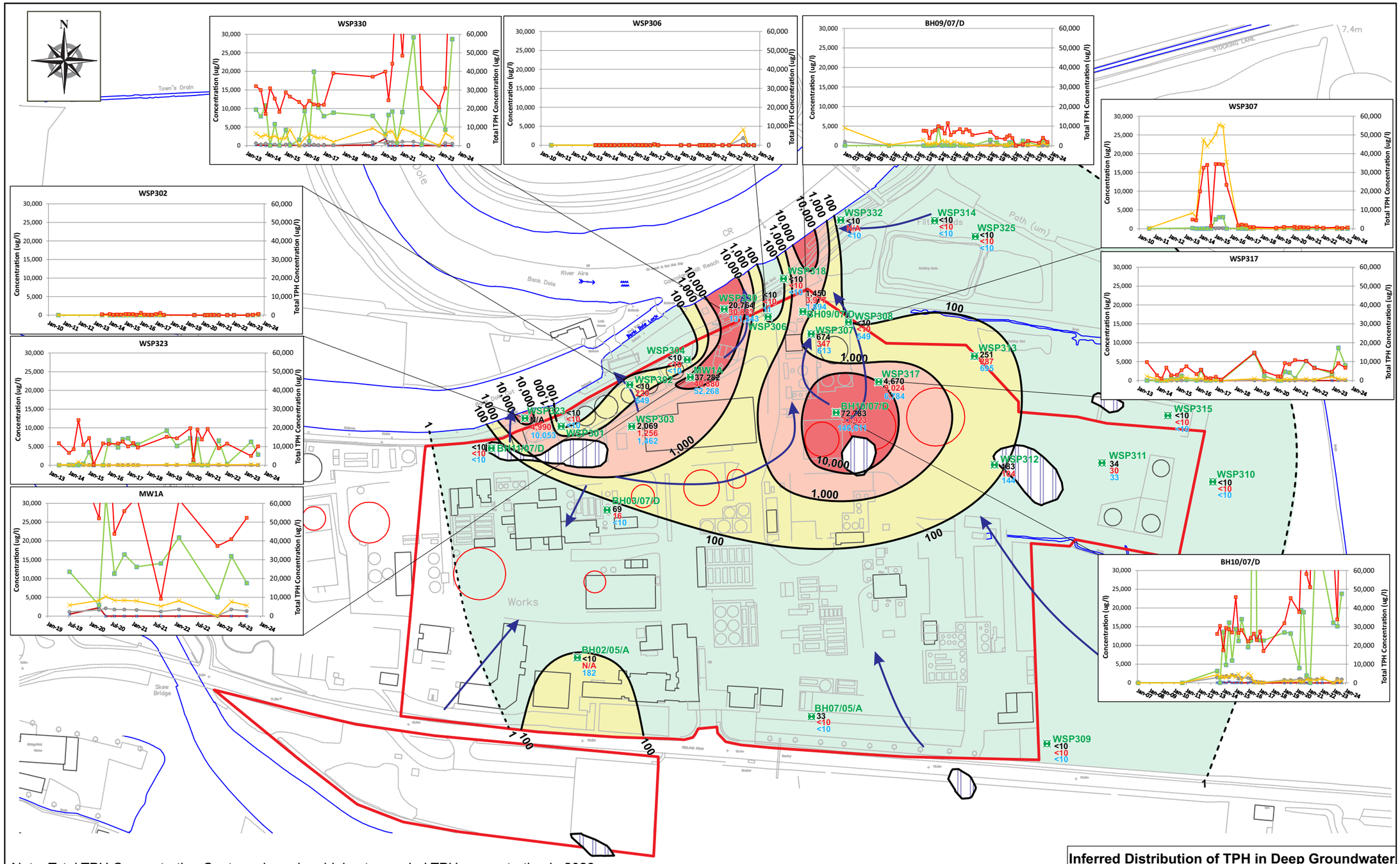
KEY

- Sampled Deep Deposits Location
- SW2 Surface Water Sampling Location
- Inferred Area where the Clay Layer is Absent
- Inferred Deep Groundwater Contour Elevation
- **7.170** Groundwater Elevation (mAOD)
- Inferred Deep Groundwater Flow Vector

0 50 100
APPROXIMATE SCALE (m)

Inferred Groundwater Flow Regime in the Deep Deposits, September 2023

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure **4c**
Delph, UK	November 2023	



Note: Total TPH Concentration Contours based on highest recorded TPH concentration in 2023.

KEY

- Sampled Deep Deposits Location
- Deep Groundwater Flow Vector
- Total TPH Concentration Contour
- Clay Layer Absent

100 Total TPH Concentration (ug/l) January 2023

100 Total TPH Concentration (ug/l) May 2023

103 Total TPH Concentration (ug/l) September 2023

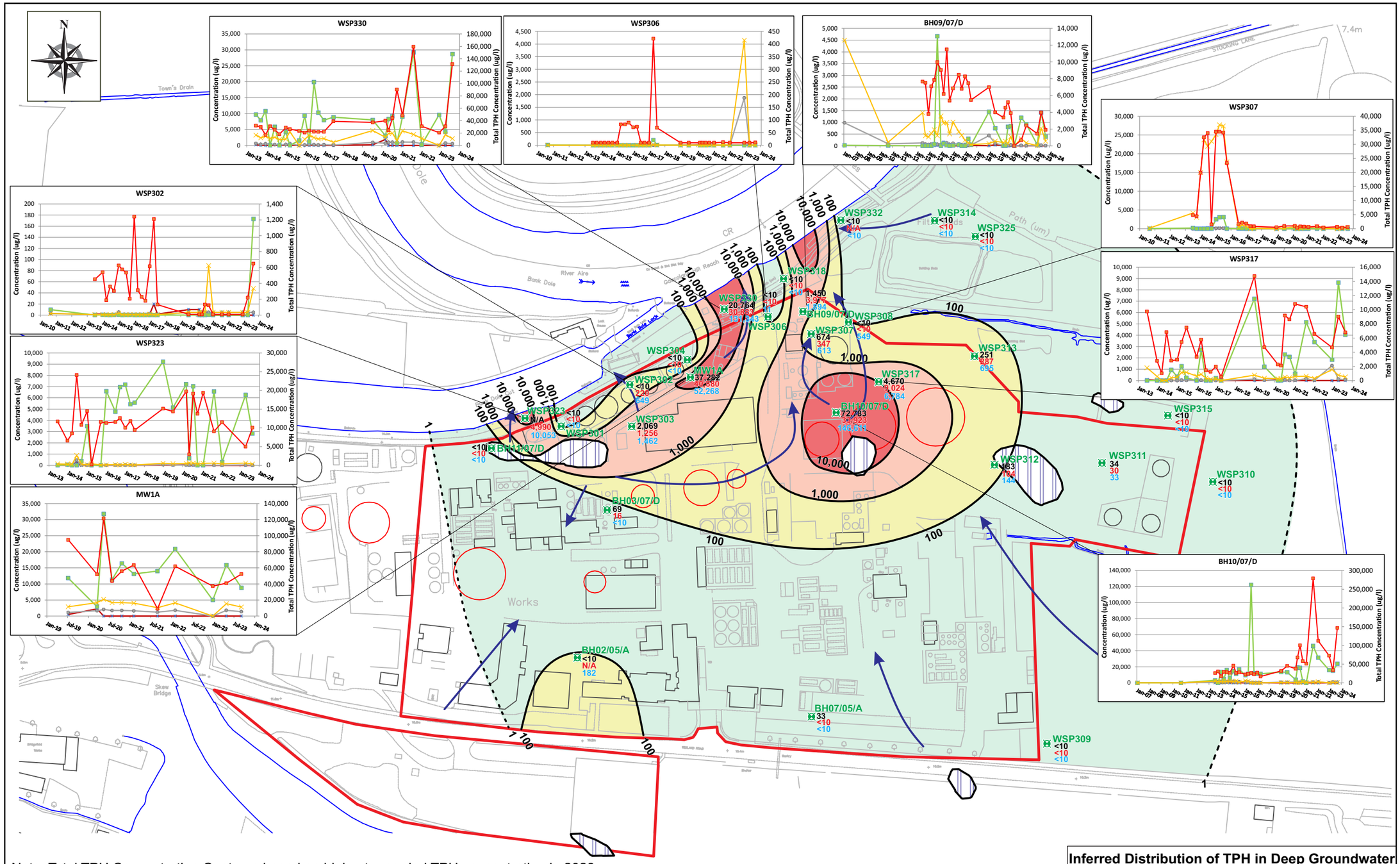
Graphed Concentration Trends

- Phenol
- Naphthalene
- Total Petroleum Hydrocarbons
- Toluene
- Benzene

0 50 100
APPROXIMATE SCALE (m)

Inferred Distribution of TPH in Deep Groundwater and Concentration Trends (Consistent Scale)

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure **5a**
Delph, UK	November 2023	



Note: Total TPH Concentration Contours based on highest recorded TPH concentration in 2023.

KEY

- Sampled Deep Deposits Location
- Inferred Deep Groundwater Flow Vector
- Total TPH Concentration Contour
- Inferred Area where the Clay Layer is Absent

- **100** Total TPH Concentration (ug/l) January 2023
- **100** Total TPH Concentration (ug/l) May 2023
- **103** Total TPH Concentration (ug/l) September 2023

Graphed Concentration Trends

- Phenol
- Naphthalene
- Total Petroleum Hydrocarbons
- Toluene
- Benzene

0 50 100
APPROXIMATE SCALE (m)

Inferred Distribution of TPH in Deep Groundwater and Concentration Trends (Variable Scale)

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure **5b**
Delph, UK	November 2023	

Note: Methane Concentration Contours based on highest recorded Methane concentration in 2023.

KEY

- Sampled Deep Deposits Location
- Inferred Deep Groundwater Flow Vector
- Methane Concentration Contour
- Inferred Area where the Clay Layer is Absent
- **100** Methane Concentration (ug/l) January 2023
- **100** Methane Concentration (ug/l) May 2023
- **103** Methane Concentration (ug/l) September 2023

0 50 100
APPROXIMATE SCALE (m)

Inferred Distribution of Methane in Deep Groundwater and Concentration Trends

Knottingley, UK	GCU0309002	
Geosyntec consultants	FCC Environment	Figure 6
Delph, UK	November 2023	

Geosyntec consultants

engineers | scientists | innovators

APPENDIX A
Laboratory Analysis Certificates, January, May and September 2023

Element Materials Technology
Unit 3 Deeside Point
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Geosyntec Consulting
1st Floor
Gatehead Business Park
Delph New Road
Delph
OL3 5DE

Attention :	Gareth Barns
Date :	3rd February, 2023
Your reference :	GCU0309001
Our reference :	Test Report 23/561 Batch 1
Location :	Knottingley
Date samples received :	14th January, 2023
Status :	Final Report
Issue :	1

Thirty one samples were received for analysis on 14th January, 2023 of which thirty one were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Authorised By:

Paul Boden BSc
Senior Project Manager

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	LOD/LOR	Units	Method No.
Sample ID	WSP301-110123	BH03/07/D-110123	WSP302-110123	WSP303-130123	WSP304-110123	MW1A-110123	WSP306-130123	BH09/07/D-130123	WSP307-110123	WSP308-120123			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	11/01/2023	11/01/2023	11/01/2023	13/01/2023	11/01/2023	11/01/2023	13/01/2023	13/01/2023	11/01/2023	12/01/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023			
PAH MS													
Naphthalene #	<0.1	12.6 AB	<0.1	477 AE	<0.1	4990 AI	<0.1	47.3 AC	3.7	0.1	<0.1	ug/l	TM4/PM30
Acenaphthylene #	<0.005	<0.005	0.033	3.00 AB	<0.005	60.5 AE	0.016	4.04	0.363	1.15	<0.005	ug/l	TM4/PM30
Acenaphthene #	0.049	2.38	<0.005	20.8 AB	<0.005	364 AE	0.016	82.2 AC	15.6 AB	0.426	<0.005	ug/l	TM4/PM30
Fluorene #	0.020	1.50	<0.005	3.67	<0.005	172 AE	<0.005	41.7 AC	5.71	0.194	<0.005	ug/l	TM4/PM30
Phenanthrene #	0.037	0.812	0.011	3.76	<0.005	251 AE	<0.005	22.5 AC	0.504	0.912	<0.005	ug/l	TM4/PM30
Anthracene #	0.008	0.282	0.035	0.213	<0.005	42.0 AE	0.034	9.38 AC	0.991	0.910	<0.005	ug/l	TM4/PM30
Fluoranthene #	0.087	0.167	0.055	0.174	<0.005	52.2 AE	0.039	14.5 AC	0.866	3.27	<0.005	ug/l	TM4/PM30
Pyrene #	0.069	0.125	0.047	0.081	0.007	34.8 AE	0.023	9.52 AC	0.477	3.03	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	0.023	0.017	0.013	0.015	<0.005	8.61 AE	0.009	2.26	0.068	1.56	<0.005	ug/l	TM4/PM30
Chrysene #	0.025	0.018	0.017	0.006	<0.005	8.45 AE	0.007	1.61	0.066	1.44	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	0.033	0.012	0.023	<0.008	<0.008	6.99 AE	0.014	1.83	0.064	4.06	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	0.006	<0.005	<0.005	<0.005	<0.005	2.23 AE	<0.005	1.07	0.015	1.22	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	0.006	<0.005	<0.005	<0.005	<0.005	2.08 AE	<0.005	0.487	0.009	1.69	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005	<0.005	<0.005	<0.005	<0.005	<0.500 AE	<0.005	0.080	<0.005	0.128	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	0.005	<0.005	<0.005	<0.005	<0.005	1.32 AE	<0.005	0.274	0.007	0.900	<0.005	ug/l	TM4/PM30
PAH 16 Total #	0.368	17.913	0.234	508.719	<0.173	5996.180 AE	<0.173	238.751	28.440	20.990	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	0.024	0.009	0.017	<0.008	<0.008	5.03 AE	0.010	1.32	0.046	2.92	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	0.009	<0.008	<0.008	<0.008	<0.008	1.96 AE	<0.008	0.512	0.018	1.14	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	79	92	70	89 AB	79	125 AE	81	87	86	78	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	<5	<5	<5	<5	<5	4150	<5	<5	330	<5	<5	ug/l	TM36/PM12
Toluene #	<5	<5	<5	<5	<5	1870	<5	<5	5	<5	<5	ug/l	TM36/PM12
Ethylbenzene #	<5	6	<5	38	<5	363	<5	<5	14	<5	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	<5	<5	204	<5	1060	<5	<5	7	<5	<5	ug/l	TM36/PM12
o-Xylene #	<5	<5	<5	111	<5	594	<5	<5	<5	<5	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	<10	<10	<10	19	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	<10	<10	<10	31	<10	1300	<10	<10	71	<10	<10	ug/l	TM36/PM12
>C8-C10 #	<10	<10	<10	144	<10	1320	<10	<10	36	<10	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	<5	<5	<5	63	<5	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	<10	<10	240	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	<10	<10	270	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	<10	120	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	<10	<10	<10	175	<10	3332	<10	<10	107	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

Please see attached notes for all abbreviations and acronyms

EMT Sample No.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	LOD/LOR	Units	Method No.
Sample ID	WSP301-110123	BH03/07/D-110123	WSP302-110123	WSP303-130123	WSP304-110123	MW1A-110123	WSP306-130123	BH09/07/D-130123	WSP307-110123	WSP308-120123			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	11/01/2023	11/01/2023	11/01/2023	13/01/2023	11/01/2023	11/01/2023	13/01/2023	13/01/2023	11/01/2023	12/01/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	<10	<10	<10	<10	<10	4150	<10	<10	330	<10	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	<10	<10	<10	1870	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC8-EC10 #	<10	11	<10	354	<10	2020	<10	<10	23	<10	<10	ug/l	TM36/PM12
>EC10-EC12 #	<5	58	<5	1190	<5	15000	<5	300	104	<5	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	<10	<10	<10	350	<10	6190	<10	680	110	<10	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	<10	<10	<10	<10	3600	<10	470	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	<10	<10	<10	1120	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	<10	69	<10	1894	<10	33950	<10	1450	567	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	<10	69	<10	2069	<10	37282	<10	1450	674	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	0.02	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	<0.01	<0.01	0.08	<0.01	6.23 AD	<0.01	<0.01	0.06	<0.01	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	<0.02	<0.02	0.47	<0.02	17.6 AD	<0.02	<0.02	0.20	<0.02	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	<0.01	<0.01	0.01	<0.01	2.50 AD	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	<0.03	<0.03	0.48	<0.03	20.10	<0.03	<0.03	0.20	<0.03	<0.03	mg/l	TM26/PM0
Xylenols #	<0.06	<0.06	<0.06	1.59	<0.06	85.6 AD	<0.06	<0.06	0.09	<0.06	<0.06	mg/l	TM26/PM0
1-naphthol	<0.01	<0.01	<0.01	0.04	<0.01	0.81 AD	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	<0.01	<0.01	0.26	<0.01	4.14 AD	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	<0.01	1.50 AD	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	<0.1	<0.1	<0.1	2.5	<0.1	118.4	<0.1	<0.1	0.4	<0.1	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	24.0	14.8	36.2	<0.5	77.6	7.7	81.4	117	122	188	<0.5	mg/l	TM38/PM0
Nitrate as NO3 #	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	51.4	<0.2	<0.2	<0.2	mg/l	TM38/PM0
Nitrite as NO2 #	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1.93	<0.02	<0.02	<0.02	mg/l	TM38/PM0
Dissolved Methane #	<1	>>3140	786	>>6830	<1	>>20700	>>2090	158	>>1380	2	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	312	338	242	366	270	422	320	164	276	322	<1	mg/l	TM75/PM0
Sulphide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	876	990	627	1010	1030	1260	1100	937	1080	1460	<2	uS/cm	TM76/PM0
Dissolved Iron II	2.98	0.56	0.19	2.03	0.60	3.35 AA	0.72	0.06	0.08	0.19	<0.02	mg/l	TM48/PM0
Dissolved Iron III	0.06	<0.02	<0.02	<0.02	<0.02	0.64	<0.02	0.50	<0.02	<0.02	<0.02	mg/l	TM30/TM48/PM0
Manganese II	1.87	1.18	0.28	0.55	1.44	0.63	0.67	0.05	0.75	0.73	<0.02	mg/l	TM62/PM0
pH #	7.89	7.93	8.04	8.25	7.90	7.80	8.00	7.42	7.75	8.02	<0.01	pH units	TM73/PM0

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	71-77	78-84	85-91	92-98	99-105	106-112	113-119	120-126	127-133	134-140	LOD/LOR	Units	Method No.
Sample ID	BH10/07/D-120123	WSP317-120123	WSP313-120123	WSP312-120123	WSP311-120123	WSP315-120123	WSP309-120123	WSP310-120123	BH02/05/A-120123	WSP332-130123			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	13/01/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023			
PAH MS													
Naphthalene #	16000 AJ	1830 AF	67.7 AC	1.9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	ug/l	TM4/PM30
Acenaphthylene #	339 AF	3.66 AC	0.148	0.245	0.007	0.005	<0.005	<0.005	0.016	<0.005	<0.005	ug/l	TM4/PM30
Acenaphthene #	1200 AJ	88.0 AC	3.22	17.0 AB	0.009	0.010	0.019	0.015	0.014	<0.005	<0.005	ug/l	TM4/PM30
Fluorene #	1160 AF	13.6 AC	0.425	3.03	0.007	0.010	0.023	0.021	0.005	<0.005	<0.005	ug/l	TM4/PM30
Phenanthrene #	2220 AJ	9.41 AC	0.613	0.299	0.021	0.029	0.051	0.042	0.080	<0.005	<0.005	ug/l	TM4/PM30
Anthracene #	593 AF	0.238	0.078	0.126	0.005	0.005	0.008	0.006	0.036	<0.005	<0.005	ug/l	TM4/PM30
Fluoranthene #	47.8 AF	0.215	0.106	0.341	0.023	0.025	0.025	0.014	0.212	<0.005	<0.005	ug/l	TM4/PM30
Pyrene #	703 AF	0.140	0.060	0.221	0.018	0.020	0.021	0.012	0.240	<0.005	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	172 AF	0.021	0.027	0.016	0.007	0.007	0.005	<0.005	0.111	<0.005	<0.005	ug/l	TM4/PM30
Chrysene #	156 AF	0.020	0.009	0.017	0.005	0.005	0.005	<0.005	0.167	<0.005	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	146 AF	0.016	0.009	0.009	0.008	<0.008	<0.008	<0.008	0.333	<0.008	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	50.9 AF	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.056	<0.005	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	41.1 AF	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.086	<0.005	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	2.50 AF	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.011	<0.005	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	24.2 AF	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.077	<0.005	<0.005	ug/l	TM4/PM30
PAH 16 Total #	22855.500 AF	1945.332	72.395	23.204	<0.173	<0.173	<0.173	<0.173	1.444	<0.173	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	105 AF	0.012	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.240	<0.008	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	40.9 AF	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	0.093	<0.008	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	119 AF	74 AC	98	81	80	76	76	89	79	82	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	976	169	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Toluene #	1320	13	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Ethylbenzene #	1180	191	16	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
m/p-Xylene #	1400	157	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
o-Xylene #	720	100	8	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	14	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	568	50	<10	<10	34	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C8-C10 #	1200	210	24	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C10-C12 #	245	<5	<5	16	<5	<5	<5	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	1140	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	1150	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	550	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	4867	260	24	16	34	<10	<10	<10	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	71-77	78-84	85-91	92-98	99-105	106-112	113-119	120-126	127-133	134-140	LOD/LOR	Units	Method No.
Sample ID	BH10/07/D-120123	WSP317-120123	WSP313-120123	WSP312-120123	WSP311-120123	WSP315-120123	WSP309-120123	WSP310-120123	BH02/05/A-120123	WSP332-130123			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	12/01/2023	13/01/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	976	169	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC7-EC8 #	1320	13	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC8-EC10 #	3300	448	27	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC10-EC12 #	17600	2980	180	87	<5	<5	<5	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	16800	710	20	80	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	20400	90	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	7520	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	67916	4410	227	167	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	72783	4670	251	183	34	<10	<10	<10	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Phenol #	0.13	0.07	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
m/p-cresol	0.37	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	mg/l	TM26/PM0
o-cresol	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	0.41	0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	TM26/PM0
Xylenols #	1.01	0.16	0.10	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	mg/l	TM26/PM0
1-naphthol	0.20	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	0.34	0.10	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	2.1	0.4	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	1.0	92.6	98.0	78.5	259	345	31.6	256	5.8	42.2	<0.5	mg/l	TM38/PM0
Nitrate as NO3 #	0.3	<0.2	<0.2	<0.2	0.4	<0.2	1.2	<0.2	<0.2	<0.2	<0.2	mg/l	TM38/PM0
Nitrite as NO2 #	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.07	<0.02	<0.02	<0.02	<0.02	mg/l	TM38/PM0
Dissolved Methane #	>>1890	>>1240	>>3020	447	60	15	<1	26	<1	>>3370	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	346	290	318	262	300	304	348	268	84	428	<1	mg/l	TM75/PM0
Sulphide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	904	1010	1080	999	1380	1440	976	1290	191	1270	<2	uS/cm	TM76/PM0
Dissolved Iron II	1.00	5.35 AA	0.23	1.74	0.10	0.08	0.05	0.09	0.02	0.67	<0.02	mg/l	TM48/PM0
Dissolved Iron III	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	mg/l	TM30/TM48/PM0
Manganese II	1.29	0.70	0.54	1.60	0.45	0.67	0.87	0.21	0.06	1.40	<0.02	mg/l	TM62/PM0
pH #	7.89	7.85	7.86	7.88	7.70	7.69	7.81	7.78	7.57	7.74	<0.01	pH units	TM73/PM0

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	141-147	148-154	155-161	162-168	169-175	176-182	183-189	190-196	197-203	204-210	LOD/LOR	Units	Method No.
Sample ID	WSP330-130123	WSP318-130123	BH07/65/A-130123	SW1-130123	SW2-130123	SW3-130123	DUP-1-110123	DUP-2-110123	WSP314-130123	WSP325-130123			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	13/01/2023	13/01/2023	13/01/2023	13/01/2023	13/01/2023	13/01/2023	11/01/2023	11/01/2023	13/01/2023	13/01/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Surface Water	Surface Water	Surface Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023			
PAH MS													
Naphthalene #	9620_{AH}	0.1	0.3	<0.1	<0.1	<0.1	14700_{AJ}	3240_{AG}	<0.1	<0.1	<0.1	ug/l	TM4/PM30
Acenaphthylene #	74.3_{AF}	<0.005	0.108	<0.005	<0.005	<0.005	59.7_{AJ}	5.04_{AC}	<0.005	0.020	<0.005	ug/l	TM4/PM30
Acenaphthene #	590_{AF}	0.012	0.609	0.013	0.030	0.013	365_{AJ}	106_{AC}	0.015	0.048	<0.005	ug/l	TM4/PM30
Fluorene #	317_{AF}	0.013	0.377	0.005	0.016	<0.005	171_{AJ}	12.4_{AC}	0.005	0.075	<0.005	ug/l	TM4/PM30
Phenanthrene #	531_{AF}	0.088	0.440	0.022	0.033	0.025	214_{AC}	8.82_{AC}	0.028	0.387	<0.005	ug/l	TM4/PM30
Anthracene #	108_{AF}	0.006	0.383	0.009	0.012	0.011	39.8_{AC}	$<0.100_{AC}$	0.005	0.083	<0.005	ug/l	TM4/PM30
Fluoranthene #	153_{AF}	0.027	1.61	0.049	0.046	0.073	51.3_{AC}	0.107_{AC}	0.005	0.139	<0.005	ug/l	TM4/PM30
Pyrene #	99.2_{AF}	0.021	1.19	0.043	0.043	0.065	34.1_{AC}	$<0.100_{AC}$	<0.005	1.02	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	28.1_{AF}	0.006	0.387	0.016	0.014	0.028	8.34_{AC}	$<0.100_{AC}$	<0.005	0.035	<0.005	ug/l	TM4/PM30
Chrysene #	23.9_{AF}	0.007	0.459	0.016	0.013	0.029	6.93_{AC}	$<0.100_{AC}$	<0.005	0.033	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	23.0_{AF}	0.008	0.829	0.027	0.024	0.054	7.51_{AC}	$<0.160_{AC}$	<0.008	0.053	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	6.48_{AF}	<0.005	0.361	<0.005	<0.005	0.021	3.21_{AC}	$<0.100_{AC}$	<0.005	0.025	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	6.23_{AF}	<0.005	0.262	0.007	<0.005	0.019	1.56_{AC}	$<0.100_{AC}$	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	$<1.000_{AF}$	<0.005	0.043	<0.005	<0.005	<0.005	0.194_{AC}	$<0.100_{AC}$	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	3.36_{AF}	<0.005	0.196	0.009	0.007	0.016	1.17_{AC}	$<0.100_{AC}$	<0.005	<0.005	<0.005	ug/l	TM4/PM30
PAH 16 Total #	11583.570_{AF}	0.288	7.554	0.216	0.238	0.354	15663.814_{AC}	3372.367_{AC}	<0.173	1.918	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	16.6_{AF}	<0.008	0.597	0.019	0.017	0.039	5.41_{AC}	$<0.160_{AC}$	<0.008	0.038	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	6.44_{AF}	<0.008	0.232	<0.008	<0.008	0.015	2.10_{AC}	$<0.160_{AC}$	<0.008	0.015	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	100_{AF}	86	82	85	83	86	127_{AJ}	81_{AC}	86	86	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	1490	<5	<5	<5	<5	<5	3970	154	<5	<5	<5	ug/l	TM36/PM12
Toluene #	410	<5	<5	<5	<5	<5	1790	14	<5	<5	<5	ug/l	TM36/PM12
Ethylbenzene #	297	<5	<5	<5	<5	<5	349	170	<5	<5	<5	ug/l	TM36/PM12
m/p-Xylene #	639	<5	<5	<5	<5	<5	1020	151	<5	<5	<5	ug/l	TM36/PM12
o-Xylene #	344	<5	<5	<5	<5	<5	568	92	<5	<5	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	21	<10	<10	<10	18	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	436	<10	<10	<10	<10	<10	1250	47	<10	<10	<10	ug/l	TM36/PM12
>C8-C10 #	620	<10	12	<10	<10	<10	1230	194	<10	<10	<10	ug/l	TM36/PM12
>C10-C12 #	68	<5	<5	<5	<5	<5	29	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	150	<10	<10	<10	<10	<10	100	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	200	<10	<10	<10	<10	<10	70	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	1474	<10	33	<10	<10	<10	2697	241	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	141-147	148-154	155-161	162-168	169-175	176-182	183-189	190-196	197-203	204-210	LOD/LOR	Units	Method No.
Sample ID	WSP330-130123	WSP318-130123	BH07/65/A-130123	SW1-130123	SW2-130123	SW3-130123	DUP-1-110123	DUP-2-110123	WSP314-130123	WSP325-130123			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	13/01/2023	13/01/2023	13/01/2023	13/01/2023	13/01/2023	13/01/2023	11/01/2023	11/01/2023	13/01/2023	13/01/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Surface Water	Surface Water	Surface Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023	14/01/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	1490	<10	<10	<10	<10	<10	3970	154	<10	<10	<10	ug/l	TM36/PM12
>EC7-EC8 #	410	<10	<10	<10	<10	<10	1790	14	<10	<10	<10	ug/l	TM36/PM12
>EC8-EC10 #	1280	<10	<10	<10	<10	<10	1930	413	<10	<10	<10	ug/l	TM36/PM12
>EC10-EC12 #	9790	<5	<5	<5	<5	<5	10100	2680	<5	<5	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	3750	<10	<10	<10	<10	<10	3300	640	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	2090	<10	<10	<10	<10	<10	1240	80	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	480	<10	<10	<10	<10	<10	120	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	19290	<10	<10	<10	<10	<10	22450	3981	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	20764	<10	33	<10	<10	<10	25147	4222	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Phenol #	0.82_{AC}	<0.01	<0.01	<0.01	<0.01	<0.01	6.47_{AD}	0.02	<0.01	<0.01	<0.01	mg/l	TM26/PM0
m/p-cresol	1.98_{AC}	<0.02	<0.02	<0.02	<0.02	<0.02	18.6_{AD}	0.07	<0.02	<0.02	<0.02	mg/l	TM26/PM0
o-cresol	0.14	<0.01	<0.01	<0.01	<0.01	<0.01	2.64_{AD}	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	2.12	<0.03	<0.03	<0.03	<0.03	<0.03	21.24	0.07	<0.03	<0.03	<0.03	mg/l	TM26/PM0
Xylenols #	32.3_{AC}	<0.06	<0.06	<0.06	<0.06	<0.06	90.9_{AD}	0.12	<0.06	<0.06	<0.06	mg/l	TM26/PM0
1-naphthol	0.26	<0.01	0.02	<0.01	<0.01	<0.01	0.83_{AD}	0.03	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	1.12_{AC}	<0.01	<0.01	<0.01	<0.01	<0.01	4.79_{AD}	0.04	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	0.41	<0.01	<0.01	<0.01	<0.01	<0.01	2.85_{AD}	0.09	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	37.1	<0.1	<0.1	<0.1	<0.1	<0.1	127.1	0.4	<0.1	<0.1	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	0.5	94.9	20.4	28.3	27.3	28.3	7.7	93.1	94.6	33.4	<0.5	mg/l	TM38/PM0
Nitrate as NO3 #	<0.2	<0.2	<0.2	12.0	12.0	12.6	<0.2	<0.2	<0.2	<0.2	<0.2	mg/l	TM38/PM0
Nitrite as NO2 #	<0.02	<0.02	<0.02	0.12	0.12	0.14	<0.02	<0.02	<0.02	<0.02	<0.02	mg/l	TM38/PM0
Dissolved Methane #	>>14500	100	306	8	5	5	>>23000	>>1230	206	>>4720	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	388	256	244	62	60	62	438	296	234	292	<1	mg/l	TM75/PM0
Sulphide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	1350	942	704	298	301	297	1280	1030	915	899	<2	uS/cm	TM76/PM0
Dissolved Iron II	6.30_{AB}	2.32	0.61	0.05	0.05	0.05	3.35_{AA}	5.30_{AB}	0.75	0.10	<0.02	mg/l	TM48/PM0
Dissolved Iron III	0.11	<0.02	<0.02	0.15	0.15	0.13	0.64	<0.02	<0.02	<0.02	<0.02	mg/l	TM30/TM48/PM0
Manganese II	0.06	0.97	0.79	0.04	0.04	0.04	0.69	0.70	0.44	0.46	<0.02	mg/l	TM62/PM0
pH #	7.92	7.76	7.83	7.25	7.30	7.14	7.68	7.78	7.76	7.74	<0.01	pH units	TM73/PM0

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

Please see attached notes for all abbreviations and acronyms

EMT Sample No.	211-217												
Sample ID	BH11/07/D-110123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	11/01/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	14/01/2023												

											LOD/LOR	Units	Method No.
PAH MS													
Naphthalene #	0.2											<0.1	ug/l	TM4/PM30
Acenaphthylene #	<0.005											<0.005	ug/l	TM4/PM30
Acenaphthene #	0.371											<0.005	ug/l	TM4/PM30
Fluorene #	0.222											<0.005	ug/l	TM4/PM30
Phenanthrene #	0.017											<0.005	ug/l	TM4/PM30
Anthracene #	0.056											<0.005	ug/l	TM4/PM30
Fluoranthene #	0.282											<0.005	ug/l	TM4/PM30
Pyrene #	2.78											<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	0.059											<0.005	ug/l	TM4/PM30
Chrysene #	0.066											<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	0.054											<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	0.020											<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.005											<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005											<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	0.007											<0.005	ug/l	TM4/PM30
PAH 16 Total #	4.134											<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	0.039											<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	0.015											<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	86											<0	%	TM4/PM30
MTBE #	<5											<5	ug/l	TM36/PM12
Benzene #	<5											<5	ug/l	TM36/PM12
Toluene #	<5											<5	ug/l	TM36/PM12
Ethylbenzene #	<5											<5	ug/l	TM36/PM12
m/p-Xylene #	<5											<5	ug/l	TM36/PM12
o-Xylene #	<5											<5	ug/l	TM36/PM12
TPH CWG														
Aliphatics														
>C5-C6 #	<10											<10	ug/l	TM36/PM12
>C6-C8 #	<10											<10	ug/l	TM36/PM12
>C8-C10 #	<10											<10	ug/l	TM36/PM12
>C10-C12 #	<5											<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10											<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10											<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10											<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	<10											<10	ug/l	TM5/TM36/PM12/PM16/PM30

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

Please see attached notes for all abbreviations and acronyms

EMT Sample No.	211-217										LOD/LOR	Units	Method No.
Sample ID	BH11/07/D-110123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	11/01/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	14/01/2023												
TPH CWG													
Aromatics													
>C5-EC7 #	<10										<10	ug/l	TM36/PM12
>EC7-EC8 #	<10										<10	ug/l	TM36/PM12
>EC8-EC10 #	<10										<10	ug/l	TM36/PM12
>EC10-EC12 #	<5										<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	<10										<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10										<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10										<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	<10										<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	<10										<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01										<0.01	mg/l	TM26/PM0
Catechol	<0.01										<0.01	mg/l	TM26/PM0
Phenol #	<0.01										<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02										<0.02	mg/l	TM26/PM0
o-cresol	<0.01										<0.01	mg/l	TM26/PM0
Total cresols #	<0.03										<0.03	mg/l	TM26/PM0
Xylenols #	<0.06										<0.06	mg/l	TM26/PM0
1-naphthol	<0.01										<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01										<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01										<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	<0.1										<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	48.1										<0.5	mg/l	TM38/PM0
Nitrate as NO3 #	<0.2										<0.2	mg/l	TM38/PM0
Nitrite as NO2 #	<0.02										<0.02	mg/l	TM38/PM0
Dissolved Methane #	120										<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	234										<1	mg/l	TM75/PM0
Sulphide	<0.01										<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	810										<2	uS/cm	TM76/PM0
Dissolved Iron II	0.26										<0.02	mg/l	TM48/PM0
Dissolved Iron III	<0.02										<0.02	mg/l	TM30/TM48/PM0
Manganese II	0.53										<0.02	mg/l	TM62/PM0
pH #	7.75										<0.01	pH units	TM73/PM0

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	36-42												
Sample ID	MW1A-110123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	11/01/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	14/01/2023												

Please see attached notes for all abbreviations and acronyms

											LOD/LOR	Units	Method No.
PAH MS													
PAH Surrogate % Recovery	73 AI										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	57-63										Please see attached notes for all abbreviations and acronyms		
Sample ID	WSP307-110123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	11/01/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	14/01/2023												
PAH MS													
PAH Surrogate % Recovery	80 AB										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	78-84										Please see attached notes for all abbreviations and acronyms		
Sample ID	WSP317-120123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	12/01/2023												
Sample Type	Ground Water												
Batch Number	1											LOD/LOR	Units	Method No.
Date of Receipt	14/01/2023												
PAH MS													
PAH Surrogate % Recovery	37 AF											<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	92-98										Please see attached notes for all abbreviations and acronyms		
Sample ID	WSP312-120123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	12/01/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	14/01/2023												
PAH MS													
PAH Surrogate % Recovery	82 AB										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	141-147												
Sample ID	WSP330-130123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	13/01/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	14/01/2023												

Please see attached notes for all abbreviations and acronyms

											LOD/LOR	Units	Method No.
PAH MS													
PAH Surrogate % Recovery	97 AH										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/561

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	190-196										Please see attached notes for all abbreviations and acronyms		
Sample ID	DUP-2-110123												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	11/01/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	14/01/2023											LOD/LOR	Units	Method No.
PAH MS														
PAH Surrogate % Recovery	78_{AG}											<0	%	TM4/PM30

Client Name: Geosyntec Consulting
Reference: GCU0309001
Location: Knottingley
Contact: Gareth Barns

EMT Job No.	Batch	Sample ID	Depth	EMT Sample No.	Analysis	Reason
No deviating sample report results for job 23/561						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

SOILS and ASH

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary. Asbestos samples are retained for 6 months.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Limits of detection for analyses carried out on as received samples are not moisture content corrected. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C. Ash samples are dried at 37°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Sufficient amount of sample must be received to carry out the testing specified. Where an insufficient amount of sample has been received the testing may not meet the requirements of our accredited methods, as such accreditation may be removed.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

STACK EMISSIONS

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation for Dioxins and Furans and Dioxin like PCBs has been performed on XAD-2 Resin, only samples which use this resin will be within our MCERTS scope.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

DEVIATING SAMPLES

All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. The temperature of sample receipt is recorded on the confirmation schedules in order that the client can make an informed decision as to whether testing should still be undertaken.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.
Laboratory records are kept for a period of no less than 6 years.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

Measurement Uncertainty

Measurement uncertainty defines the range of values that could reasonably be attributed to the measured quantity. This range of values has not been included within the reported results. Uncertainty expressed as a percentage can be provided upon request.

Customer Provided Information

Sample ID and depth is information provided by the customer.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
>>	Results above calibration range, the result should be considered the minimum value. The actual result could be significantly higher.
*	Analysis subcontracted to an Element Materials Technology approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x5 Dilution
AB	x10 Dilution
AC	x20 Dilution
AD	x50 Dilution
AE	x100 Dilution
AF	x200 Dilution

AG	x400 Dilution
AH	x1000 Dilution
AI	x2000 Dilution
AJ	x4000 Dilution

HWOL ACRONYMS AND OPERATORS USED

HS	Headspace Analysis.
EH	Extractable Hydrocarbons - i.e. everything extracted by the solvent.
CU	Clean-up - e.g. by florisil, silica gel.
1D	GC - Single coil gas chromatography.
Total	Aliphatics & Aromatics.
AL	Aliphatics only.
AR	Aromatics only.
2D	GC-GC - Double coil gas chromatography.
#1	EH_Total but with humics mathematically subtracted
#2	EU_Total but with fatty acids mathematically subtracted
_	Operator - underscore to separate acronyms (exception for +).
+	Operator to indicate cumulative e.g. EH+HS_Total or EH_CU+HS_Total
MS	Mass Spectrometry.

EMT Job No: 23/561

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM4	Modified USEPA 8270D v5:2014 method for the solvent extraction and determination of PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
TM4	Modified USEPA 8270D v5:2014 method for the solvent extraction and determination of PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM5	Modified 8015B v2:1996 method for the determination of solvent Extractable Petroleum Hydrocarbons (EPH) within the range C8-C40 by GCFID. For waters the solvent extracts dissolved phase plus a sheen if present.	PM16/PM30	Fractionation into aliphatic and aromatic fractions using a Rapid Trace SPE/Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM5/TM36	please refer to TM5 and TM36 for method details	PM12/PM16/PM30	please refer to PM16/PM30 and PM12 for method details	Yes			
TM25	Determintaion of Dissolved Methane, Ethane and Ethene by Headspace GC-FID	PM0	No preparation is required.	Yes			
TM26	Determination of phenols by Reversed Phased High Performance Liquid Chromatography and Electro-Chemical Detection.	PM0	No preparation is required.				
TM26	Determination of phenols by Reversed Phased High Performance Liquid Chromatography and Electro-Chemical Detection.	PM0	No preparation is required.	Yes			
TM30/TM48	Calculation of Fe (III) based on Iron and Fe(II)	PM0	No preparation is required.				
TM36	Modified US EPA method 8015B v2:1996. Determination of Gasoline Range Organics (GRO) in the carbon chain range of C4-12 by headspace GC-FID. MTBE by GCFID co-elutes with 3-methylpentane if present and therefore can give a false positive. Positive MTBE results will be re-run using GC-MS to double check, when requested.	PM12	Modified US EPA method 5021A v2:2014. Preparation of solid and liquid samples for GC headspace analysis.	Yes			
TM38	Soluble Ion analysis using Discrete Analyser. Modified US EPA methods: Chloride 325.2 (1978), Sulphate 375.4 (Rev.2 1993), o-Phosphate 365.2 (Rev.2 1993), TON 353.1 (Rev.2 1993), Nitrite 354.1 (1971), Hex Cr 7196A (1992), NH4+ 350.1 (Rev.2 1993) – All anions comparable to BS ISO 15923-1: 2013l	PM0	No preparation is required.	Yes			

EMT Job No: 23/561

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM48	Determination of Ferrous Iron by reaction with Sodium Carbonate and Morfamquat Sulphate which is analysed spectrophotometrically.	PM0	No preparation is required.				
TM62	Determination of Manganese (II) by reaction with Formaldoxime in ammoniacal solution to form a manganese complex which is analysed spectrophotometrically.	PM0	No preparation is required.				
TM73	Modified US EPA methods 150.1 (1982) and 9045D Rev. 4 - 2004) and BS1377-3:1990. Determination of pH by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			
TM75	Modified US EPA method 310.1 (1978). Determination of Alkalinity by Metrohm automated titration analyser.	PM0	No preparation is required.	Yes			
TM76	Modified US EPA method 120.1 (1982). Determination of Specific Conductance by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			
TM107	Determination of Sulphide/Thiocyanate by Skalar Continuous Flow Analyser	PM0	No preparation is required.				

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Gatehead Business Park
Delph New Road
Delph
United Kingdom
OL3 5DE

Attention :	Gareth Barns
Date :	5th June, 2023
Your reference :	GCU0309002
Our reference :	Test Report 23/7606 Batch 1
Location :	Knottingley
Date samples received :	13th May, 2023
Status :	Final Report
Issue :	1

Thirty one samples were received for analysis on 13th May, 2023 of which thirty one were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Authorised By:

Simon Gomery BSc
Project Manager

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	LOD/LOR	Units	Method No.
Sample ID	WG-BH03/07/D-100523	WG-BH07/05/A-110523	WG-BH09/07/D-100523	WG-BH10/07/D-100523	WG-BH11/07/D-100523	WG-MWA-100523	SW01-110523	SW02-110523	SW03-110523	WG-WSP301-100523			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	10/05/2023	11/05/2023	10/05/2023	10/05/2023	10/05/2023	10/05/2023	11/05/2023	11/05/2023	11/05/2023	10/05/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023			
Total Dissolved Iron #	2470	228	<20	4070	286	6080	100	113	103	228	<20	ug/l	TM30/PM14
PAH MS													
Naphthalene #	<0.1	<0.1	1420_{AG}	$15100^{SV}{}_{AI}$	<0.1	$15900^{SV}{}_{AI}$	$<0.1^{SV}$	<0.1	<0.1	<0.1	<0.1	ug/l	TM4/PM30
Acenaphthylene #	<0.005	<0.005	<0.005	89.8_{AE}	0.016	$75.4^{SV}{}_{AI}$	$<0.005^{SV}$	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Acenaphthene #	<0.005	<0.005	74.0_{AG}	$514^{SV}{}_{AI}$	0.030	$599^{SV}{}_{AI}$	$<0.005^{SV}$	<0.005	0.005	<0.005	<0.005	ug/l	TM4/PM30
Fluorene #	<0.005	<0.005	37.4_{AG}	$257^{SV}{}_{AI}$	0.022	$331^{SV}{}_{AI}$	$<0.005^{SV}$	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Phenanthrene #	<0.005	<0.005	34.4_{AG}	$445^{SV}{}_{AI}$	0.011	$561^{SV}{}_{AI}$	0.005^{SV}	<0.005	0.018	<0.005	<0.005	ug/l	TM4/PM30
Anthracene #	<0.005	<0.005	3.96	69.0_{AE}	0.009	95.2_{AE}	$<0.005^{SV}$	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Fluoranthene #	<0.005	0.005	3.45	79.4_{AE}	0.105	132_{AE}	0.011^{SV}	<0.005	0.020	<0.005	<0.005	ug/l	TM4/PM30
Pyrene #	0.043	0.005	2.02	52.7_{AE}	0.128	83.3_{AE}	0.011^{SV}	0.006	0.019	<0.005	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.005	<0.005	0.341	8.93_{AE}	0.037	22.5_{AE}	0.007^{SV}	<0.005	0.009	<0.005	<0.005	ug/l	TM4/PM30
Chrysene #	<0.005	<0.005	0.331	9.26_{AE}	0.049	20.4_{AE}	0.007^{SV}	<0.005	0.009	<0.005	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	<0.008	<0.008	0.265	4.52_{AE}	0.102	17.0_{AE}	0.012^{SV}	<0.008	0.013	<0.008	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	<0.005	<0.005	0.088	2.14_{AE}	0.043	6.46_{AE}	$<0.005^{SV}$	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.005	<0.005	0.046	1.39_{AE}	0.019	4.10_{AE}	$<0.005^{SV}$	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005	<0.005	<0.005	$<0.100_{AE}$	<0.005	0.326_{AE}	$<0.005^{SV}$	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.005	<0.005	<0.005	0.742_{AE}	0.013	2.31_{AE}	$<0.005^{SV}$	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
PAH 16 Total #	<0.173	<0.173	1576.301	16633.882_{AE}	0.584	17849.996_{AE}	$<0.173^{SV}$	<0.173	<0.173	<0.173	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	<0.008	<0.008	0.191	3.25_{AE}	0.073	12.2_{AE}	0.009^{SV}	<0.008	0.009	<0.008	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.008	<0.008	0.074	1.27_{AE}	0.029	4.76_{AE}	$<0.008^{SV}$	<0.008	<0.008	<0.008	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	82	76	113	127_{AE}	80	$205^{SV}{}_{AI}$	68^{SV}	72	83	79	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	<5	<5	748	621	<5	3840	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Toluene #	<5	<5	30	1080	<5	1780	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Ethylbenzene #	<5	<5	43	686	<5	351	<5	<5	<5	<5	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	<5	75	1250	<5	1040	<5	<5	<5	<5	<5	ug/l	TM36/PM12
o-Xylene #	<5	<5	119	670	<5	590	<5	<5	<5	<5	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	<10	13	<10	20	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	<10	<10	165	424	<10	1260	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C8-C10 #	<10	<10	116	915	<10	1230	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	<5	$<35_{AC}$	<5	$<35_{AC}$	<5	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	$<70_{AC}$	<10	$<70_{AC}$	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	$<70_{AC}$	<10	$<70_{AC}$	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	$<70_{AC}$	<10	$<70_{AC}$	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	<10	<10	281	1352_{AC}	<10	2510_{AC}	<10	<10	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	LOD/LOR	Units	Method No.
Sample ID	WG-BH03/07/D-100523	WG-BH07/05/A-110523	WG-BH09/07/D-100523	WG-BH10/07/D-100523	WG-BH11/07/D-100523	WG-MWA-100523	SW01-110523	SW02-110523	SW03-110523	WG-WSP301-100523			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	10/05/2023	11/05/2023	10/05/2023	10/05/2023	10/05/2023	10/05/2023	11/05/2023	11/05/2023	11/05/2023	10/05/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	<10	<10	748	621	<10	3840	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	30	1080	<10	1780	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC8-EC10 #	<10	<10	238	2610	<10	1990	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC10-EC12 #	16	<5	1650	16500_{AC}	<5	18700_{AC}	<5	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	<10	<10	640	6120_{AC}	<10	7070_{AC}	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	<10	290	4340_{AC}	<10	3830_{AC}	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	100	1300_{AC}	<10	1160_{AC}	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	16	<10	3696	32571_{AC}	<10	38370_{AC}	<10	<10	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	16	<10	3977	33923_{AC}	<10	40880_{AC}	<10	<10	<10	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	<0.01	2.54_{AF}	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	<0.01	$<1.00_{AF}$	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	<0.01	0.01	0.03	<0.01	6.33_{AF}	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	<0.02	0.02	<0.02	<0.02	19.1_{AF}	<0.02	<0.02	<0.02	<0.02	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	<0.01	<0.01	0.01	<0.01	3.47_{AF}	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	<0.03	<0.03	<0.03	<0.03	22.57_{AF}	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	TM26/PM0
Xylenols #	0.10	<0.06	0.08	0.53	<0.06	89.8_{AF}	<0.06	<0.06	<0.06	<0.06	<0.06	mg/l	TM26/PM0
1-naphthol	<0.01	<0.01	<0.01	0.15	<0.01	1.05_{AF}	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	<0.01	<0.01	<0.01	<0.01	6.53_{AF}	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	<0.01	2.52_{AF}	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	0.1	<0.1	0.1	0.7	<0.1	131.3_{AF}	<0.1	<0.1	<0.1	<0.1	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	36.9	18.6	32.7	5.0	49.4	20.4	71.0	70.4	71.4	18.2	<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	5.46	5.33	5.47	1.96	<0.05	mg/l	TM38/PM0
Nitrite as N #	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.157	0.159	0.156	0.010	<0.006	mg/l	TM38/PM0
Dissolved Methane #	186	540	>>6780	434	8	>>22600	21	19	13	<1	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	318	278	398	352	252	556	116	106	110	350	<1	mg/l	TM75/PM0
Sulphide	<0.01	<0.01	0.14	0.35	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	952	815	1110	903	817	1590	616	606	614	910	<2	uS/cm	TM76/PM0
Dissolved Iron II	1	2	<1	4	<1	5	<1	<1	<1	<1	<1	mg/l	TM213/PM31
Dissolved Iron III	1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	mg/l	TM30/TM213/PM0
Manganese II	1.08	1.09	0.18	1.30	0.48	0.75	<0.02	<0.02	<0.02	1.47	<0.02	mg/l	TM62/PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	71-77	78-84	85-91	92-98	99-105	106-112	113-118	119-125	126-132	133-139	LOD/LOR	Units	Method No.
Sample ID	WG-WSP302-100523	WG-WSP303-100523	WG-WSP304-100523	WG-WSP306-100523	WG-WSP307-100523	WG-WSP308-100523	WG-WSP309-110523	WG-WSP310-110523	WG-WSP311-110523	WG-WSP312-110523			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	10/05/2023	10/05/2023	10/05/2023	10/05/2023	10/05/2023	10/05/2023	11/05/2023	11/05/2023	11/05/2023	11/05/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023			
Total Dissolved Iron #	496	2020	<20	238	85	136	114	967	73	2260	<20	ug/l	TM30/PM14
PAH MS													
Naphthalene #	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	ug/l	TM4/PM30
Acenaphthylene #	0.032	0.032	<0.005	<0.005	0.027	0.194	<0.005	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Acenaphthene #	<0.005	0.009	<0.005	0.019	0.096	0.053	0.005	0.008	0.022	8.06 AD	<0.005	ug/l	TM4/PM30
Fluorene #	<0.005	<0.005	<0.005	<0.005	0.015	0.027	0.006	0.007	0.027	1.59	<0.005	ug/l	TM4/PM30
Phenanthrene #	<0.005	<0.005	<0.005	0.018	<0.005	0.112	0.022	0.046	0.122	0.097	<0.005	ug/l	TM4/PM30
Anthracene #	0.035	<0.005	<0.005	<0.005	<0.005	0.142	<0.005	0.006	0.021	0.087	<0.005	ug/l	TM4/PM30
Fluoranthene #	0.033	<0.005	<0.005	<0.005	0.332	0.311	<0.005	0.049	0.045	0.272	<0.005	ug/l	TM4/PM30
Pyrene #	0.028	<0.005	<0.005	<0.005	0.087	0.326	0.014	0.035	0.032	0.161	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	0.011	<0.005	<0.005	<0.005	0.031	0.133	0.005	0.018	<0.005	0.011	<0.005	ug/l	TM4/PM30
Chrysene #	0.011	0.006	<0.005	<0.005	0.025	0.165	0.005	0.020	<0.005	0.011	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	0.013	0.015	<0.008	<0.008	0.014	0.302	<0.008	0.019	<0.008	0.011	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	<0.005	<0.005	<0.005	<0.005	0.006	0.131	<0.005	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.005	<0.005	<0.005	<0.005	<0.005	0.088	<0.005	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.005	<0.005	<0.005	<0.005	<0.005	0.051	<0.005	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
PAH 16 Total #	<0.173	<0.173	<0.173	<0.173	0.633	2.035	<0.173	0.208	0.269	10.300	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	0.009	0.011	<0.008	<0.008	0.010	0.217	<0.008	0.014	<0.008	<0.008	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.008	<0.008	<0.008	<0.008	<0.008	0.085	<0.008	<0.008	<0.008	<0.008	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	77	87	96	85	83	86	94	98	95	76	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	<5	<5	<5	<5	112	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Toluene #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Ethylbenzene #	<5	<5	<5	<5	6	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	107	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
o-Xylene #	<5	66	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	<10	23	<10	<10	33	<10	<10	<10	30	<10	<10	ug/l	TM36/PM12
>C8-C10 #	<10	107	<10	<10	17	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	<10	130	<10	<10	50	<10	<10	<10	30	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	71-77	78-84	85-91	92-98	99-105	106-112	113-118	119-125	126-132	133-139	LOD/LOR	Units	Method No.
Sample ID	WG-WSP302-100523	WG-WSP303-100523	WG-WSP304-100523	WG-WSP306-100523	WG-WSP307-100523	WG-WSP308-100523	WG-WSP309-110523	WG-WSP310-110523	WG-WSP311-110523	WG-WSP312-110523			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	10/05/2023	10/05/2023	10/05/2023	10/05/2023	10/05/2023	10/05/2023	11/05/2023	11/05/2023	11/05/2023	11/05/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	<10	<10	<10	<10	112	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC8-EC10 #	<10	172	<10	<10	11	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>EC10-EC12 #	150	504	<5	<5	94	<5	<5	<5	<5	24	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	70	400	<10	<10	80	<10	<10	<10	<10	80	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	50	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	220	1126	<10	<10	297	<10	<10	<10	<10	104	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	220	1256	<10	<10	347	<10	<10	<10	30	104	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	<0.05 AB	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	0.05	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	0.05	<0.03	<0.03	0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	mg/l	TM26/PM0
Xylenols #	<0.06	0.47	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	mg/l	TM26/PM0
1-naphthol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	<0.1	0.6	<0.1	<0.1	<0.5 AB	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	24.2	1.1	78.5	78.5	125	209	18.0	113	260	82.5	<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	<0.05	mg/l	TM38/PM0
Nitrite as N #	<0.006	<0.006	0.015	<0.006	<0.006	<0.006	0.085	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Dissolved Methane #	2	>>2230	<1	10	>>1300	<1	<1	3	37	142	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	280	376	282	326	282	344	348	286	318	282	<1	mg/l	TM75/PM0
Sulphide	<0.01	<0.01	<0.01	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	652	987	1020	1060	1080	1500	904	1030	1440	951	<2	uS/cm	TM76/PM0
Dissolved Iron II	<1	1	<1	<1	6	<1	<1	<1	<1	2	<1	mg/l	TM213/PM31
Dissolved Iron III	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	mg/l	TM30/TM213/PM0
Manganese II	0.47	0.46	0.27	0.44	0.81	0.63	0.47	0.38	0.63	0.97	<0.02	mg/l	TM62/PM0

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	140-146	147-153	154-160	161-167	168-174	175-181	182-188	189-195	196-202	203-209	LOD/LOR	Units	Method No.
Sample ID	WG-WSP313-110523	WG-WSP314-120523	WG-WSP315-110523	WG-WSP317-110523	WG-WSP318-120523	WG-WSP323-120523	WG-WSP325-120523	WG-WSP330-120523	DUP-1-100523	DUP-2-110523			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	11/05/2023	12/05/2023	11/05/2023	11/05/2023	12/05/2023	12/05/2023	12/05/2023	12/05/2023	12/05/2023	12/05/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023			
Total Dissolved Iron #	70	233	31	5900	2680	6750	199	13400$_{AB}$	236	5970	<20	ug/l	TM30/PM14
PAH MS													
Naphthalene #	52.0$_{AD}$	<0.1	<0.1^{SV}	8650$^{SV}_{AG}$	0.1	6270$_{AG}$	<0.1^{SV}	4250$_{AH}$	<0.1	5810$_{AG}$	<0.1	ug/l	TM4/PM30
Acenaphthylene #	<0.005	<0.005	<0.005^{SV}	14.2$^{SV}_{AG}$	0.018	3.07$_{AE}$	<0.005^{SV}	40.5$_{AE}$	<0.005	8.66$_{AE}$	<0.005	ug/l	TM4/PM30
Acenaphthene #	1.81	0.011	0.013^{SV}	302$^{SV}_{AG}$	0.078	186$_{AE}$	0.011^{SV}	312$_{AH}$	0.008	166$_{AE}$	<0.005	ug/l	TM4/PM30
Fluorene #	0.124	<0.005	0.016^{SV}	57.1$^{SV}_{AG}$	0.049	35.7$_{AE}$	0.006^{SV}	123$_{AE}$	<0.005	33.3$_{AE}$	<0.005	ug/l	TM4/PM30
Phenanthrene #	0.064	0.018	0.059^{SV}	35.6$^{SV}_{AG}$	0.520	15.8$_{AE}$	0.012^{SV}	153$_{AH}$	<0.005	20.0$_{AE}$	<0.005	ug/l	TM4/PM30
Anthracene #	0.021	<0.005	0.007^{SV}	<0.005	0.122	1.61$_{AE}$	<0.005^{SV}	24.3$_{AE}$	0.017	0.437$_{AE}$	<0.005	ug/l	TM4/PM30
Fluoranthene #	0.043	0.014	0.028^{SV}	0.486	1.28	3.11$_{AE}$	0.025^{SV}	19.7$_{AE}$	0.011	0.430$_{AE}$	<0.005	ug/l	TM4/PM30
Pyrene #	0.034	0.012	0.019^{SV}	0.325	1.13	2.18$_{AE}$	0.019^{SV}	11.6$_{AE}$	<0.005	0.304$_{AE}$	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	0.019	<0.005	0.007^{SV}	0.054	0.569	1.12$_{AE}$	0.006^{SV}	1.46$_{AE}$	<0.005	<0.100$_{AE}$	<0.005	ug/l	TM4/PM30
Chrysene #	0.023	<0.005	0.006^{SV}	0.039	0.675	1.18$_{AE}$	<0.005^{SV}	1.27$_{AE}$	<0.005	<0.100$_{AE}$	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	0.021	<0.008	<0.008^{SV}	0.028	0.795	0.994$_{AE}$	<0.008^{SV}	0.815$_{AE}$	<0.008	<0.160$_{AE}$	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	0.011	<0.005	<0.005^{SV}	0.008	0.330	0.404$_{AE}$	<0.005^{SV}	0.347$_{AE}$	<0.005	<0.100$_{AE}$	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.005	<0.005	<0.005^{SV}	0.005	0.229	<0.100$_{AE}$	<0.005^{SV}	0.153$_{AE}$	<0.005	<0.100$_{AE}$	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005	<0.005	<0.005^{SV}	<0.005	<0.005	<0.100$_{AE}$	<0.005^{SV}	<0.100$_{AE}$	<0.005	<0.100$_{AE}$	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.005	<0.005	<0.005^{SV}	<0.005	0.149	<0.100$_{AE}$	<0.005^{SV}	<0.100$_{AE}$	<0.005	<0.100$_{AE}$	<0.005	ug/l	TM4/PM30
PAH 16 Total #	54.170	<0.173	<0.173^{SV}	9059.845	6.044	6521.168$_{AE}$	<0.173^{SV}	4938.145$_{AE}$	<0.173	6039.131$_{AE}$	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	0.015	<0.008	<0.008^{SV}	0.020	0.572	0.716$_{AE}$	<0.008^{SV}	0.587$_{AE}$	<0.008	<0.160$_{AE}$	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.008	<0.008	<0.008^{SV}	<0.008	0.223	0.278$_{AE}$	<0.008^{SV}	0.228$_{AE}$	<0.008	<0.160$_{AE}$	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	115	87	65^{SV}	223$^{SV}_{AG}$	94	123$_{AE}$	68^{SV}	145$^{SV}_{AH}$	75	102$_{AE}$	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	21^{SV}	<5	<5	<5	ug/l	TM36/PM12
Benzene #	<5	<5	<5	472	<5	201	<5	3350^{SV}	<5	482	<5	ug/l	TM36/PM12
Toluene #	<5	<5	<5	123	<5	37	<5	733^{SV}	<5	128	<5	ug/l	TM36/PM12
Ethylbenzene #	34	<5	<5	198	<5	146	<5	365^{SV}	<5	231	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	<5	<5	482	<5	148	<5	874^{SV}	<5	496	<5	ug/l	TM36/PM12
o-Xylene #	12	<5	<5	278	<5	105	<5	474^{SV}	<5	286	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	<10	11	<10	<10	<10	<10^{SV}	<10	11	<10	ug/l	TM36/PM12
>C6-C8 #	19	<10	<10	176	<10	78	<10	859^{SV}	<10	177	<10	ug/l	TM36/PM12
>C8-C10 #	39	<10	<10	444	<10	196	<10	748^{SV}	<10	472	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	<5	<5	<5	<5	<5	23	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	<10	<10	<10	<10	110	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	<10	<10	<10	<10	50	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	58	<10	<10	631	<10	274	<10	1790	<10	660	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	140-146	147-153	154-160	161-167	168-174	175-181	182-188	189-195	196-202	203-209	LOD/LOR	Units	Method No.
Sample ID	WG-WSP313-110523	WG-WSP314-120523	WG-WSP315-110523	WG-WSP317-110523	WG-WSP318-120523	WG-WSP323-120523	WG-WSP325-120523	WG-WSP330-120523	DUP-1-100523	DUP-2-110523			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	11/05/2023	12/05/2023	11/05/2023	11/05/2023	12/05/2023	12/05/2023	12/05/2023	12/05/2023	12/05/2023	12/05/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023	13/05/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	<10	<10	<10	472	<10	201	<10	3350 SV	<10	482	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	<10	123	<10	37	<10	733 SV	<10	128	<10	ug/l	TM36/PM12
>EC8-EC10 #	50	<10	<10	958	<10	398	<10	1710 SV	<10	1010	<10	ug/l	TM36/PM12
>EC10-EC12 #	89	<5	<5	5330	<5	2330	<5	16400	<5	263	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	90	<10	<10	1250	<10	1520	<10	4830	<10	510	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	<10	<10	260	<10	230	<10	1810	<10	140	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	<10	<10	<10	<10	<10	260	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	229	<10	<10	8393	<10	4716	<10	29093	<10	2533	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	287	<10	<10	9024	<10	4990	<10	30883	<10	3193	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	<0.01	<0.01	0.08	<0.01	0.02	<0.01	0.86 AE	<0.01	0.07	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	<0.02	<0.02	0.05	<0.02	0.14	<0.02	2.36 AE	<0.02	0.04	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.21	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	<0.03	<0.03	0.05	<0.03	0.16	<0.03	2.57	<0.03	0.04	<0.03	mg/l	TM26/PM0
Xylenols #	0.31	<0.06	<0.06	0.82	<0.06	1.05	<0.06	56.0 AE	<0.06	0.60	<0.06	mg/l	TM26/PM0
1-naphthol	0.03	<0.01	<0.01	0.11	<0.01	0.06	<0.01	0.37 AE	<0.01	0.06	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.97 AE	<0.01	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.23 AE	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	0.4	<0.1	<0.1	1.1	<0.1	1.3	<0.1	63.0	<0.1	0.8	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	63.9	93.2	354	32.5	81.4	<0.5	129	<0.5	77.0	45.8	<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05	<0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	mg/l	TM38/PM0
Nitrite as N #	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Dissolved Methane #	<1	192	33	3170	62	>>24700	27	>>26700	167	>>3230	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	384	240	336	372	282	286	272	558	320	350	<1	mg/l	TM75/PM0
Sulphide	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	1110	903	1510	1010	946	757	1040	2200	1060	1010	<2	uS/cm	TM76/PM0
Dissolved Iron II	<1	<1	<1	5	3	7	<1	11 AA	<1	6	<1	mg/l	TM213/PM31
Dissolved Iron III	<1	<1	<1	<1	<1	<1	<1	2	<1	<1	<1	mg/l	TM30/TM213/PM0
Manganese II	0.44	0.34	0.56	0.51	0.94	0.06	0.29	0.13	0.44	0.65	<0.02	mg/l	TM62/PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	210-216												
Sample ID	DUP-3-120523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	12/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023												

Please see attached notes for all abbreviations and acronyms

		LOD/LOR	Units	Method No.
Total Dissolved Iron #	6600	<20	ug/l	TM30/PM14
PAH MS				
Naphthalene #	6690^{SV}_{AG}	<0.1	ug/l	TM4/PM30
Acenaphthylene #	3.44_{AE}	<0.005	ug/l	TM4/PM30
Acenaphthene #	197_{AE}	<0.005	ug/l	TM4/PM30
Fluorene #	37.8_{AE}	<0.005	ug/l	TM4/PM30
Phenanthrene #	14.9_{AE}	<0.005	ug/l	TM4/PM30
Anthracene #	1.60_{AE}	<0.005	ug/l	TM4/PM30
Fluoranthene #	2.68_{AE}	<0.005	ug/l	TM4/PM30
Pyrene #	1.92_{AE}	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	0.913_{AE}	<0.005	ug/l	TM4/PM30
Chrysene #	1.03_{AE}	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	0.814_{AE}	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	0.315_{AE}	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	$<0.100_{AE}$	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	$<0.100_{AE}$	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	0.242_{AE}	<0.005	ug/l	TM4/PM30
PAH 16 Total #	6952.654_{AE}	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	0.586_{AE}	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	0.228_{AE}	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	88_{AE}	<0	%	TM4/PM30
MTBE #	<5	<5	ug/l	TM36/PM12
Benzene #	204	<5	ug/l	TM36/PM12
Toluene #	38	<5	ug/l	TM36/PM12
Ethylbenzene #	150	<5	ug/l	TM36/PM12
m/p-Xylene #	153	<5	ug/l	TM36/PM12
o-Xylene #	110	<5	ug/l	TM36/PM12
TPH CWG				
Aliphatics				
>C5-C6 #	<10	<10	ug/l	TM36/PM12
>C6-C8 #	77	<10	ug/l	TM36/PM12
>C8-C10 #	205	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	282	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	210-216										LOD/LOR	Units	Method No.
Sample ID	DUP-3-120523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	12/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023												
TPH CWG													
Aromatics													
>C5-EC7 #	204										<10	ug/l	TM36/PM12
>EC7-EC8 #	38										<10	ug/l	TM36/PM12
>EC8-EC10 #	413										<10	ug/l	TM36/PM12
>EC10-EC12 #	2730										<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	1610										<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	230										<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10										<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	5225										<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	5507										<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01										<0.01	mg/l	TM26/PM0
Catechol	0.02										<0.01	mg/l	TM26/PM0
Phenol #	0.02										<0.01	mg/l	TM26/PM0
m/p-cresol	0.15										<0.02	mg/l	TM26/PM0
o-cresol	0.02										<0.01	mg/l	TM26/PM0
Total cresols #	0.17										<0.03	mg/l	TM26/PM0
Xylenols #	1.03										<0.06	mg/l	TM26/PM0
1-naphthol	0.06										<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01										<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01										<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	1.3										<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	<0.5										<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05										<0.05	mg/l	TM38/PM0
Nitrite as N #	<0.006										<0.006	mg/l	TM38/PM0
Dissolved Methane #	>>24900										<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	284										<1	mg/l	TM75/PM0
Sulphide	<0.01										<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	760										<2	uS/cm	TM76/PM0
Dissolved Iron II	7										<1	mg/l	TM213/PM31
Dissolved Iron III	<1										<1	mg/l	TM30/TM213/PM0
Manganese II	0.07										<0.02	mg/l	TM62/PM0

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	15-21										Please see attached notes for all abbreviations and acronyms		
Sample ID	WG-BH09/07/D-100523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	10/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023												
PAH MS													
PAH Surrogate % Recovery	92 AG										<0	%	TM4/PM30

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	22-28										Please see attached notes for all abbreviations and acronyms		
Sample ID	WG-BH10/07/D-100523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	10/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023												
PAH MS													
PAH Surrogate % Recovery	133 SV AI										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	133-139										Please see attached notes for all abbreviations and acronyms		
Sample ID	WG-WSP312-110523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	11/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023												
PAH MS													
PAH Surrogate % Recovery	79_{AD}										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	140-146										Please see attached notes for all abbreviations and acronyms		
Sample ID	WG-WSP313-110523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	11/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023												
											LOD/LOR	Units	Method No.
PAH MS													
PAH Surrogate % Recovery	93_{AD}										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	175-181										Please see attached notes for all abbreviations and acronyms		
Sample ID	WG-WSP323-120523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	12/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023												
PAH MS													
PAH Surrogate % Recovery	94 AG										<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/7606

Report : Liquid (Duplicate results)

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

EMT Sample No.	203-209										Please see attached notes for all abbreviations and acronyms		
Sample ID	DUP-2-110523												
Depth													
COC No / misc													
Containers	V HCL Z P G												
Sample Date	12/05/2023												
Sample Type	Ground Water												
Batch Number	1												
Date of Receipt	13/05/2023											LOD/LOR	Units	Method No.
PAH MS														
PAH Surrogate % Recovery	115 AG											<0	%	TM4/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns

EMT Job No.	Batch	Sample ID	Depth	EMT Sample No.	Analysis	Reason
No deviating sample report results for job 23/7606						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

EMT Job No.: 23/7606

SOILS and ASH

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary. Asbestos samples are retained for 6 months.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Limits of detection for analyses carried out on as received samples are not moisture content corrected. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C. Ash samples are dried at 37°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Sufficient amount of sample must be received to carry out the testing specified. Where an insufficient amount of sample has been received the testing may not meet the requirements of our accredited methods, as such accreditation may be removed.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

STACK EMISSIONS

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation for Dioxins and Furans and Dioxin like PCBs has been performed on XAD-2 Resin, only samples which use this resin will be within our MCERTS scope.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

DEVIATING SAMPLES

All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. The temperature of sample receipt is recorded on the confirmation schedules in order that the client can make an informed decision as to whether testing should still be undertaken.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a requirement of our Accreditation Body for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.
Laboratory records are kept for a period of no less than 6 years.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

Measurement Uncertainty

Measurement uncertainty defines the range of values that could reasonably be attributed to the measured quantity. This range of values has not been included within the reported results. Uncertainty expressed as a percentage can be provided upon request.

Customer Provided Information

Sample ID and depth is information provided by the customer.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
>>	Results above quantitative calibration range. The result should be considered the minimum value and is indicative only. The actual result could be significantly higher.
*	Analysis subcontracted to an Element Materials Technology approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x2 Dilution
AB	x5 Dilution
AC	x7 Dilution
AD	x10 Dilution
AE	x20 Dilution
AF	x100 Dilution

AG	x200 Dilution
AH	x400 Dilution
AI	x2000 Dilution

HWOL ACRONYMS AND OPERATORS USED

HS	Headspace Analysis.
EH	Extractable Hydrocarbons - i.e. everything extracted by the solvent.
CU	Clean-up - e.g. by florisil, silica gel.
1D	GC - Single coil gas chromatography.
Total	Aliphatics & Aromatics.
AL	Aliphatics only.
AR	Aromatics only.
2D	GC-GC - Double coil gas chromatography.
#1	EH_Total but with humics mathematically subtracted
#2	EU_Total but with fatty acids mathematically subtracted
_	Operator - underscore to separate acronyms (exception for +).
+	Operator to indicate cumulative e.g. EH+HS_Total or EH_CU+HS_Total
MS	Mass Spectrometry.

EMT Job No: 23/7606

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM4	Modified USEPA 8270D v5:2014 method for the solvent extraction and determination of PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
TM4	Modified USEPA 8270D v5:2014 method for the solvent extraction and determination of PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM5	Modified 8015B v2:1996 method for the determination of solvent Extractable Petroleum Hydrocarbons (EPH) within the range C8-C40 by GCFID. For waters the solvent extracts dissolved phase plus a sheen if present.	PM16/PM30	Fractionation into aliphatic and aromatic fractions using a Rapid Trace SPE/Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM5/TM36	please refer to TM5 and TM36 for method details	PM12/PM16/PM30	please refer to PM16/PM30 and PM12 for method details	Yes			
TM25	Determintaion of Dissolved Methane, Ethane and Ethene by Headspace GC-FID	PM0	No preparation is required.	Yes			
TM26	Determination of phenols by Reversed Phased High Performance Liquid Chromatography and Electro-Chemical Detection.	PM0	No preparation is required.				
TM26	Determination of phenols by Reversed Phased High Performance Liquid Chromatography and Electro-Chemical Detection.	PM0	No preparation is required.	Yes			
TM30	Determination of Trace Metals by ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry): WATERS by Modified USEPA Method 200.7, Rev. 4.4, 1994; Modified EPA Method 6010B, Rev.2, Dec 1996; Modified BS EN ISO 11885:2009: SOILS by Modified USEP 6010B, Rev.2, Dec.1996; Modified EPA Method 3050B, Rev.2, Dec.1996	PM14	Preparation of waters and leachates for metals by ICP OES/ICP MS. Samples are filtered for Dissolved metals, and remain unfiltered for Total metals then acidified	Yes			
TM30/TM213	Calculation of Fe (III) based on Iron and Fe(II)	PM0	No preparation is required.				
TM36	Modified US EPA method 8015B v2:1996. Determination of Gasoline Range Organics (GRO) in the carbon chain range of C4-12 by headspace GC-FID. MTBE by GCFID co-elutes with 3-methylpentane if present and therefore can give a false positive. Positive MTBE results will be re-run using GC-MS to double check, when requested.	PM12	Modified US EPA method 5021A v2:2014. Preparation of solid and liquid samples for GC headspace analysis.	Yes			

EMT Job No: 23/7606

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM38	Soluble Ion analysis using Discrete Analyser. Modified US EPA methods: Chloride 325.2 (1978), Sulphate 375.4 (Rev.2 1993), o-Phosphate 365.2 (Rev.2 1993), TON 353.1 (Rev.2 1993), Nitrite 354.1 (1971), Hex Cr 7196A (1992), NH4+ 350.1 (Rev.2 1993) – All anions comparable to BS ISO 15923-1: 2013I	PM0	No preparation is required.	Yes			
TM62	Determination of Manganese (II) by reaction with Formaldoxime in ammoniacal solution to form a manganese complex which is analysed spectrophotometrically.	PM0	No preparation is required.				
TM75	Modified US EPA method 310.1 (1978). Determination of Alkalinity by Metrohm automated titration analyser.	PM0	No preparation is required.	Yes			
TM76	Modified US EPA method 120.1 (1982). Determination of Specific Conductance by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			
TM107	Determination of Sulphide/Thiocyanate by Skalar Continuous Flow Analyser	PM0	No preparation is required.				
TM213	Fe(II) and Mn(II) by IC and Spectro	PM31	Prep of Waters for Inorganics				

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OL3 5DE

Attention :	Gareth Barns
Date :	31st October, 2023
Your reference :	GCU0309002
Our reference :	Test Report 23/15723 Batch 1
Location :	Knottingley
Date samples received :	22nd September, 2023
Status :	Final Report
Issue :	1

Thirty three samples were received for analysis on 22nd September, 2023 of which thirty three were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

The greenhouse gas emissions generated (in Carbon – Co2e) to obtain the results in this report are estimated as:

Scope 1&2 emissions - 75.368 kg of CO2

Scope 1&2&3 emissions - 178.115 kg of CO2

Authorised By:

Simon Gomery BSc
Senior Project Manager

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	LOD/LOR	Units	Method No.
Sample ID	WG-DUP-1-190923	WG-DUP-2-200923	WG-DUP-3-200923	WG-BH11/07/D-190923	WG-BH03/07/D-190923	WG-WSP301-190923	WG-WSP302-190923	WG-WSP303-190923	WG-WSP304-190923	WG-MW1A-190923			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	19/09/2023	20/09/2023	20/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023			
PAH MS													
Naphthalene #	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	173 AE	850 AF	<0.1	8790 SV AF	<0.1	ug/l	TM4/PM30
Acenaphthylene #	0.005	<0.005	<0.005	0.014	<0.005	<0.005	0.155	2.53	<0.005	183 SV AF	<0.005	ug/l	TM4/PM30
Acenaphthene #	0.005	<0.005	0.016	0.296	<0.005	<0.005	4.09	31.0	0.031	1770 SV AF	<0.005	ug/l	TM4/PM30
Fluorene #	<0.005	<0.005	0.008	0.208	<0.005	<0.005	0.826	5.63	0.009	1070 SV AF	<0.005	ug/l	TM4/PM30
Phenanthrene #	<0.005	0.011	0.078	0.022	<0.005	<0.005	0.472	3.76	<0.005	2390 SV AF	<0.005	ug/l	TM4/PM30
Anthracene #	0.012	<0.005	0.018	0.022	<0.005	<0.005	0.070	0.594	<0.005	431 SV AF	<0.005	ug/l	TM4/PM30
Fluoranthene #	0.019	0.010	0.177	0.189	<0.005	0.016	0.093	0.563	0.012	707 SV AF	<0.005	ug/l	TM4/PM30
Pyrene #	0.010	0.008	0.173	0.185	<0.005	0.012	0.060	0.369	0.016	487 SV AF	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.005	<0.005	0.063	0.071	<0.005	0.007	<0.005	<0.005	<0.005	146 SV AF	<0.005	ug/l	TM4/PM30
Chrysene #	<0.005	<0.005	0.095	0.095	<0.005	0.010	<0.005	<0.005	<0.005	167 SV AF	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	<0.008	<0.008	0.108	0.069	<0.008	0.011	<0.008	0.026	<0.008	121 SV AF	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	<0.005	<0.005	0.058	0.041	<0.005	<0.005	<0.005	0.012	<0.005	58.8 SV AF	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.005	<0.005	0.019	0.016	<0.005	<0.005	<0.005	<0.005	<0.005	20.5 SV AF	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.500 SV AF	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.005	<0.005	0.021	0.016	<0.005	<0.005	<0.005	<0.005	<0.005	19.1 SV AF	<0.005	ug/l	TM4/PM30
PAH 16 Total #	<0.173	<0.173	0.834	1.244	<0.173	<0.173	178.766	894.484	<0.173	16360.400 SV AF	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	<0.008	<0.008	0.078	0.050	<0.008	<0.008	<0.008	0.019	<0.008	87.1 SV AF	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.008	<0.008	0.030	0.019	<0.008	<0.008	<0.008	<0.008	<0.008	33.9 SV AF	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	84	83	81	80	79	81	101	125	95	86 SV AF	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	13	<5	<5	<5	<5	<5	48	<5	<5	2810	<5	ug/l	TM36/PM12
Toluene #	<5	<5	<5	<5	<5	<5	<5	<5	<5	1370	<5	ug/l	TM36/PM12
Ethylbenzene #	<5	<5	<5	<5	<5	<5	<5	<5	<5	277	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	<5	<5	<5	<5	<5	10	187	<5	807	<5	ug/l	TM36/PM12
o-Xylene #	<5	<5	<5	<5	<5	<5	11	103	<5	444	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	17	<10	ug/l	TM36/PM12
>C6-C8 #	<10	<10	<10	<10	<10	<10	16	30	<10	1010	<10	ug/l	TM36/PM12
>C8-C10 #	<10	<10	<10	<10	<10	<10	15	126	<10	915	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	<5	<5	<5	<5	<5	<5	<5	296 AB	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	1280 AB	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	1450 AB	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<70 AB	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	<10	<10	<10	<10	<10	<10	31	156	<10	4968 AB	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	LOD/LOR	Units	Method No.
Sample ID	WG-DUP-1-190923	WG-DUP-2-200923	WG-DUP-3-200923	WG-BH11/07/D-190923	WG-BH03/07/D-190923	WG-WSP301-190923	WG-WSP302-190923	WG-WSP303-190923	WG-WSP304-190923	WG-MW1A-190923			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	19/09/2023	20/09/2023	20/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	13	<10	<10	<10	<10	<10	48	<10	<10	2810	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	1370	<10	ug/l	TM36/PM12
>EC8-EC10 #	<10	<10	<10	<10	<10	<10	21	290	<10	1530	<10	ug/l	TM36/PM12
>EC10-EC12 #	<5	<5	<5	<5	<5	<5	319	526	<5	19400$_{AB}$	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	<10	<10	<10	<10	<10	<10	190	420	<10	10700$_{AB}$	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	<10	<10	<10	<10	<10	40	70	<10	8770$_{AB}$	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	2720$_{AB}$	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	13	<10	<10	<10	<10	<10	618	1306	<10	47300$_{AB}$	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	13	<10	<10	<10	<10	<10	649	1462	<10	52268$_{AB}$	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10$_{AC}$	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10$_{AC}$	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	0.03	<0.01	3.85$_{AC}$	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	<0.02	<0.02	<0.02	<0.02	0.39	<0.02	0.26	<0.02	13.1$_{AF}$	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.78$_{AC}$	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	<0.03	<0.03	<0.03	<0.03	0.39	<0.03	0.26	<0.03	14.88$_{AC}$	<0.03	mg/l	TM26/PM0
Xylenols #	<0.06	<0.06	<0.06	<0.06	<0.06	0.14	<0.06	1.38	<0.06	78.6$_{AF}$	<0.06	mg/l	TM26/PM0
1-naphthol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.75$_{AC}$	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	0.21	<0.01	4.65$_{AC}$	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.08	<0.01	1.34$_{AC}$	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	<0.1	2.0	<0.1	104.1$_{AC}$	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	24.6	5.9	82.1	46.6	32.6	0.7	7.8	<0.5	74.1	15.4	<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	mg/l	TM38/PM0
Nitrite as N #	<0.006	0.037	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Dissolved Methane #	>>2060	3	34	<1	524	>>6460	>>4880	>>4840	1	>>17700	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	396	306	278	250	306	394	298	368	276	468	<1	mg/l	TM75/PM0
Sulphide	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	1100	868	943	810	920	951	756	935	1010	1320	<2	uS/cm	TM76/PM0
Dissolved Iron II	<1	<1	3	<1	1	<1	<1	3	<1	3	<1	mg/l	TM213/PM31
Dissolved Iron III	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	mg/l	TM30/TM213/PM0
Manganese II	0.56	1.58	1.03	0.48	1.13	1.90	0.92	0.55	0.95	0.76	<0.02	mg/l	TM62/PM0

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	71-77	78-84	85-91	92-98	99-105	106-112	113-119	120-126	127-133	134-140	LOD/LOR	Units	Method No.
Sample ID	WG-WSP306-190923	WG-WSP307-190923	WG-WSP308-190923	WG-BH09/07/D-190923	WG-BH10/07/D-190923	SW1-210923	SW2-210923	SW3-210923	WG-WSP317-190923	WG-WSP313-190923			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	21/09/2023	21/09/2023	21/09/2023	19/09/2023	19/09/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Surface Water	Surface Water	Surface Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023			
PAH MS													
Naphthalene #	<0.1	<0.1	<0.1	387 AE	23800 AH	<0.5 AA	<0.1	<0.1	>>4030 AG	>>157 AC	<0.1	ug/l	TM4/PM30
Acenaphthylene #	0.005	0.023	0.110	2.77	293 AH	<0.025 AA	<0.005	<0.005	2.92	0.030	<0.005	ug/l	TM4/PM30
Acenaphthene #	0.005	0.027	0.013	100 AE	2230 AH	<0.025 AA	0.016	0.012	135 AG	3.15	<0.005	ug/l	TM4/PM30
Fluorene #	<0.005	0.035	0.006	44.2 AE	1430 AH	<0.025 AA	0.007	0.006	30.1 AG	0.145	<0.005	ug/l	TM4/PM30
Phenanthrene #	<0.005	0.043	0.011	65.4 AE	3620 AH	<0.025 AA	0.020	0.017	17.2 AG	0.079	<0.005	ug/l	TM4/PM30
Anthracene #	0.014	0.041	0.076	11.4 AE	642 AH	<0.025 AA	0.005	<0.005	0.400	<0.005	<0.005	ug/l	TM4/PM30
Fluoranthene #	0.019	0.119	0.073	12.4 AE	1040 AH	<0.025 AA	0.034	0.037	0.307	0.020	<0.005	ug/l	TM4/PM30
Pyrene #	0.010	0.129	0.082	7.42 AE	795 AH	0.027 AA	0.032	0.036	0.218	0.017	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.005	0.053	0.056	1.20	215 AH	0.030 AA	0.015	0.019	0.048	0.008	<0.005	ug/l	TM4/PM30
Chrysene #	<0.005	0.074	0.079	1.37	204 AH	0.059 AA	0.017	0.022	0.035	0.007	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	<0.008	0.105	0.223	0.796	171 AH	0.051 AA	0.029	0.037	0.029	0.012	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	<0.005	0.061	0.142	0.466	115 AH	<0.025 AA	0.014	0.016	0.013	<0.005	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.005	0.021	0.058	0.175	44.6 AH	0.032 AA	0.009	0.009	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005	<0.005	<0.005	<0.005	<10.000 AH	<0.025 AA	<0.005	<0.005	<0.005	<0.005	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.005	0.021	0.059	0.169	30.1 AH	<0.025 AA	0.007	0.009	<0.005	<0.005	<0.005	ug/l	TM4/PM30
PAH 16 Total #	<0.173	0.752	0.988	634.766	34629.700 AH	<0.865 AA	0.205	0.220	4216.270	160.468	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	<0.008	0.076	0.161	0.573	123 AH	<0.040 AA	0.021	0.027	0.021	0.009	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.008	0.029	0.062	0.223	47.9 AH	<0.040 AA	0.008	0.010	0.008	<0.008	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	85	82	83	75	141 SV AH	83 AA	81	80	93 AG	122	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	11	292	293	199	377	<5	<5	<5	323	<5	<5	ug/l	TM36/PM12
Toluene #	<5	<5	<5	9	930	<5	<5	<5	83	<5	<5	ug/l	TM36/PM12
Ethylbenzene #	<5	<5	74	18	665	<5	<5	<5	256	<5	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	<5	12	26	1050	<5	<5	<5	368	<5	<5	ug/l	TM36/PM12
o-Xylene #	<5	<5	23	41	553	<5	<5	<5	217	<5	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	<10	<10	11	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	<10	72	84	57	360	<10	<10	<10	117	<10	<10	ug/l	TM36/PM12
>C8-C10 #	<10	22	62	70	819	<10	<10	<10	350	<10	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	<5	<5	474 AB	<5	<5	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	<10	2400 AB	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	<10	2830 AB	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	1140 AB	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	<10	94	146	127	8034 AB	<10	<10	<10	467	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Please see attached notes for all abbreviations and acronyms

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	71-77	78-84	85-91	92-98	99-105	106-112	113-119	120-126	127-133	134-140	LOD/LOR	Units	Method No.
Sample ID	WG-WSP306-190923	WG-WSP307-190923	WG-WSP308-190923	WG-BH09/07/D-190923	WG-BH10/07/D-190923	SW1-210923	SW2-210923	SW3-210923	WG-WSP317-190923	WG-WSP313-190923			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	19/09/2023	19/09/2023	19/09/2023	19/09/2023	19/09/2023	21/09/2023	21/09/2023	21/09/2023	19/09/2023	19/09/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Surface Water	Surface Water	Surface Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	11	292	293	199	377	<10	<10	<10	323	<10	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	<10	<10	930	<10	<10	<10	83	<10	<10	ug/l	TM36/PM12
>EC8-EC10 #	<10	<10	110	84	2270	<10	<10	<10	841	<10	<10	ug/l	TM36/PM12
>EC10-EC12 #	<5	107	<5	224	33800$_{AB}$	<5	<5	<5	3540	485	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	<10	120	<10	710	38000$_{AB}$	<10	<10	<10	1300	210	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	<10	<10	550	46000$_{AB}$	<10	<10	<10	230	<10	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	<10	<10	17200$_{AB}$	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	11	519	403	1767	138577$_{AB}$	<10	<10	<10	6317	695	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	11	613	549	1894	146611$_{AB}$	<10	<10	<10	6784	695	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	<0.10$_{AC}$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	0.02	<0.10$_{AC}$	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	0.09	<0.01	0.01	<0.10$_{AC}$	<0.01	<0.01	<0.01	0.04	0.02	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	0.24	<0.02	0.03	<0.20$_{AC}$	<0.02	<0.02	<0.02	0.03	0.09	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	<0.01	<0.01	0.01	<0.10$_{AC}$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	0.24	<0.03	0.04	<0.30$_{AC}$	<0.03	<0.03	<0.03	0.03	0.09	<0.03	mg/l	TM26/PM0
Xylenols #	<0.06	<0.06	<0.06	0.11	<0.60$_{AC}$	<0.06	<0.06	<0.06	0.48	0.54	<0.06	mg/l	TM26/PM0
1-naphthol	<0.01	<0.01	<0.01	<0.01	0.12$_{AC}$	<0.01	<0.01	<0.01	0.09	0.03	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	<0.01	<0.01	<0.01	<0.10$_{AC}$	<0.01	<0.01	<0.01	0.23	0.08	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	0.16$_{AC}$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	<0.1	0.3	<0.1	0.2	<1.0$_{AC}$	<0.1	<0.1	<0.1	0.9	0.8	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	21.9	31.3	169	26.4	6.3	24.9	25.0	25.2	65.6	28.6	<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05	<0.05	<0.05	<0.05	<0.05	2.17	2.21	2.17	<0.05	<0.05	<0.05	mg/l	TM38/PM0
Nitrite as N #	<0.006	<0.006	0.007	<0.006	<0.006	0.034	0.035	0.035	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Dissolved Methane #	>>2000	>>1990	2	>>12200	>>226	3	3	3	>>1470	>>8700	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	402	380	352	342	362	66	62	64	262	380	<1	mg/l	TM75/PM0
Sulphide	0.03	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	1050	1090	1260	928	887	281	281	276	942	1140	<2	uS/cm	TM76/PM0
Dissolved Iron II	<1	<1	1	1	4	<1	<1	<1	4	<1	<1	mg/l	TM213/PM31
Dissolved Iron III	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	mg/l	TM30/TM213/PM0
Manganese II	0.59	1.42	0.77	0.09	1.56	<0.02	<0.02	<0.02	0.82	0.54	<0.02	mg/l	TM62/PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

Please see attached notes for all abbreviations and acronyms

EMT Sample No.	141-147	148-154	155-161	162-168	169-175	176-182	183-189	190-196	197-203	204-210	LOD/LOR	Units	Method No.
Sample ID	WG-WSP312-200923	WG-WSP311-200923	WG-WSP309-200923	WG-WSP310-200923	WG-WSP315-200923	WG-WSP314-210923	WG-WSP325-210923	WG-WSP318-200923	WG-WSP330-200923	WG-WSP323-200923			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	20/09/2023	20/09/2023	20/09/2023	20/09/2023	20/09/2023	21/09/2023	21/09/2023	20/09/2023	20/09/2023	20/09/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023			
PAH MS													
Naphthalene #	<0.5 AA	<0.5 AA	<0.1	<0.1	<0.1	<0.5 AA	<0.1	<0.5 AA	>>28700 AH	>>2830 AF	<0.1	ug/l	TM4/PM30
Acenaphthylene #	<0.025 AA	<0.025 AA	<0.005	<0.005	<0.005	<0.025 AA	0.019	<0.025 AA	269 AD	0.627	<0.005	ug/l	TM4/PM30
Acenaphthene #	<0.025 AA	<0.025 AA	0.010	0.008	0.009	<0.025 AA	0.125	<0.025 AA	3460 AH	104 AF	<0.005	ug/l	TM4/PM30
Fluorene #	0.079 AA	<0.025 AA	0.005	0.006	0.006	<0.025 AA	0.194	<0.025 AA	2270 AH	18.1 AF	<0.005	ug/l	TM4/PM30
Phenanthrene #	0.028 AA	<0.025 AA	0.012	0.013	0.019	<0.025 AA	0.912	<0.025 AA	5370 AH	>>8.71	<0.005	ug/l	TM4/PM30
Anthracene #	0.033 AA	<0.025 AA	<0.005	0.011	<0.005	<0.025 AA	0.144	<0.025 AA	1090 AH	0.242	<0.005	ug/l	TM4/PM30
Fluoranthene #	0.313 AA	<0.025 AA	0.014	0.013	0.010	<0.025 AA	0.376	<0.025 AA	1880 AH	0.234	<0.005	ug/l	TM4/PM30
Pyrene #	0.175 AA	<0.025 AA	0.010	0.015	0.008	<0.025 AA	0.275	<0.025 AA	1240 AH	0.121	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	0.025 AA	<0.025 AA	<0.005	0.057	<0.005	<0.025 AA	0.097	<0.025 AA	398 AD	0.018	<0.005	ug/l	TM4/PM30
Chrysene #	0.036 AA	<0.025 AA	<0.005	0.060	<0.005	<0.025 AA	0.087	<0.025 AA	298 AD	0.016	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	0.042 AA	<0.040 AA	<0.008	0.125	<0.008	<0.040 AA	0.129	<0.040 AA	356 AD	0.028	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	<0.025 AA	<0.025 AA	<0.005	0.055	<0.005	<0.025 AA	0.080	<0.025 AA	230 AD	0.012	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.025 AA	<0.025 AA	<0.005	0.045	<0.005	<0.025 AA	0.037	<0.025 AA	105 AD	0.008	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.025 AA	<0.025 AA	<0.005	0.034	<0.005	<0.025 AA	<0.005	<0.025 AA	10.8 AD	<0.005	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.025 AA	<0.025 AA	<0.005	0.043	<0.005	<0.025 AA	0.032	<0.025 AA	69.4 AD	0.007	<0.005	ug/l	TM4/PM30
PAH 16 Total #	<0.865 AA	<0.865 AA	<0.173	0.485	<0.173	<0.865 AA	2.507	<0.865 AA	45746.200 AD	2962.123	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	<0.040 AA	<0.040 AA	<0.008	0.090	<0.008	<0.040 AA	0.093	<0.040 AA	256 AD	0.020	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.040 AA	<0.040 AA	<0.008	0.035	<0.008	<0.040 AA	0.036	<0.040 AA	99.7 AD	<0.008	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	86 AA	86 AA	86	86	85	88 AA	74	86 AA	100 AH	79 AF	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	<5	<5	<5	<5	11	<5	<5	ug/l	TM36/PM12
Benzene #	<5	<5	<5	<5	<5	<5	<5	<5	2160	115	<5	ug/l	TM36/PM12
Toluene #	<5	<5	<5	<5	<5	<5	<5	<5	550	12	<5	ug/l	TM36/PM12
Ethylbenzene #	<5	<5	<5	<5	<5	<5	<5	<5	319	144	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	<5	<5	<5	<5	<5	<5	<5	743	110	<5	ug/l	TM36/PM12
o-Xylene #	<5	<5	<5	<5	<5	<5	<5	<5	409	90	<5	ug/l	TM36/PM12
TPH CWG													
Aliphatics													
>C5-C6 #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	<10	33	<10	<10	<10	<10	<10	<10	648	50	<10	ug/l	TM36/PM12
>C8-C10 #	<10	<10	<10	<10	<10	<10	<10	<10	765	192	<10	ug/l	TM36/PM12
>C10-C12 #	40	<5	<5	<5	<5	<5	<5	<5	1020 AB	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	<10	<10	<10	<10	<10	3980 AB	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	<10	<10	<10	<10	<10	3620 AB	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	<10	<10	<10	<10	1030 AB	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	40	33	<10	<10	<10	<10	<10	<10	11063 AB	242	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Element Materials Technology

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	141-147	148-154	155-161	162-168	169-175	176-182	183-189	190-196	197-203	204-210	LOD/LOR	Units	Method No.
Sample ID	WG-WSP312-200923	WG-WSP311-200923	WG-WSP309-200923	WG-WSP310-200923	WG-WSP315-200923	WG-WSP314-210923	WG-WSP325-210923	WG-WSP318-200923	WG-WSP330-200923	WG-WSP323-200923			
Depth													
COC No / misc													
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G	V HCL Z P G			
Sample Date	20/09/2023	20/09/2023	20/09/2023	20/09/2023	20/09/2023	21/09/2023	21/09/2023	20/09/2023	20/09/2023	20/09/2023			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023	22/09/2023			
TPH CWG													
Aromatics													
>C5-EC7 #	<10	<10	<10	<10	<10	<10	<10	<10	2160	115	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	<10	<10	<10	<10	<10	<10	550	12	<10	ug/l	TM36/PM12
>EC8-EC10 #	<10	<10	<10	<10	<10	<10	<10	<10	1470	344	<10	ug/l	TM36/PM12
>EC10-EC12 #	54	<5	<5	<5	<5	<5	<5	<5	30800 AB	6870	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	50	<10	<10	<10	<10	<10	<10	<10	34200 AB	2090	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	<10	<10	<10	<10	<10	<10	<10	36800 AB	380	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	<10	<10	<10	<10	<10	<10	14300 AB	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	104	<10	<10	<10	<10	<10	<10	<10	120280 AB	9811	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	144	33	<10	<10	<10	<10	<10	<10	131343 AB	10053	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10 AC	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10 AC	0.01	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.59 AC	0.01	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.86 AC	0.11	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.10 AC	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.86 AC	0.11	<0.03	mg/l	TM26/PM0
Xylenols #	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	29.2 AC	0.61	<0.06	mg/l	TM26/PM0
1-naphthol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.24 AC	0.06	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.41 AC	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.80 AC	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	33.1 AC	0.8	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	59.6	257	5.8	103	347	92.0	122	82.3	<0.5	<0.5	<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05	<0.05	<0.05	0.42	<0.05	<0.05	<0.05	<0.05	0.56	<0.05	<0.05	mg/l	TM38/PM0
Nitrite as N #	<0.006	<0.006	0.024	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Dissolved Methane #	72	16	<1	<1	32	380	<1	26	>>15200	>>25000	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	266	248	266	260	252	178	224	246	414	244	<1	mg/l	TM75/PM0
Sulphide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	940	1400	831	1060	1480	867	1020	921	1490	721	<2	uS/cm	TM76/PM0
Dissolved Iron II	3	<1	<1	<1	<1	<1	<1	2	4	6	<1	mg/l	TM213/PM31
Dissolved Iron III	<1	<1	<1	<1	<1	<1	<1	<1	3	<1	<1	mg/l	TM30/TM213/PM0
Manganese II	1.09	0.40	1.60	<0.02	0.69	0.39	0.34	1.03	0.08	0.09	<0.02	mg/l	TM62/PM0

Please see attached notes for all abbreviations and acronyms

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	211-217	218-224	225-231									
Sample ID	WG-WSP332-200923	BH02/05/A-200923	BH07/05/A-200923									
Depth												
COC No / misc												
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G									
Sample Date	20/09/2023	20/09/2023	20/09/2023									
Sample Type	Ground Water	Ground Water	Ground Water									
Batch Number	1	1	1									
Date of Receipt	22/09/2023	22/09/2023	22/09/2023									

Please see attached notes for all abbreviations and acronyms

				LOD/LOR	Units	Method No.
PAH MS						
Naphthalene #	<0.1	<0.5 AA	<0.1	<0.1	ug/l	TM4/PM30
Acenaphthylene #	<0.005	<0.025 AA	<0.005	<0.005	ug/l	TM4/PM30
Acenaphthene #	0.024	<0.025 AA	0.009	<0.005	ug/l	TM4/PM30
Fluorene #	0.015	<0.025 AA	<0.005	<0.005	ug/l	TM4/PM30
Phenanthrene #	0.060	<0.025 AA	0.016	<0.005	ug/l	TM4/PM30
Anthracene #	0.014	0.051 AA	<0.005	<0.005	ug/l	TM4/PM30
Fluoranthene #	0.090	<0.025 AA	0.033	<0.005	ug/l	TM4/PM30
Pyrene #	0.076	0.029 AA	0.027	<0.005	ug/l	TM4/PM30
Benzo(a)anthracene #	0.042	<0.025 AA	0.012	<0.005	ug/l	TM4/PM30
Chrysene #	0.041	<0.025 AA	0.012	<0.005	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	0.070	0.042 AA	0.020	<0.008	ug/l	TM4/PM30
Benzo(a)pyrene #	0.029	<0.025 AA	0.008	<0.005	ug/l	TM4/PM30
Indeno(123cd)pyrene #	0.021	<0.025 AA	<0.005	<0.005	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.005	<0.025 AA	<0.005	<0.005	ug/l	TM4/PM30
Benzo(ghi)perylene #	0.017	<0.025 AA	<0.005	<0.005	ug/l	TM4/PM30
PAH 16 Total #	0.499	<0.865 AA	<0.173	<0.173	ug/l	TM4/PM30
Benzo(b)fluoranthene	0.050	<0.040 AA	0.014	<0.008	ug/l	TM4/PM30
Benzo(k)fluoranthene	0.020	<0.040 AA	<0.008	<0.008	ug/l	TM4/PM30
PAH Surrogate % Recovery	81	88 AA	85	<0	%	TM4/PM30
MTBE #	<5	<5	<5	<5	ug/l	TM36/PM12
Benzene #	<5	<5	<5	<5	ug/l	TM36/PM12
Toluene #	<5	<5	<5	<5	ug/l	TM36/PM12
Ethylbenzene #	<5	<5	<5	<5	ug/l	TM36/PM12
m/p-Xylene #	<5	21	<5	<5	ug/l	TM36/PM12
o-Xylene #	<5	8	<5	<5	ug/l	TM36/PM12
TPH CWG						
Aliphatics						
>C5-C6 #	<10	<10	<10	<10	ug/l	TM36/PM12
>C6-C8 #	<10	<10	<10	<10	ug/l	TM36/PM12
>C8-C10 #	<10	29	<10	<10	ug/l	TM36/PM12
>C10-C12 #	<5	<5	<5	<5	ug/l	TM5/PM16/PM30
>C12-C16 #	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C16-C21 #	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>C21-C35 #	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aliphatics C5-35 #	<10	29	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30

Client Name: Geosyntec Consulting
Reference: GCU0309002
Location: Knottingley
Contact: Gareth Barns
EMT Job No: 23/15723

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

EMT Sample No.	211-217	218-224	225-231									
Sample ID	WG-WSP332-200923	BH02/05/A-200923	BH07/05/A-200923									
Depth												
COC No / misc												
Containers	V HCL Z P G	V HCL Z P G	V HCL Z P G									
Sample Date	20/09/2023	20/09/2023	20/09/2023									
Sample Type	Ground Water	Ground Water	Ground Water									
Batch Number	1	1	1									
Date of Receipt	22/09/2023	22/09/2023	22/09/2023									

Please see attached notes for all abbreviations and acronyms

				LOD/LOR	Units	Method No.
TPH CWG						
Aromatics						
>C5-EC7 #	<10	<10	<10	<10	ug/l	TM36/PM12
>EC7-EC8 #	<10	<10	<10	<10	ug/l	TM36/PM12
>EC8-EC10 #	<10	32	<10	<10	ug/l	TM36/PM12
>EC10-EC12 #	<5	101	<5	<5	ug/l	TM5/PM16/PM30
>EC12-EC16 #	<10	20	<10	<10	ug/l	TM5/PM16/PM30
>EC16-EC21 #	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
>EC21-EC35 #	<10	<10	<10	<10	ug/l	TM5/PM16/PM30
Total aromatics C5-35 #	<10	153	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Total aliphatics and aromatics(C5-35) #	<10	182	<10	<10	ug/l	TM5/TM36/PM12/PM16/PM30
Resorcinol	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Catechol	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Phenol #	<0.01	0.71 AC	<0.01	<0.01	mg/l	TM26/PM0
m/p-cresol	<0.02	2.44 AC	<0.02	<0.02	mg/l	TM26/PM0
o-cresol	<0.01	1.42 AC	<0.01	<0.01	mg/l	TM26/PM0
Total cresols #	<0.03	3.86 AC	<0.03	<0.03	mg/l	TM26/PM0
Xylenols #	<0.06	4.18 AC	<0.06	<0.06	mg/l	TM26/PM0
1-naphthol	<0.01	0.02	<0.01	<0.01	mg/l	TM26/PM0
2,3,5-trimethyl phenol	<0.01	0.13	<0.01	<0.01	mg/l	TM26/PM0
2-isopropylphenol	<0.01	<0.01	<0.01	<0.01	mg/l	TM26/PM0
Total Speciated Phenols HPLC	<0.1	8.9	<0.1	<0.1	mg/l	TM26/PM0
Sulphate as SO4 #	66.6	72.8	12.8	<0.5	mg/l	TM38/PM0
Nitrate as N #	<0.05	<0.05	<0.05	<0.05	mg/l	TM38/PM0
Nitrite as N #	0.010	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Dissolved Methane #	<1	279	273	<1	ug/l	TM25/PM0
Total Alkalinity as CaCO3 #	286	160	258	<1	mg/l	TM75/PM0
Sulphide	<0.01	<0.01	<0.01	<0.01	mg/l	TM107/PM0
Electrical Conductivity @25C #	981	545	772	<2	uS/cm	TM76/PM0
Dissolved Iron II	<1	<1	1	<1	mg/l	TM213/PM31
Dissolved Iron III	<1	<1	<1	<1	mg/l	TM30/TM213/PM0
Manganese II	0.50	0.18	1.09	<0.02	mg/l	TM62/PM0

Client Name: Geosyntec Consulting

Reference: GCU0309002

Location: Knottingley

Contact: Gareth Barns

Matrix : Liquid

EMT Job No.	Batch	Sample ID	Depth	EMT Sample No.	Analysis	Reason
23/15723	1	SW1-210923		106-112	PAH	Sample holding time exceeded
23/15723	1	WG-WSP312-200923		141-147	PAH	Sample holding time exceeded
23/15723	1	WG-WSP311-200923		148-154	PAH	Sample holding time exceeded
23/15723	1	WG-WSP314-210923		176-182	PAH	Sample holding time exceeded
23/15723	1	WG-WSP318-200923		190-196	PAH	Sample holding time exceeded
23/15723	1	BH02/05/A-200923		218-224	PAH	Sample holding time exceeded

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating. Only analyses which are accredited are recorded as deviating if set criteria are not met.

It is a requirement under ISO 17025 that we inform clients if samples are deviating i.e. outside what is expected. A deviating sample indicates that the sample 'may' be compromised but not necessarily will be compromised. The result is still accredited and our analytical reports will still show accreditation on the relevant analytes.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

EMT Job No.: 23/15723

SOILS and ASH

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary. Asbestos samples are retained for 6 months.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Limits of detection for analyses carried out on as received samples are not moisture content corrected. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C. Ash samples are dried at 37°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

Sufficient amount of sample must be received to carry out the testing specified. Where an insufficient amount of sample has been received the testing may not meet the requirements of our accredited methods, as such accreditation may be removed.

Negative Neutralization Potential (NP) values are obtained when the volume of NaOH (0.1N) titrated (pH 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 - 2.5. Any negative NP values are corrected to 0.

The calculation of Pyrite content assumes that all oxidisable sulphides present in the sample are pyrite. This may not be the case. The calculation may be an overesitimate when other sulphides such as Barite (Barium Sulphate) are present.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 accreditation applies to surface water and groundwater and usually one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

STACK EMISSIONS

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation for Dioxins and Furans and Dioxin like PCBs has been performed on XAD-2 Resin, only samples which use this resin will be within our MCERTS scope.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

DEVIATING SAMPLES

All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. The temperature of sample receipt is recorded on the confirmation schedules in order that the client can make an informed decision as to whether testing should still be undertaken.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

BLANKS

Where analytes have been found in the blank, the sample will be treated in accordance with our laboratory procedure for dealing with contaminated blanks.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a requirement of our Accreditation Body for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.
Laboratory records are kept for a period of no less than 6 years.

REPORTS FROM THE SOUTH AFRICA LABORATORY

Any method number not prefixed with SA has been undertaken in our UK laboratory unless reported as subcontracted.

Measurement Uncertainty

Measurement uncertainty defines the range of values that could reasonably be attributed to the measured quantity. This range of values has not been included within the reported results. Uncertainty expressed as a percentage can be provided upon request.

Customer Provided Information

Sample ID and depth is information provided by the customer.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS Ref No. 4225) accredited - UK.
SA	ISO17025 (SANAS Ref No.T0729) accredited - South Africa
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
>>	Results above quantitative calibration range. The result should be considered the minimum value and is indicative only. The actual result could be significantly higher.
*	Analysis subcontracted to an Element Materials Technology approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x5 Dilution
AB	x7 Dilution
AC	x10 Dilution
AD	x20 Dilution
AE	x50 Dilution
AF	x100 Dilution

AG	x200 Dilution
AH	x2000 Dilution

HWOL ACRONYMS AND OPERATORS USED

HS	Headspace Analysis.
EH	Extractable Hydrocarbons - i.e. everything extracted by the solvent.
CU	Clean-up - e.g. by florisil, silica gel.
1D	GC - Single coil gas chromatography.
Total	Aliphatics & Aromatics.
AL	Aliphatics only.
AR	Aromatics only.
2D	GC-GC - Double coil gas chromatography.
#1	EH_Total but with humics mathematically subtracted
#2	EU_Total but with fatty acids mathematically subtracted
_	Operator - underscore to separate acronyms (exception for +).
+	Operator to indicate cumulative e.g. EH+HS_Total or EH_CU+HS_Total
MS	Mass Spectrometry.

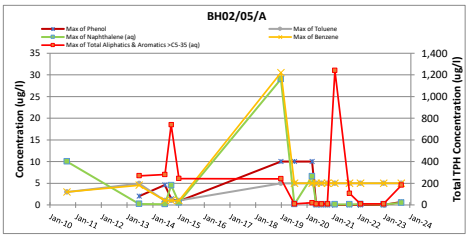
EMT Job No: 23/15723

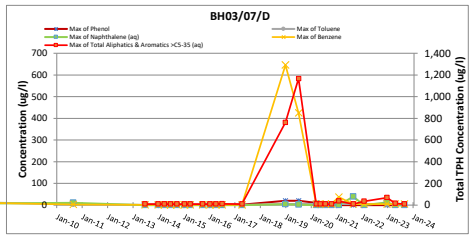
Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM4	Modified USEPA 8270D v5:2014 method for the solvent extraction and determination of PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
TM4	Modified USEPA 8270D v5:2014 method for the solvent extraction and determination of PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM5	Modified 8015B v2:1996 method for the determination of solvent Extractable Petroleum Hydrocarbons (EPH) within the range C8-C40 by GCFID. For waters the solvent extracts dissolved phase plus a sheen if present.	PM16/PM30	Fractionation into aliphatic and aromatic fractions using a Rapid Trace SPE/Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM5/TM36	please refer to TM5 and TM36 for method details	PM12/PM16/PM30	please refer to PM16/PM30 and PM12 for method details	Yes			
TM25	Determintaion of Dissolved Methane, Ethane and Ethene by Headspace GC-FID	PM0	No preparation is required.	Yes			
TM26	Determination of phenols by Reversed Phased High Performance Liquid Chromatography and Electro-Chemical Detection.	PM0	No preparation is required.				
TM26	Determination of phenols by Reversed Phased High Performance Liquid Chromatography and Electro-Chemical Detection.	PM0	No preparation is required.	Yes			
TM30/TM213	Calculation of Fe (III) based on Iron and Fe(II)	PM0	No preparation is required.				
TM36	Modified US EPA method 8015B v2:1996. Determination of Gasoline Range Organics (GRO) in the carbon chain range of C4-12 by headspace GC-FID. MTBE by GCFID co-elutes with 3-methylpentane if present and therefore can give a false positive. Positive MTBE results will be re-run using GC-MS to double check, when requested.	PM12	Modified US EPA method 5021A v2:2014. Preparation of solid and liquid samples for GC headspace analysis.	Yes			
TM38	Soluble Ion analysis using Discrete Analyser. Modified US EPA methods: Chloride 325.2 (1978), Sulphate 375.4 (Rev.2 1993), o-Phosphate 365.2 (Rev.2 1993), TON 353.1 (Rev.2 1993), Nitrite 354.1 (1971), Hex Cr 7196A (1992), NH4+ 350.1 (Rev.2 1993) – All anions comparable to BS ISO 15923-1: 2013l	PM0	No preparation is required.	Yes			

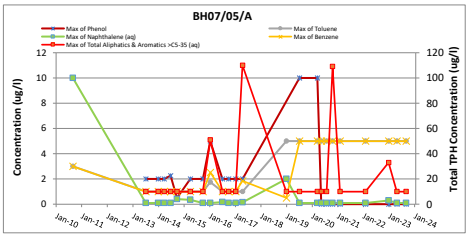
EMT Job No: 23/15723

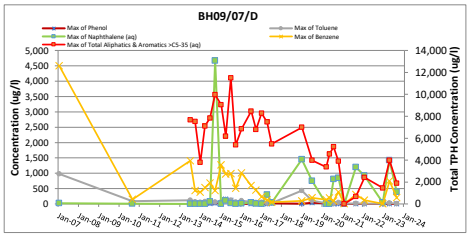
Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS/SANAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM62	Determination of Manganese (II) by reaction with Formaldoxime in ammoniacal solution to form a manganese complex which is analysed spectrophotometrically.	PM0	No preparation is required.				
TM75	Modified US EPA method 310.1 (1978). Determination of Alkalinity by Metrohm automated titration analyser.	PM0	No preparation is required.	Yes			
TM76	Modified US EPA method 120.1 (1982). Determination of Specific Conductance by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			
TM107	Determination of Sulphide/Thiocyanate by Skalar Continuous Flow Analyser	PM0	No preparation is required.				
TM213	Fe(II) and Mn(II) by IC and Spectro	PM31	Prep of Waters for Inorganics				

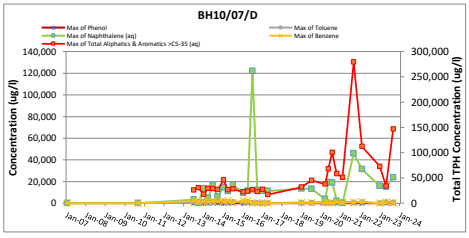
Appendix B: Deep Groundwater and Surface Water Quality Graphs

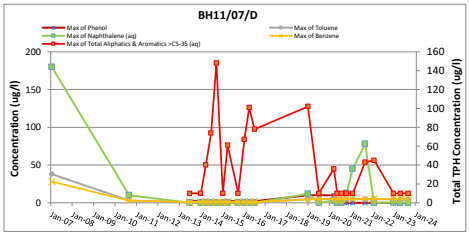


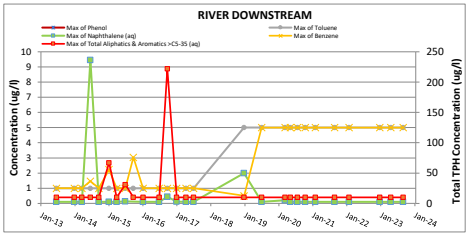


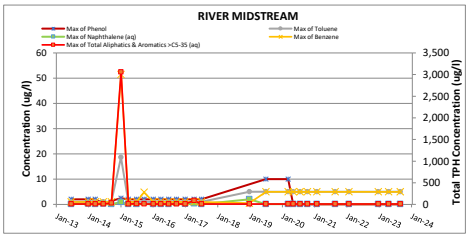


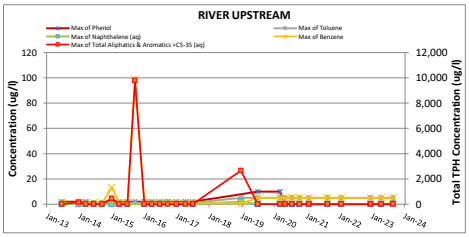


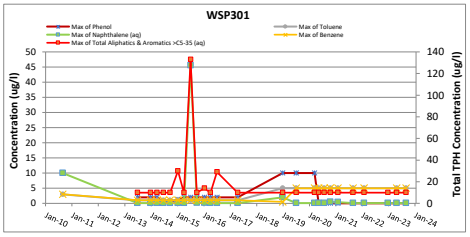


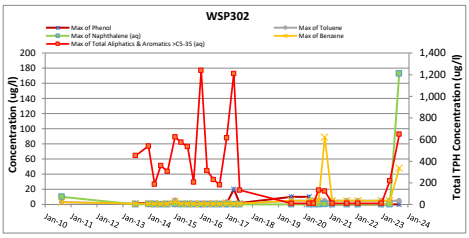


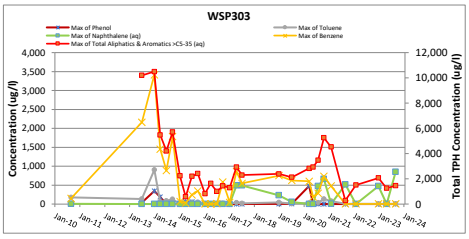


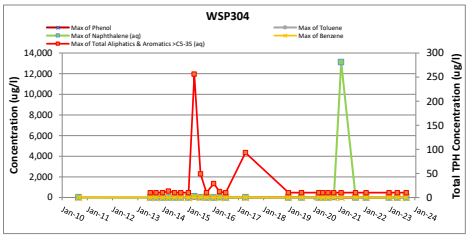


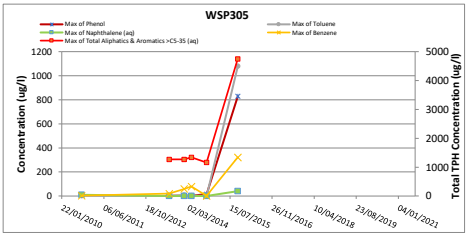




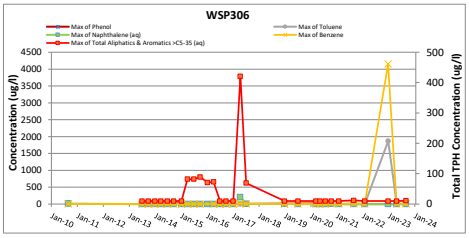


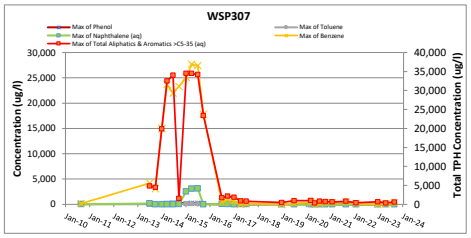


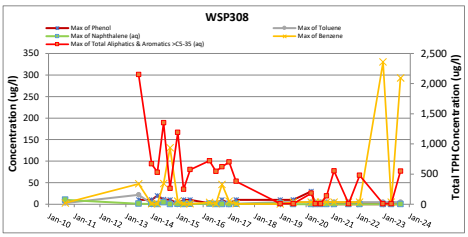


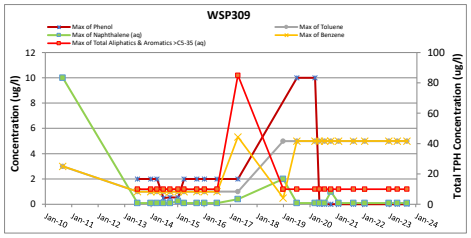


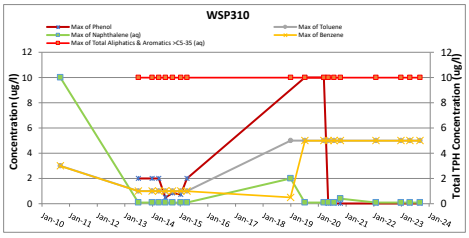
Appendix B: Deep Groundwater and Surface Water Quality Graphs

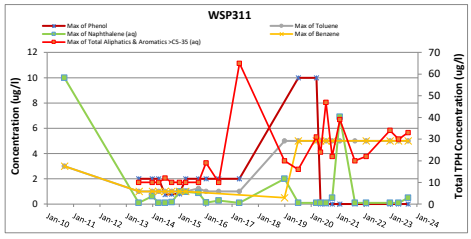


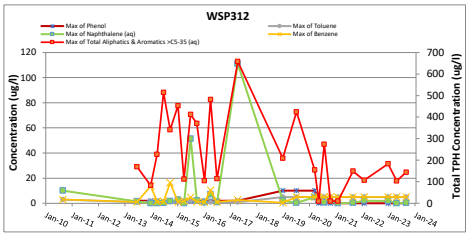


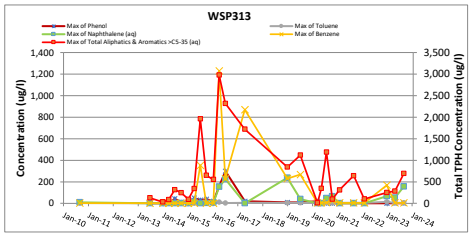


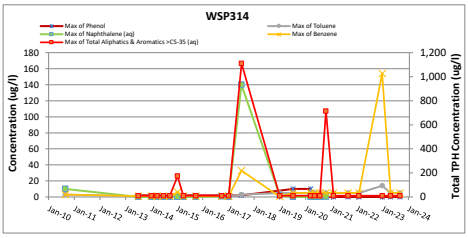


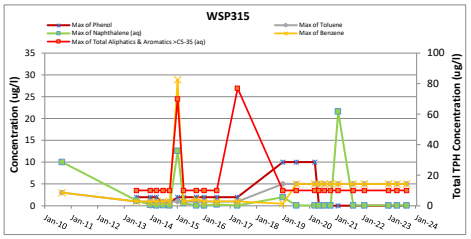


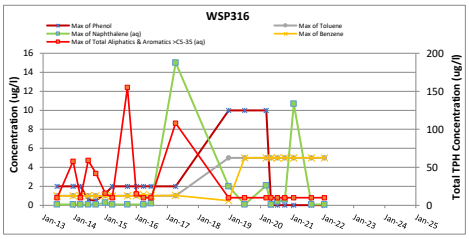


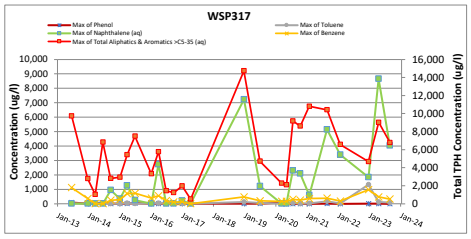


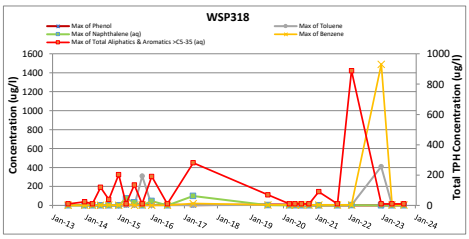


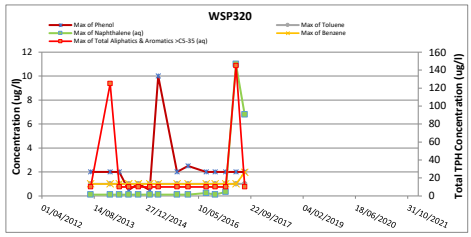




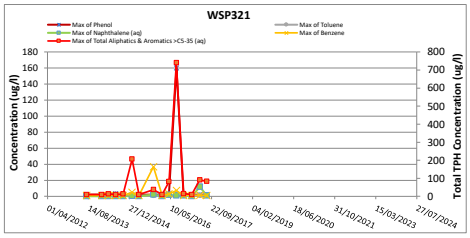


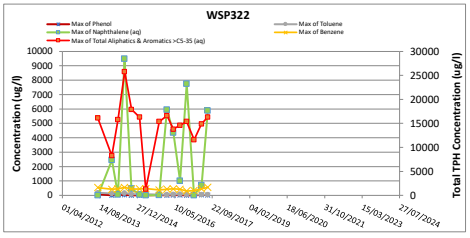


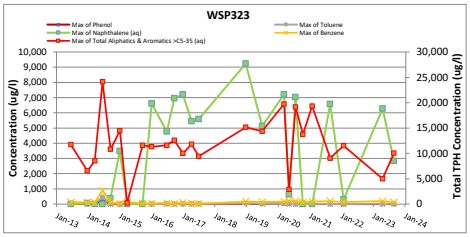


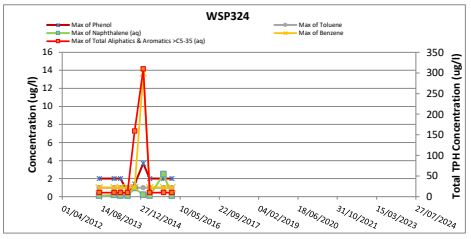


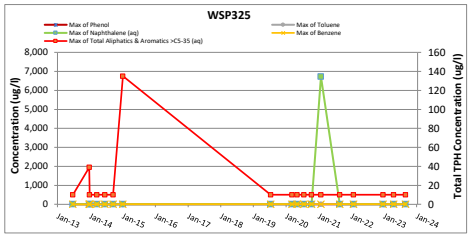
Appendix B: Deep Groundwater and Surface Water Quality Graphs

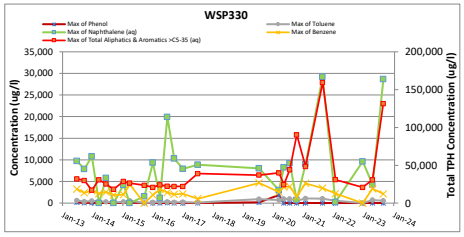


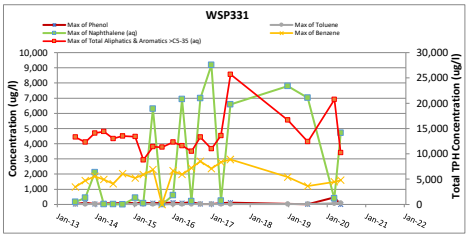


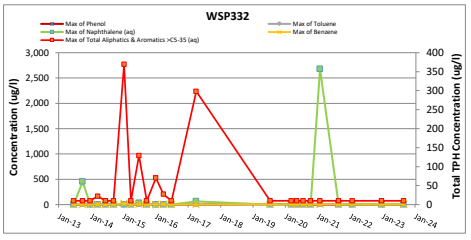


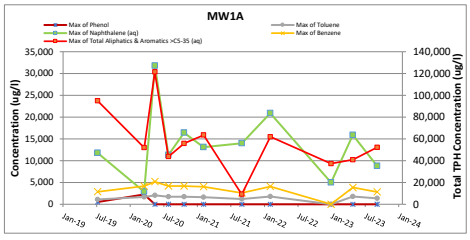












APPENDIX C

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APPENDIX 4

Stage 2 – Identify Substances which are Relevant Hazardous Substances or substances with pollution potential

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
Treatment substances									
Leachate (ammoniacal nitrogen)	Chemical Type: Inorganic nitrogen compound Definition: Refers to the sum of ammonia (NH_3) and ammonium ion (NH_4^+) in water or soil Chemical Forms: NH_3 (ammonia, un-ionized) – volatile gas NH_4^+ (ammonium, ionized) – stable in water and soil Environmental Indicator: Often used as a measure of nitrogen pollution in water quality assessments Regulatory Status: Monitored parameter under drinking water and wastewater discharge regulations (e.g., U.S. EPA, EU WFD) Not classified as a carcinogen but a regulated nutrient pollutant due to eutrophication risk	NH_3 (Ammonia): Colourless gas with a pungent odour at room temperature; soluble in water NH_4^+ (Ammonium): Exists as a dissolved ion in aqueous phase or bound to soil particles In environmental samples, ammoniacal nitrogen is usually found as a dissolved species in water or adsorbed in moist soil	Highly Soluble in water NH_3 readily dissolves to form NH_4^+ in water, depending on pH At lower pH (< 7), most of the ammonia is in the NH_4^+ form Forms soluble salts with various anions (e.g., ammonium sulfate, ammonium nitrate)	NH_3 (Unionized ammonia): Toxic to aquatic organisms, especially fish Toxicity increases with higher pH and temperature NH_4^+ (Ammonium ion): Less toxic than NH_3 Human Health: At low levels in drinking water, generally not toxic to humans High concentrations may cause taste and odour issues or secondary effects (e.g., promoting nitrification to nitrite/nitrate) Ecological Impact: Major contributor to eutrophication, leading to oxygen depletion and algal blooms	In Water: Highly mobile NH_4^+ can migrate with groundwater depending on soil cation exchange properties In Soil: NH_4^+ binds to negatively charged soil particles, reducing mobility Can be converted to nitrate (NO_3^-) via nitrification, which is far more mobile NH_3 can volatilize from soil or water surfaces under high pH and temperature conditions	Not Persistent in Natural Conditions Readily transformed via microbial processes: Nitrification ($NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$) under aerobic conditions Volatilization ($NH_4^+ \rightarrow NH_3$ gas) under alkaline or warm conditions Assimilation into plant and microbial biomass Short environmental half-life unless conditions limit microbial activity (e.g., cold or anaerobic soils)	Moderate to High Potential, depending on environmental conditions: In waterlogged or low-Cation Exchange Capacity (CEC) soils, NH_4^+ can leach into groundwater In alkaline or dry soils, NH_3 volatilization can lead to atmospheric nitrogen loss Contributes to nitrate formation, which has a high groundwater contamination risk Groundwater Impacts: Elevated ammoniacal nitrogen can indicate sewage or fertilizer contamination	Sources: Agricultural runoff (fertilizers, manure, slurry) Domestic and industrial wastewater Leachate from landfills Atmospheric deposition from NH_3 emissions Environmental Relevance: Major concern in eutrophication of lakes, rivers, and estuaries Used as an indicator in nutrient management and water quality monitoring programs Regulatory Benchmarks: Surface water quality guidelines typically limit un-ionized NH_3 to <0.02–0.1 mg/L depending on ecosystem sensitivity	**Yes**
Aqueous and inorganic wastes, solids and sludge (cadmium)	Chemical Type: Heavy metal Chemical Symbol: Cd Atomic Number: 48 Common Forms: Elemental cadmium (Cd^0) Cadmium salts: cadmium chloride ($CdCl_2$), cadmium sulfate ($CdSO_4$), cadmium oxide (CdO), etc. Regulatory Classification: Carcinogen: IARC Group 1 – Known human carcinogen (especially inhalation of cadmium compounds) Reprotoxic and mutagenic Priority pollutant (EPA, EU Water Framework Directive, Stockholm Convention–linked regulation) Restricted substance under REACH and RoHS (electronics directive)	Appearance: Silvery-white, soft, ductile metal State: Solid at room temperature Melting Point: 321°C Boiling Point: 767°C Density: 8.65 g/cm^3 Can form fine airborne particles when vaporized and condensed (e.g., in industrial emissions)	Elemental Cadmium: Insoluble in water Cadmium Compounds: Soluble: $CdCl_2$, $CdSO_4$ – dissolve easily in water Insoluble or sparingly soluble: CdS (cadmium sulfide), $CdCO_3$ Solubility increase under acidic conditions, facilitating environmental mobility	Highly Toxic to humans and animals even at low concentrations Routes of Exposure: Inhalation, ingestion, dermal (less common) Health Effects: Acute exposure: Respiratory irritation, pulmonary edema (via inhalation of dust/fumes) Chronic exposure: Kidney damage (tubular dysfunction) Bone demineralization (e.g., Itai-Itai disease in Japan) Liver and reproductive toxicity Carcinogenic (lung and prostate cancers via inhalation) Bioaccumulation: Cadmium accumulates in kidneys and liver and has a long biological half-life (~10–30 years)	In Air: Can be transported as fine particles or cadmium oxide fumes from industrial sources In Soil: Moderate mobility in acidic or sandy soils Stronger binding in alkaline or clay-rich soils In Water: Soluble cadmium salts can be highly mobile, especially under acidic and low organic matter conditions	Extremely Persistent: Non-biodegradable Stable in soil and sediment for decades to centuries Exists in various oxidation states but commonly remains as Cd^{2+} in natural environments Not transformed easily by microbial or abiotic processes	Very High Potential, especially near: Mining and metal refining operations Battery manufacturing or disposal sites Waste incinerators and phosphate fertilizer use (which may contain cadmium as an impurity) Soil: Cadmium can accumulate and pose risks to food crops (e.g., rice, leafy vegetables) Groundwater: Leaching occurs under acidic or saline conditions, particularly in areas with contaminated sludge or industrial waste	Common Uses: Nickel-cadmium (Ni-Cd) batteries Electroplating, pigments (e.g., cadmium red/yellow), coatings Plastic stabilizers (historically) Environmental and Regulatory Concern: Phased out or restricted in many regions due to toxicity Still found in older batteries, electronics, and industrial effluents Common contaminant in agricultural soils, especially where phosphate fertilizers or sewage sludge are applied	**Yes**

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
RDF (polyethylene)	Chemical Type: Synthetic polymer (thermoplastic) Chemical Formula: $(C_2H_4)_n$ – long chains of ethylene monomers CAS Number: Low-density polyethylene (LDPE): 9002-88-4 High-density polyethylene (HDPE): 9002-88-8 Regulatory Classification: Not classified as hazardous under normal use Considered inert and non-toxic in solid form Microplastic concerns increasingly regulated (e.g., EU microplastic restriction proposals)	Appearance: Solid plastic – varies from flexible films to rigid containers Forms: LDPE: Flexible, low melting point (~105–115°C) HDPE: Rigid, higher melting point (~120–130°C) Colour: Typically translucent or white; can be coloured for specific applications	Appearance: Solid plastic – varies from flexible films to rigid containers Forms: LDPE: Flexible, low melting point (~105–115°C) HDPE: Rigid, higher melting point (~120–130°C) Colour: Typically translucent or white; can be coloured for specific applications	Inert in Solid Form: Non-toxic under typical conditions of use Does not leach hazardous substances in normal environments Combustion Products: Burning can release toxic fumes such as carbon monoxide, aldehydes, and hydrocarbons Microplastic Form: Can adsorb pollutants and enter food chains Potential ecological and health risks from long-term exposure to micro- and nano-plastics	As Macroplastic: Low mobility; remains where deposited unless physically transported As Microplastic: High environmental mobility via wind, water, and runoff Can disperse widely in terrestrial and aquatic environments	Extremely Persistent: Non-biodegradable under natural conditions Resistant to microbial attack Degradation Pathways: Photodegradation: UV exposure can cause cracking and fragmentation Mechanical breakdown: Into smaller particles over time Full degradation can take decades to centuries	Soil: Can accumulate as plastic debris or microplastics Affects soil structure, microbial communities, and plant growth Groundwater: Low direct leaching risk, but microplastics can potentially transport adsorbed pollutants to groundwater Indirect Pollution Pathway: Acts as a vector for persistent organic pollutants (POPs), heavy metals, and pathogens	Uses: Packaging (plastic bags, films, containers), piping, insulation, toys, textiles, medical products Types: LDPE: Plastic bags, cling film, squeeze bottles HDPE: Milk jugs, detergent bottles, water pipes Environmental Relevance: One of the most widely produced and discarded plastics globally Major component of marine plastic pollution Found in soil, freshwater, oceans, and even remote environments (e.g., Arctic snow, deep sea)	**No**
Raw materials									
Acids (Sulphuric acid)	Chemical Type: Inorganic mineral acid Chemical Formula: H_2SO_4 CAS Number: 7664-93-9 Regulatory Classification: Corrosive (GHS Category 1A) Hazardous substance under multiple regulations (OSHA, REACH, CLP) Not classified as a carcinogen itself, but aerosolized forms (especially occupational exposure) are classified as carcinogenic (IARC Group 1) Included in lists of priority pollutants in industrial discharge regulations	Appearance: Clear, colourless to slightly yellow, oily liquid Odour: Odourless (though irritating fumes can be released with decomposition) Boiling Point: ~337°C (decomposes at higher temperatures) Melting Point: ~10.4°C Density: ~1.84 g/cm³ (concentrated) Viscosity: High, especially in concentrated form	Highly Soluble in Water: Exothermic reaction when mixed with water — must always add acid to water, not the reverse Fully dissociates in water to form H_3O^+ (hydronium) and HSO_4^- / SO_4^{2-} ions Solubility in Other Solvents: Miscible with alcohols and slightly with some organic solvents	Corrosive and Highly Toxic via Contact: Causes severe burns to skin, eyes, respiratory tract Inhalation of mists can cause lung damage, bronchitis, and delayed pulmonary edema Ingestion leads to severe internal damage, potentially fatal Occupational Exposure Limits: TLV (ACGIH): 0.2 mg/m³ (as mist) Carcinogenicity: Sulfuric acid mists are Group 1 carcinogens (IARC) due to link with laryngeal and lung cancers in certain industries	In Air: Low volatility, but forms aerosols or acid mists which are highly mobile and hazardous In Soil and Water: Dissolves readily and moves with water, especially in low pH environments Can leach metals from soil and pipes, increasing secondary pollution	Persistent as an Acid: Does not degrade chemically under normal environmental conditions Neutralized by natural buffering agents (e.g., carbonates, lime) Remains highly reactive and corrosive until neutralized Decomposition: Under high heat, may release SO_3 and eventually convert to SO_2	High Potential: Acid spills or leaks can cause soil acidification, killing microorganisms and plants Increases mobility of heavy metals like lead, cadmium, and arsenic Can contaminate groundwater directly or indirectly by leaching pollutants from surrounding materials Environmental Impact: Contributes to acid mine drainage and acid rain (indirectly via SO_2/SO_3 emissions) Destroys aquatic habitats if released into surface waters without neutralization	Industrial Uses: Fertilizer manufacturing (e.g., superphosphate), petroleum refining Battery acid (lead-acid batteries) Metal processing (pickling, electroplating) Chemical synthesis (detergents, dyes, explosives) Environmental Relevance: One of the most widely produced and consumed industrial chemicals A major component in industrial accidents, chemical spills, and wastewater discharges	**Yes**
Bases (Alkaline Substances) (Caustic Soda - sodium hydroxide)	Chemical Type: Inorganic base (strong alkali)Chemical Formula: NaOHCAS Number: 1310-73-2Regulatory Classification:Corrosive (GHS Category 1A)Hazardous substance under OSHA, REACH, CLPNot carcinogenic or mutagenic, but dangerous due to its high alkalinityCommonly regulated for occupational	Appearance: White solid (pellets, flakes, or powder)State: Solid at room temperature; forms a colourless, odourless solution in waterMelting Point: ~318°CBoiling Point: ~1,388°CDensity: ~2.13 g/cm³ (solid)	Very Soluble in Water:Exothermic dissolution – generates heatForms a strongly alkaline solution (caustic soda)Solubility in Water: ~111 g/100 mL at 20°CSoluble in Alcohols and GlycerolInsoluble in non-polar solvents	Highly Corrosive:Causes severe burns to skin, eyes, and mucous membranesInhalation of dust or mist may lead to respiratory irritation or damageIngestion can cause serious internal burnsNot Systemically Toxic (i.e., not absorbed into the body to cause internal organ damage like some poisons), but extremely dangerous	In Water: Very mobile; dissolves and disperses rapidly as hydroxide ionsIn Soil: High mobility; moves with water flow unless neutralized by soil buffering capacityCan alter pH significantly, affecting soil and water chemistry	Chemically Stable:Does not degrade but reacts readily with acids, CO_2 (forming sodium carbonate), and organic matterPersists as hydroxide ion in absence of neutralizing agentsReactivity: Rapidly reacts with acidic or amphoteric substances, potentially altering environmental chemistry	Moderate to High Potential:Alters pH dramatically if spilled or leaked, causing alkaline burns in soil organisms and plantsIn water, can cause caustic conditions toxic to aquatic lifeGroundwater contamination is possible due to high solubility and mobility, especially in unbuffered environmentsNeutralizatio	Common Uses:Chemical manufacturing (soap, detergents, paper, textiles)Water treatment, pH controlFood processing (e.g., peeling fruits/vegetables, cocoa processing). Cleaning agents, degreasers, drain cleanersEnvironmental Relevance: Widely used industrially and domesticallyAccidental releases can cause	**Yes**

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
	exposure and environmental release			locally due to its corrosivenessOccupational Limits:ACGIH TLV (Ceiling): 2 mg/m³			n: Can be mitigated by natural soil buffering or engineered neutralization (e.g., acid dosing)	significant ecological damage due to high alkalinity. Often involved in chemical spills and wastewater treatment system imbalances	
Salts (sodium oxalate)	Chemical Type: Inorganic salt of oxalic acid Chemical Formula: $Na_2C_2O_4$ CAS Number: 62-76-0 Regulatory Classification: Toxic (GHS Acute Toxicity Category 4, Oral) Not classified as carcinogenic or mutagenic May be classified as hazardous under OSHA and EU CLP due to toxicity and environmental impact at higher concentrations	Appearance: White, crystalline, odourless powder Melting Point: Decomposes at ~290°C (releases CO and CO_2) Density: ~2.34 g/cm³ Stability: Stable under normal storage conditions, but decomposes when heated	In Water: Moderately soluble (~3.7 g/100 mL at 20°C) In Organic Solvents: Practically insoluble Solubility increases with temperature and decreases with the presence of divalent cations (e.g., Ca^{2+}), which can form insoluble oxalates	Moderate to High Toxicity, especially by ingestion LD_{50} (oral, rat): ~10,000 mg/kg, but toxic effects occur at much lower doses in humans Health Effects: Can cause hypocalcemia, kidney damage, and formation of calcium oxalate crystals in the body Irritation to eyes, skin, and respiratory tract Biological Impact: Oxalate ions can bind calcium and disrupt normal cellular functions Chronic Exposure: May lead to kidney stones or renal dysfunction	In Water: Soluble form is mobile and can migrate in surface and groundwater In Soil: Mobile under neutral to alkaline conditions Under acidic or calcium-rich conditions, oxalate can precipitate as calcium oxalate, reducing mobility Readily transported in aqueous environments unless immobilized by ion exchange or precipitation	Moderately Persistent: Not volatile or prone to rapid degradation in abiotic conditions Biodegradable under aerobic microbial activity Can persist in environments lacking active microbial communities In the environment, microbial species (e.g., Oxalobacter) can degrade oxalate over time	Moderate Potential: Can leach into groundwater from industrial waste or laboratory discharges May alter soil pH and bind essential metal ions, affecting nutrient availability Can lead to precipitation of calcium oxalate, reducing calcium bioavailability Environmental Impact: Risk of localized chemical imbalances, especially in calcium-sensitive environments	Uses: Analytical chemistry (e.g., titrations and standardizations) Reducing agent in metallurgy and photography Precursor in some dye and pigment manufacturing Byproduct in chemical and pharmaceutical synthesis Environmental Relevance: Present in waste streams from labs, industries, and some natural plant degradation processes Monitored where used in larger-scale industrial or academic settings due to potential human and ecological toxicity	**No**
Hydrocarbons (kerosene)	Chemical Type: Petroleum-derived liquid hydrocarbon mixture Chemical Formula: Complex mixture (mainly C_{10}–C_{16} alkanes, cycloalkanes, and aromatic hydrocarbons) CAS Number: Commonly 8008-20-6 or 64742-81-0 Regulatory Classification: Flammable Liquid (GHS Category 3) Harmful or toxic if inhaled or ingested Contains volatile organic compounds (VOCs) and potentially carcinogenic substances (e.g., naphthalene, benzene traces) Regulated under transportation, workplace safety, and environmental protection laws	Appearance: Clear to pale yellow liquid Odour: Characteristic petroleum-like smell Boiling Range: ~150–300°C Density: ~0.78–0.81 g/cm³ at 15°C Flash Point: Typically >38°C (varies by grade)	In Water: Insoluble to slightly soluble (~1–10 mg/L) In Organic Solvents: Soluble in alcohol, ether, benzene, and other hydrocarbons Forms an oily layer on water and resists mixing	Acute Toxicity: Inhalation of vapors can cause dizziness, headache, CNS depression Ingestion may result in aspiration pneumonia, a serious condition Skin contact may cause irritation or dermatitis Chronic Exposure: Prolonged inhalation of vapors or mists can affect liver, kidneys, and nervous system Some formulations may contain or degrade into carcinogenic compounds (e.g., PAHs) Environmental Toxicity: Toxic to aquatic life; can affect fish, invertebrates, and birds if spilled	In Air: Contains volatile components that can evaporate and travel in vapor form In Soil: Moderate mobility; can percolate through porous soil Lighter fractions may volatilize, while heavier components may adsorb to soil In Water: Forms slicks; spreads quickly on the surface but limited dissolution	In Environment: Moderate to high persistence depending on environmental conditions and kerosene type Degrades slowly through microbial activity (biodegradation), especially under aerobic conditions Some components (e.g., aromatics) are more persistent and toxic Half-life: Varies from days to weeks for light components; months for heavier ones in anaerobic conditions	High Potential: Frequent contaminant in areas with fuel storage, transport leaks, or improper disposal Can migrate into groundwater, especially in sandy or gravelly soils Can act as a non-aqueous phase liquid (NAPL), creating long-term contamination plumes Soil Impact: Redces aeration, kills soil microbes, and affects plant growth	Uses: Fuel for jet engines, heaters, lamps, and stoves Solvent or carrier fluid in insecticides and industrial processes Component of diesel fuel, heating oil, and cleaning agents Environmental Relevance: Often involved in accidental spills, particularly from storage tanks and transportation accidents Subject to cleanup under oil spill response protocols Regulated under environmental statutes like CERCLA, RCRA, and Spill Prevention, Control, and Countermeasure (SPCC) plans	**Yes**

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
Adsorbents / Ion Exchangers (Activated carbon)	Chemical Type: Amorphous carbon (highly porous form of carbon) Synonyms: Activated charcoal, activated coal CAS Number: 64365-11-3 (general), 7440-44-0 (carbon) Regulatory Classification: Generally regarded as non-hazardous Not classified as carcinogenic, mutagenic, or reprotoxic Used as a sorbent, not as a chemical hazard itself May be regulated based on dust inhalation risk in occupational settings (nuisance dust limits)	Appearance: Black, odourless, solid material Forms: Powdered, granular, or pelletized Texture: Very porous with high surface area (500–1500 m^2/g) Inert: Does not melt or vaporize under normal environmental conditions	In Water: Insoluble In Organic Solvents: Insoluble Chemically inert but highly adsorptive (not soluble, but binds other substances)	Low Toxicity: Non-toxic when ingested (used medically for poisoning treatment) Inhalation of fine dust can cause mechanical irritation to lungs or eyes Occupational exposure limits may apply for inhalable dust (e.g., ACGIH TLV for particulates: 10 mg/m^3 total dust) Ecotoxicity: Not inherently toxic to aquatic or terrestrial organisms; may alter contaminant bioavailability	As a Solid: Low mobility in environment Granules or pellets are physically immobile unless carried by water or wind In Soil or Water: Immobilizes other chemicals through adsorption, reducing their mobility Sometimes used in situ to bind pollutants in contaminated sediments or soils	Extremely Persistent: Does not degrade or decompose in normal environmental conditions Chemically stable and inert Long-Term Stability: Effective as a long-term sorbent in environmental remediation	Very Low: Not a pollutant; often used to remediate contaminated soil or groundwater Binds pollutants like heavy metals, hydrocarbons, pesticides, PFAS, etc. Does not leach or degrade into harmful byproducts	Uses: Water treatment (removal of organics, chlorine, taste, odour) Air purification (e.g., gas masks, VOC control) Medical applications (e.g., poison antidote) Soil and sediment remediation (e.g., binding PAHs, PCBs, mercury) Environmental Relevance: Used in activated carbon filters in municipal, industrial, and household systems Increasingly applied for in situ groundwater remediation and stormwater treatment Considered an environmentally friendly tool in pollution control	**No**
Flocculants / Coagulants	Chemical Type: Treatment agents used in water and wastewater to aggregate suspended particles into larger clumps (flocs) for easier removal Main Types: Inorganic flocculants: e.g., aluminum sulfate (alum), ferric chloride Organic flocculants: e.g., polyacrylamide (PAM), polydadmac Natural flocculants: e.g., starch, chitosan, tannin-based polymers Function: Facilitate coagulation/flocculation in treatment processes	Appearance: Inorganic: Powder, granules, or liquid solutions Organic: Typically dry powders or emulsions State: Solid or liquid depending on formulation Colour/Odour: Varies; most are colourless to white or slightly yellow	Inorganic flocculants: Generally highly soluble in water Organic flocculants: Water-soluble or water-swellable polymers Emulsions (oil-based formulations): Disperse in water with agitation	Varies by Type: Inorganic flocculants: Can cause pH shifts, corrosiveness, and metal toxicity (e.g., excess aluminium or iron) Organic flocculants (e.g., polyacrylamide): Generally considered low-toxicity, but concerns exist over residual monomers like acrylamide (neurotoxic and carcinogenic) Natural flocculants: Typically non-toxic and biodegradable Ecotoxicity: Improper dosing may cause fish kills or aquatic pH imbalance Polymer flocculants can affect gill function in fish if overdosed	In Water: Soluble types dissolve and act in suspension Once flocculated, solids settle and are removed from water In Soil: Can bind with soil particles; limited mobility Organic polymers can persist in sediments	Inorganic Flocculants: Do not degrade; remain as residual salts (e.g., aluminium hydroxide sludge) Synthetic Organic Polymers: Moderately persistent; degrade slowly via microbial or photochemical processes Natural Flocculants: Biodegradable within days to weeks	Inorganic Flocculants: Can accumulate in sludge and soil; potential to alter pH and metal concentrations Leaching risk if overapplied or disposed improperly Organic Flocculants: Generally low risk if properly used Concerns arise if acrylamide monomer is present or migrates Natural Flocculants: Low to no pollution potential, biodegradable and non-toxic	Common Examples: Aluminium sulfate (alum) – widely used in drinking water treatment Ferric chloride – used in municipal and industrial wastewater Polyacrylamide (PAM) – used in mining, agriculture, and sludge dewatering Chitosan – a biodegradable flocculant from crustacean shells Uses: Municipal water treatment, industrial wastewater, mining operations, paper industry, agriculture (soil erosion control) Environmental Relevance: Essential in pollutant removal processes Must be carefully managed to prevent chemical overdosing or secondary pollution	**No**
Temporarily stored wastes									

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
Chlorinated Solvents (carbon tetrachloride)	Chemical Class: Halogenated aliphatic hydrocarbonRegulatory Classifications:IARC: Group 2B (possibly carcinogenic to humans)EPA: B2 (probable human carcinogen)GHS: Acute toxicity (oral, inhalation), specific target organ toxicity (repeated exposure), hazardous to the aquatic environment	Appearance: Colourless, volatile liquidOdour: Sweet, chloroform-like odourBoiling Point: 76.7°C (170°F)Melting Point: -22.9°C (-9.2°F)Vapor Pressure: Relatively high (91 mm Hg at 20°C)Density: 1.59 g/cm³ at 20°C (heavier than water)	Water Solubility: Low (~0.08 g/100 mL at 25°C)Soluble in: Organic solvents such as ethanol, ether, benzene, and chloroform	Acute Effects:Inhalation or ingestion can cause liver, kidney, and central nervous system damageMay cause dizziness, nausea, and unconsciousnessChronic Effects:Liver and kidney damage with prolonged exposureSuspected carcinogen and reproductive toxicantLD50 (oral, rat): ~2,350 mg/kgLC50 (inhalation, rat, 6 hr): ~8000 ppm	In Soil: Moderate to high mobility due to low adsorption to soil particlesIn Air: Volatile; can travel long distances in the atmosphereIn Water: Can volatilize from surface water but also persist in groundwater	In Air: Stable; atmospheric half-life ~30–100 daysIn Water/Soil: Moderate persistence; does not hydrolyze easily, and microbial degradation is slow under anaerobic conditionsOverall: Considered persistent in the environment	High potential: Due to:Low sorption to soilHigh volatilityHigh mobility in the subsurfaceFrequently found as a contaminant in groundwater near industrial or former manufacturing sites	CAS Number: 56-23-5Synonyms: Tetrachloromethane, Carbon tet, Halon-104Use:Formerly used as a cleaning agent, fire extinguisher component, and in refrigerantsUse now restricted or banned in many countries due to toxicity and environmental impact	**Yes**
Chlorinated aromatics (1,2,4-trichlorobenzene)	Chemical Class: Chlorinated aromatic hydrocarbon (halogenated benzene derivative) Regulatory Classifications: IARC: Not classifiable as to carcinogenicity (Group 3) GHS: Acute toxicity (oral and inhalation) Skin and eye irritation Hazardous to aquatic environment (chronic and acute) EPA: Listed as a priority pollutant under the Clean Water Act	Appearance: Colourless to pale yellow liquid Odour: Mild aromatic odour Boiling Point: ~213°C Melting Point: ~−24°C Vapor Pressure: ~0.3 mm Hg at 25°C Density: ~1.45 g/cm³ at 20°C	Water Solubility: Low (~49 mg/L at 25°C) Soluble in: Organic s0lvents such as ethanol, benzene, and ether	Acute Effects: Irritation to eyes, skin, and respiratory system CNS effects such as dizziness and headache upon inhalation Chronic Effects: Liver and kidney damage in long-term animal studies Possible effects on the endocrine system LD50 (oral, rat): ~756 mg/kg LC50 (inhalation, rat, 4 hr): ~880 ppm	In Soil: Low to moderate mobility due to moderate Koc (soil adsorption coefficient) In Air: Moderately volatile; can partition from water/soil into the atmosphere In Water: Low solubility, but potential for transport in contaminated surface water	In Air: Degrades slowly by photochemical reactions; atmospheric half-life estimated at 11–16 days In Water/Soil: Persistent; biodegrades slowly under aerobic conditions Overall: Considered moderately to highly persistent in the environment	Moderate potential: Low solubility and moderate volatility limit leaching somewhat Still a concern due to persistence and toxicity Found in industrial waste and hazardous waste site leachate	CAS Number: 120-82-1 Synonyms: 1,2,4-Trichlorobenzol Benzene, 1,2,4-trichloro- Common Uses: Solvent in dyes, pesticides, and heat-transfer fluids Intermediate in chemical synthesis Historically used as an herbicide carrier (now limited)	**Yes**
Chlorinated alkanes (1-chlorohexane)	Chemical Class: Halogenated aliphatic hydrocarbon (chloroalkane) Regulatory Classifications: Not classified as carcinogenic by IARC or EPA GHS: May cause skin and eye irritation; flammable liquid and vapor	Appearance: Colourless liquid Odour: Mild, sweet, ether-like odour Boiling Point: ~131°C Melting Point: ~−90°C Vapor Pressure: ~5.5 mm Hg at 25°C Density: ~0.88 g/cm³ at 20°C	Water Solubility: Very low (~8 mg/L at 25°C) Soluble in: Organic solvents like ethanol, ether, and acetone	Acute Effects: Can cause skin and eye irritation Inhalation may lead to respiratory tract irritation and CNS depression at high concentrations Chronic Effects: Limited data available; not classified as a known carcinogen or reproductive toxin LD50 (oral, rat): ~3,000–5,000 mg/kg (estimated; limited direct data) Generally considered to have moderate toxicity	In Soil: High mobility due to low adsorption and moderate vapor pressure In Air: Volatile and can disperse into the atmosphere In Water: Limited solubility, but may float due to being less dense than water	In Air: Reacts slowly with hydroxyl radicals; atmospheric half-life estimated around 2–5 days In Soil/Water: Biodegradable under aerobic conditions, but may persist under anaerobic conditions Overall: Moderately persistent, depending on environmental conditions	Potential: Moderate to high Due to high mobility and moderate persistence Can leach into groundwater if spilled or improperly disposed Not as persistent or hazardous as chlorinated aromatics but still a pollutant of concern	CAS Number: 544-10-5 Synonyms: Hexyl chloride 1-chloro-n-hexane Common Uses: Intermediate in organic synthesis Occasionally used as a solvent or in pharmaceutical manufacture Not widely used in commercial consumer products	**Yes**

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
Phenolic (2,4,5-trichlorophenol)	Chemical Class: Chlorinated aromatic compound (chlorinated phenol) Regulatory Classifications: IARC: Not classifiable as to carcinogenicity (Group 3) GHS: Harmful if swallowed or inhaled Causes skin and eye irritation Toxic to aquatic life with long-lasting effects EPA: Listed as a Priority Pollutant and Hazardous Air Pollutant (HAP)	Appearance: White to off-white crystalline solid Odour: Phenolic (medicinal) odour Boiling Point: ~246°C Melting Point: ~69°C Vapor Pressure: Low (~0.004 mm Hg at 25°C) Density: ~1.61 g/cm³	Water Solubility: Low (~200 mg/L at 25°C) Soluble in: Organic solvents such as ethanol, ether, and benzene	Acute Effects: Irritating to skin, eyes, and respiratory tract Can be absorbed through the skin Chronic Effects: Liver and kidney damage reported in animal studies Possible endocrine disruption LD50 (oral, rat): ~350 mg/kg Inhalation: Harmful at high concentrations; limited data on LC50 Note: A known contaminant in the production of Agent Orange, often associated with dioxin (TCDD) impurities, which are highly toxic	In Soil: Moderate mobility (moderate sorption and low volatility) In Air: Low volatility; unlikely to travel far in vapor phase In Water: Can bind to sediments or organic matter, reducing mobility	In Air: Degraded by hydroxyl radicals; not highly persistent In Soil/Water: Biodegrades slowly under anaerobic conditions More readily degraded under aerobic conditions Overall: Moderately persistent, especially in anaerobic or poorly drained environments	Potential: Moderate to high Can leach through soil under certain conditions Persistent in sediments and groundwater when biodegradation is limited Detected at contaminated sites, especially those linked to wood preservation or herbicide manufacturing	CAS Number: 95-95-4 Synonyms: TCP (2,4,5-trichlorophenol) Phenol, 2,4,5-trichloro- Common Uses: Formerly used in herbicide and fungicide production Precursor to the herbicide 2,4,5-T (now banned in many countries) Also used in wood preservation and disinfectants (historic use)	**Yes**
Chlorophenoxy Herbicides, Pesticides/Insecticides/ Fungicides/Triazines and Herbicide-like Structures (Meroprop – methyl chlorophenoxypropionic acid)	Chemical Class: Chlorophenoxy herbicide (selective systemic herbicide) Regulatory Classifications: IARC: Not classifiable as to carcinogenicity (Group 3) GHS: Harmful if swallowed Causes eye irritation Toxic to aquatic life (long-term) EPA: Registered pesticide active ingredient; categorized as Group D (not classifiable for carcinogenicity)	Appearance: White crystalline solid (technical grade), or amber liquid in formulation Odour: Mild phenolic odour Melting Point: ~90–100°C (technical grade) Boiling Point: Decomposes before boiling Density: ~1.4–1.6 g/cm³ (technical solid) Formulations: Usually as a salt or ester (e.g., MCPP-potassium or MCPP-ester)	Water Solubility: As acid: Moderate (~620 mg/L at 25°C) As potassium or sodium salt: Highly soluble (>10,000 mg/L) Soluble in: Alcohols, acetone, and some organic solvents	Acute Effects: Mild to moderate toxicity if ingested Irritating to eyes and skin Chronic Effects: Long-term animal studies show possible effects on liver and kidney No clear evidence of carcinogenicity or mutagenicity in humans LD50 (oral, rat): ~700–1,000 mg/kg (acid form) Inhalation: Low volatility; inhalation toxicity is low in typical use conditions	In Soil: Moderate to high mobility depending on soil type and pH Anionic form (salt) is more mobile in alkaline soils In Water: Readily dissolves and can migrate with runoff In Air: Not volatile under environmental conditions	In Soil: Half-life ranges from 7 to 28 days (can vary based on climate and soil microbes) In Water: Degrades via microbial activity; slower under anaerobic conditions Overall: Low to moderate persistence, generally not long-lasting in aerobic conditions	Potential: Moderate Can leach into groundwater, especially in sandy or alkaline soils Often detected in surface water due to runoff from treated lawns and agricultural land Monitored in drinking water programs in some countries due to frequent use	Chemical Name: (±)-2-(4-chloro-2-methylphenoxy)propionic acid Common Name: MCPP or Mecoprop CAS Number: 93-65-2 Synonyms: Mecoprop MCPP Uses: Widely used herbicide for control of broadleaf weeds in lawns, turf, cereals, and non-crop areas Often combined with other herbicides (like 2,4-D or dicamba)	**Yes**
Polychlorinated biphenyls and dioxins	Chemical Class: Chlorinated aromatic hydrocarbons (specifically, chlorinated biphenyls) Regulatory Classifications: IARC: Group 1 – Carcinogenic to humans EPA: Probable human carcinogen (B2 class) GHS: Causes long-term health effects Very toxic to aquatic life with long-lasting effects Stockholm Convention: Listed as Persistent Organic Pollutants (POPs) PCBs are banned	Appearance: Colourless to light yellow viscous liquids or waxy solids (depending on degree of chlorination) Odour: Mild, often described as chlorinated or oily Melting Point: Varies (from -20°C to 170°C, depending on mixture) Boiling Point: 325–380°C Density: ~1.18–1.56 g/cm³ Commercial Forms: Sold under names like Aroclor, Clophen, Kanechlor	Water Solubility: Extremely low (ranges from 0.0027 to 0.42 mg/L, depending on congeners) Soluble in: Organic solvents (e.g., benzene, acetone, hexane, oils)	Acute Effects: Low acute toxicity but can cause skin and eye irritation Chronic Effects: Liver damage, immune system suppression Developmental and reproductive toxicity Endocrine disruption Known human carcinogen (particularly linked to liver and skin cancers) Bioaccumulation: Strong tendency to accumulate in fat tissues and magnify in food chains	In Soil: Low mobility due to strong adsorption to organic matter In Air: Semi-volatile – can be transported long distances via atmospheric deposition In Water: Low solubility but binds strongly to sediments and suspended particles	In Environment: Highly persistent Resistant to biodegradation, photolysis, and hydrolysis Half-lives in soil and sediment can be decades In Organisms: Persistent in fat tissues with bioaccumulation and biomagnification	High potential, especially near: Former industrial sites (transformers, capacitors, hydraulic fluids) Landfills and contaminated sediments Groundwater contamination is limited by low mobility, but sediment and soil contamination is widespread and long-lasting Often requires remediation of hazardous waste sites	CAS Numbers: Range from 1336-36-3 (technical mixtures) to specific PCB congeners (e.g., PCB-28) Synonyms: PCBs, Aroclors (e.g., Aroclor 1242) Common Uses (historical): Electrical transformers and capacitors, Hydraulic fluids Plasticizers in paints, sealants, carbonless copy paper Current Status: Production banned in many countries since the late 1970s–1980s, but environmental contamination persists	**Yes**

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
Nitroaromatics	Chemical Class: Aromatic compounds containing one or more nitro groups (-NO_2) directly bonded to an aromatic ringExamples: Nitrobenzene, Dinitrotoluenes (DNTs), Trinitrotoluene (TNT)NitrophenolsRegulatory Classifications (varies by compound):Some are classified as toxic, mutagenic, or carcinogenicIARC: Nitrobenzene (Group 2B – possibly carcinogenic); others varyGHS: Often classified as toxic, flammable (some), and hazardous to aquatic lifeEPA: Many are listed as Priority Pollutants or Hazardous Substances	Appearance: Often yellow to brown crystalline solids or oily liquidsOdour: Mildly sweet to bitter almond-like (e.g., nitrobenzene)Melting/Boiling Points: Vary by compoundNitrobenzene: b.p. 210°C, m.p. 5.7°CTNT: m.p. 80.1°C	Water Solubility: Moderate to lowNitrobenzene: ~2 g/L at 25°CTNT: ~130 mg/LSoluble in: Organic solvents such as ethanol, acetone, and benzene	Acute Effects:Can cause methemoglobinemia (reduces oxygen-carrying capacity of blood)Irritation to eyes, skin, respiratory tractChronic Effects:Liver, kidney, and reproductive toxicitySome compounds (e.g., TNT, dinitrotoluenes) are suspected carcinogens or mutagensNeurotoxicity and blood disorders (anemia, cyanosis) are common with long-term exposureBioaccumulation: Generally low, but some nitrophenols can bioaccumulate in aquatic organisms	In Soil:Moderate mobility depending on solubility and soil typeCompounds like TNT and DNTs can leach into groundwater under certain conditionsIn Air: Some nitroaromatics are semi-volatile and can disperse in vapor phaseIn Water: Can adsorb to sediments or remain in solution depending on the pH and structure	In Environment: Moderately to highly persistentNitro groups resist microbial and chemical degradationDegradation is slow under anaerobic conditionsSome compounds (e.g., TNT) degrade more readily in aerobic environments but produce toxic intermediatesIn Soil/Water: Half-lives can range from weeks to years depending on conditions	High potential:Frequently found in military, industrial, and munitions-contaminated sitesPersistent and mobile in subsurface environmentsPresent in leachate from landfills, ammunition plants, and explosive manufacturing areasLong-term contamination of groundwater is well-documented (e.g., TNT at military sites)	Common Nitroaromatics: Nitrobenzene (CAS 98-95-3) – used in aniline production2,4-Dinitrotoluene (DNT, CAS 121-14-2) – used in plasticizers and explosivesTrinitrotoluene (TNT, CAS 118-96-7) – widely known explosive2,4-Dinitrophenol (CAS 51-28-5) – once used in pesticides and as a weight-loss drug (now banned)Uses:Explosives, dyes, pesticides, solvents, and chemical intermediates	**Yes**
Monoaromatic (benzene)	Chemical Type: Aromatic hydrocarbon Chemical Formula: C_6H_6 CAS Number: 71-43-2 Regulatory Classification: Carcinogenicity: Group 1 (IARC) – Known human carcinogen Flammable: Highly flammable liquid and vapor (GHS hazard) Toxic: Acute and chronic toxicity hazards recognized under OSHA, REACH, and other frameworks	Appearance: Colourless liquid Odour: Sweet, aromatic odour Boiling Point: ~80.1°C (176.2°F) Melting Point: ~5.5°C (41.9°F) Density: 0.8796 g/cm³ at 15°C	In Water: Slightly soluble (~1.8 g/L at 25°C) In Organic Solvents: Soluble in ethanol, ether, acetone, chloroform – miscible with most organic solvents	Acute Toxicity: Inhalation can cause dizziness, headaches, High concentrations may result in unconsciousness or death Chronic Toxicity: Bone marrow suppression Linked to aplastic anemia, leukemia, particularly acute myeloid leukemia (AML) Routes of Exposure: Inhalation, skin absorption, ingestion Regulatory Limits (e.g., OSHA PEL): 1 ppm (8-hour TWA)	Air: High volatility – readily evaporates and can travel significant distances Soil: Moderately mobile; can leach into groundwater under certain conditions Water: Can disperse in aquatic environments, limited solubility slows dilutio	In Air: Degraded by reaction with hydroxyl radicals (half-life ~ several days) In Soil/Water: Moderate persistence – can degrade via microbial activity under aerobic/anaerobic conditions, but may persist in anaerobic or low-nutrient environments	High Potential: Due to its mobility and moderate persistence, benzene is a common groundwater contaminant near petroleum and chemical industrial sites Can persist below surface in low-oxygen or confined zones Often found in leaking underground storage tanks (LUSTs) and petroleum spills	Common Sources: Crude oil, gasoline, industrial solvents, combustion emissions Also used in the manufacture of plastics, resins, synthetic fibers, and detergents Environmental Relevance: Considered a priority pollutant under the U.S. EPA and EU Water Framework Directive Frequently monitored in contaminated land and water assessments	**Yes**
Polycyclic aromatic hydrocarbons (benzo(a) pyrene)	Chemical Type: Polycyclic aromatic hydrocarbon (PAH) Chemical Formula: $C_{20}H_{12}$ CAS Number: 50-32-8 Regulatory Classification: Carcinogenicity: Group 1 (IARC) – Known carcinogen Mutagenicity: Known mutagen Toxic for Reproduction: Recognized reproductive toxicant Persistent Organic Pollutant (POP): Listed under Stockholm Convention (indirectly via PAHs)	Appearance: Pale yellow to greenish crystalline solid Odour: Odourless Melting Point: ~179°C (354°F) Boiling Point: Sublimes (decomposes at high temperature before boiling) Vapor Pressure: Extremely low	In Water: Extremely low (~3.8 µg/L at 25°C) In Organic Solvents: Soluble in benzene, toluene, acetone, and other non-polar solvents	Acute Toxicity: Relatively low, but more dangerous due to long-term effects Chronic Toxicity: Potent carcinogen: Associated with lung, skin, and bladder cancers Metabolized into DNA-reactive causing mutations Exposure Routes: Inhalation of particulates, dermal, ingestion via water, or soil Health Effects: Developmental effects Genotoxicity, teratogenicity, immunotoxicity	Air: Adsorbed onto fine particulate matter (PM); long-range transport possible Soil: Low mobility; tends to bind strongly to organic matter in soil Water: Binds to sediments and suspended particulates; does not stay in dissolved phase	In Air: Can degrade via photochemical reactions, but bound to particles can persist In Soil and Sediment: Highly persistent, with degradation half-lives often exceeding months to years (especially under anaerobic conditions) In Water: Strong sorption to sediments; slow microbial degradation	High Potential in Soil: Due to strong adsorption and persistence, BaP can accumulate in contaminated soils (especially around industrial, petroleum, and combustion sites) Low Groundwater Contamination Potential: Due to low solubility and mobility, but possible if dissolved in co-contaminants or in colloidal transport Common in Contaminated Sediments and Urban Runoff	Sources: Incomplete combustion of organic material (e.g., wood, coal, diesel, tobacco, charred foods, tar, vehicle exhaust, and industrial emissions Environmental Significance: Indicator compound for PAH contamination Priority pollutant by the U.S. EPA, EU, and under the Stockholm Convention Used in environmental risk assessments as a representative PAH carcinogen	**Yes**

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
Halogenated alcohols and ethers (2-chloroethanol)	Chemical Type: Halogenated aliphatic alcohol Chemical Formula: C_2H_5ClO CAS Number: 107-07-3 Regulatory Classification: Acute Toxicity: Classified as toxic/harmful if inhaled, swallowed, or absorbed through the skin Carcinogenicity: Not classifiable by IARC (Group 3), but suspected based on structural alerts Flammable Liquid: GHS Hazard Category 3 Corrosive/Irritant: Irritating to eyes, skin, and respiratory tract	Appearance: Colourless, oily liquid Odour: Ether-like or faint sweet odour Boiling Point: ~128°C Melting Point: -70°C Density: 1.20 g/cm³ at 20°C Vapor Pressure: Moderate (~3.5 mmHg at 25°C)	In Water: Completely miscible (very soluble) In Organic Solvents: Miscible with alcohols, ethers, and acetone	Acute Toxicity: Toxic via inhalation, ingestion, and skin contact LD_{50} (oral, rat): ~140 mg/kg Can cause CNS depression, liver and kidney damage Chronic Effects: May cause liver damage and neurological effects with long-term exposure Possibly carcinogenic and mutagenic based on animal studies Exposure Routes: Occupational inhalation and dermal contact; environmental via spills	Air: Moderate volatility; can evaporate into air from soil or water Soil: High mobility due to water solubility and low soil adsorption Water: Fully dissolves and disperses; not readily adsorbed to sediments	In Air: Degrades via reaction with hydroxyl radicals (half-life ~1–2 days) In Water and Soil: Biodegradable under aerobic conditions but can persist in anaerobic or low-oxygen environments Degradation Products: Ethylene oxide, chloroacetaldehyde (both potentially toxic)	High Potential: Due to high water solubility and mobility, 2-chloroethanol can readily leach into groundwater Frequently associated with industrial discharge and chemical manufacturing sites Can contaminate drinking water sources if not properly managed	Uses: Intermediate in the production of ethylene oxide, dyes, pharmaceuticals, pesticides, and surfactants Used historically as a solvent, fumigant, and in chemical synthesis Environmental Relevance: Monitored due to toxicity and mobility May be a degradation product of certain pesticides and chemical agents (e.g., from ethylene oxide hydrolysis)	**Yes**
Phenyls and anilines (2-chloroaniline)	Chemical Type: Halogenated aromatic amine Chemical Formula: C_6H_6ClN CAS Number: 95-51-2 Regulatory Classification: Harmful/Toxic: Harmful if inhaled, ingested, or absorbed through skin Suspected Carcinogen: Not classifiable by IARC (Group 3), but structurally related to known carcinogens Environmental Hazard: Toxic to aquatic life with long-lasting effects Irritant: Causes skin and eye irritation	Appearance: Clear to pale yellow oily liquid Odour: Aromatic or aniline-like odour Boiling Point: ~209°C Melting Point: ~-2°C Density: ~1.22 g/cm³ at 20°C Vapor Pressure: Low (~0.1 mmHg at 25°C)	In Water: Slightly soluble (~2.4 g/L at 25°C) In Organic Solvents: Soluble in alcohol, ether, chloroform, benzene	Acute Toxicity: LD_{50} (oral, rat): ~850 mg/kg Can cause methemoglobinemia (interfering with oxygen transport in blood) Chronic Toxicity: Liver, kidney, and spleen effects observed in prolonged exposure Potential genotoxicity and reproductive toxicity in animal studies Exposure Routes: Inhalation, ingestion, and dermal absorption	Air: Low volatility; may adsorb onto particulate matter Soil: Moderate mobility; can leach through soil depending on conditions Water: Partial solubility may allow movement through aquatic systems; moderate sorption to sediments	In Air: Degraded by hydroxyl radicals; moderate atmospheric half-life In Soil/Water: Moderately persistent Can undergo biodegradation under aerobic conditions, but slower under anaerobic conditions Degradation Products: Includes chlorinated aniline derivatives and possibly nitroso or azo compounds	Moderate to High Potential: Due to partial solubility and moderate persistence, 2-chloroaniline can pose a threat to groundwater Frequently found in soils and groundwater at sites associated with dye manufacturing, pesticides, and chemical processing Often part of contamination from aniline-based herbicides or azo dyes	Uses: Intermediate in synthesis of dyes, pigments, pharmaceuticals, agrochemicals (e.g., herbicides like diuron) Used in rubber processing chemicals and corrosion inhibitors Environmental Relevance: Identified as a priority pollutant in some regulatory frameworks due to toxicity and persistence Often found in industrial effluents from textile and dye plants	**Yes**
Fluorinated compounds (PFAS)	Chemical Group: Synthetic organofluorine compounds General Formula: R-$(CF_2)n–CF_3$ or derivatives (R = variable functional groups) Examples: PFOA (Perfluorooctanoic acid), PFOS (Perfluorooctane sulfonate) GenX, PFNA, PFHxS, etc. Regulatory Classification: Persistent Organic Pollutants (POPs) – Some PFAS (e.g., PFOS, PFOA) are listed under the Stockholm Convention	Form: Varies – typically solid (salts) or liquid at room temperature Pure Compounds: White powders or waxy solids (e.g., PFOS potassium salt); viscous liquids (some fluorotelomers)	In Water: Many PFAS are highly water-soluble (e.g., PFOS, PFOA) Short-chain PFAS are generally more soluble than long-chain ones In Organic Solvents: Some solubility depending on the PFAS compound and solvent used Amphiphilic Nature: Both hydrophobic (fluorinated tail) and hydrophilic (acid/sulfonate head) properties	Health Concerns (varies by PFAS type): Cancer: Linked to kidney, testicular, and other cancers (notably PFOA) Reproductive and Developmental Effects: Low birth weight, pregnancy-induced hypertension Thyroid Dysfunction Immune Suppression: Reduced vaccine response in children Bioaccumulative: Especially long-chain PFAS Toxic at Low Concentrations: Safe drinking water advisories	High Mobility in Aquatic Systems: Especially true for short- and medium-chain PFAS Long-Range Transport: Can travel globally in air and water Soil Mobility: Depends on chain length and functional group; shorter chains more mobile	Extremely Persistent: Sometimes called "forever chemicals" due to strong C–F bonds Resistant to environmental degradation (chemical, biological, thermal) PFOA, PFOS, and many others do not break down in typical environmental conditions Very slow degradation of precursors into terminal PFAS compounds	Very High Potential: Commonly detected in groundwater near industrial sites, airports, military bases, firefighting training areas (due to AFFF foams) Long-term leaching from contaminated soils to aquifers Complex sorption behavior: long-chain PFAS bind to soil organic matter; short-chain can leach more easily Groundwater Contamination: Ubiquitous across the	Common Uses: Firefighting foams (AFFF) Non-stick cookware (Teflon) Water-repellent fabrics, stain-resistant coatings Food packaging (e.g., microwave popcorn bags, fast food wrappers) Industrial surfactants and emulsifiers Environmental and Regulatory Focus: Thousands of PFAS exist; regulatory attention is now expanding beyond PFOA/PFOS to entire PFAS classes Subject to increasing	**Yes**

Substance (inc based on physico-chemical properties)	Classification	Physical state	Solubility	Toxicity	Mobility	Persistence	Soil and groundwater pollution potential	CAS Number and use	Relevant substance
	Probable Carcinogens (e.g., PFOA by US EPA) Endocrine Disruptors Developmental and Immunotoxic Agents			are in parts per trillion (ppt)			globe, often at levels of concern	global restriction, replacement efforts, and cleanup programs	
Metals and metalloids (e.g. lead, elemental and inorganic forms)	Chemical Symbol: PbAtomic Number: 82Common Forms: Elemental lead, lead oxides, lead salts (e.g., lead acetate, lead nitrate), lead-based pigmentsRegulatory Classification:Toxic: Highly toxic to humans and wildlifeCarcinogenicity:Inorganic lead compounds – Possibly carcinogenic (IARC Group 2A)Elemental lead – Not classifiable (IARC Group 3)Priority Pollutant (U.S. EPA, EU Water Framework Directive)Restricted in consumer products, fuels, paints, and electronics (e.g., under RoHS, REACH)	Appearance: Dense, soft, bluish-gray solid metalMelting Point: 327.5°CBoiling Point: 1,749°CDensity: 11.34 g/cm³Vapor Pressure: Low at room temperature; lead fumes can be released when heated	Elemental Lead: Practically insoluble in waterInorganic Lead Compounds:Varying solubility; some (e.g., lead acetate, lead nitrate) are water-solubleOthers (e.g., lead sulfide, lead phosphate) are poorly solubleSolubility influenced by pH: More soluble under acidic conditions	Very High Toxicity, especially to childrenAcute Effects:Abdominal pain, nausea, vomiting, anemia, neurological symptomsChronic Effects:Neurotoxicity, developmental delay, decreased IQ in childrenKidney damage, cardiovascular issues, reproductive toxicityNo known safe blood lead level in children (CDC)Bioaccumulation: Can accumulate in bones, blood, and soft tissues over timeCommon Exposure Routes: Ingestion of contaminated dust, water, soil, or old paint; inhalation in occupational settings	Air: Low volatility, but lead-containing particles can be transported through air (especially from smelting or combustion)Soil: Low mobility; tends to bind strongly to soil particles and organic matterWater: Lead ions can leach into water, particularly under low pH or high mineral conditions	Highly Persistent:Elemental lead and many lead compounds do not degrade in the environmentRemains in soils and sediments for decades to centuriesNon-biodegradable: No natural degradation pathway	High Potential, especially near:Industrial sites, lead smelters, battery recycling plants, shooting rangesUrban areas with legacy lead paint or past use of leaded gasolineGroundwater: Lead can leach under acidic or chemically reducing conditions, but generally low mobility in neutral soilsSoil: Major sink for lead contamination; remediation is often difficult and costly	Historical and Current Uses:Batteries (especially lead-acid), pipes, paints (banned or restricted in many countries), ammunition, solder, ceramics, glass, gasoline (now phased out)Major Environmental Concern:Legacy contamination in older buildings, urban soils, and water systems Still used in some industrial processes and products in certain countries	**Yes**

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