Remediation Statement
Appendix C

Plot A Soil and Groundwater Investigation former Albright and Wilson Works, Whitehaven, Cumbria

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Where field investigations have been carried out, these have been restricted to a level of detail required to achieve the stated objectives of the services. The results of any measurements taken may vary spatially or with time and further confirmatory measurements should be made after any significant delay in using this Report.

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CONTENTS

CONTENTS

LIST OF FIGURES

CONTENTS

Section **Page No**

LIST OF TABLES

LIST OF PHOTOGRAPHS

EXECUTIVE SUMMARY

URS Corporation Ltd (URS) was commissioned by Rhodia UK Ltd (Rhodia) to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson site in Whitehaven, Cumbria. The work comprised investigation of soil and groundwater conditions associated with an area of land identified as "Plot A" - one of a sequence of plots on the Whitehaven site identified as requiring further assessment in a Site Remediation Statement document. The report aimed to specifically address the potential significance of controlled waters pollutant linkages identified by Copeland Borough Council following their determination of the site as Contaminated Land.

Plot A comprises an area of the site most recently occupied by the "Cathedral" which collected the site's effluent, the Fatty Alcohol Plant and Wet and Dry Salts area. All above ground structures have been demolished and the area is now open ground. It is understood by URS at the time of reporting that the site is proposed as a public 'right-to-roam' open space land use.

A trial pitting exercise was undertaken which also allowed detailed visual assessment of the subsurface. A total of 30no. trial pits were excavated. Following the trial pitting exercise a limited shallow soil boring investigation was completed at 5no. locations which allowed the installation of 4no. monitoring wells. Soil and groundwater samples were collected and scheduled for a suite of analyses following agreement with the Environment Agency.

Ground conditions observed comprised Made Ground, overlying natural clay deposits subsequently underlain by rock head. Ground cover over the majority of the site comprised concrete slab hardstanding. Made Ground generally comprised a heterogeneous mix of building rubble, ash and clinker. The depth of these horizons varied across the site and were further complicated by the presence of underground foundations, former basements and other subsurface structures. The natural clay deposits were not observed continuously beneath the site and in areas where they were not present made ground generally lay directly on rock head. Bedrock was encountered at a number of locations as a limestone or sandstone and interpreted as the St Bees Evaporite Formation. Groundwater was not generally encountered during the investigation.

A Stage 2 controlled waters generic screening exercise was completed on all data collected from the within the Plot A boundary of the site to date (this included data from previous investigations). The key receptor identified for the controlled waters assessment comprised the Byerstead Spring, located approximately 1.3km south west of the site. The screening exercise identified exceedances of Total Petroleum Hydrocarbons (TPH), Poly nuclear Aromatic Hydrocarbons (PAH), copper, zinc, sulphate and cyanide in soil, soil leachate or shallow groundwater.

A Stage 3 detailed quantitative risk assessment was undertaken using a mass balance model and assumed that contaminants entered solution features in the St Bees Evaporite Formation beneath the site, resulting in undiluted rapid transport to the Byerstead Spring. The Controlled Waters Risk Assessment identified potential risks associated with: TPH, PAH, zinc and cyanide.

The following outline scope of works is recommended to assess the necessity for remedial action.

Area 1- The area in the vicinity of TP628A to TP630A: Further investigation for TPH

Area 2- The area in the vicinity of TP624A: Further investigation for TPH

Area 3- The area in the vicinity of WS115 and TP602A: Further investigation for PAH, zinc and cyanide.

Following completion of this additional invesitgation, the Stage 3 risk assessment will be updated and the pollutant linkage assessment refined accordingly.

A Human Health DQRA was also completed considering the proposed 'right-to-roam' end use. No risks were identified.

URS has addressed the specific controlled waters pollutant linkages identified by Copeland Borough Council in their determination of the site as Contaminated Land. URS has also addressed additional COPC and potential pollutant linkages identified during the course of the works at the site.

URS concludes that there are no significant pollutant linkages with respect to Human Health, either in the current site use or for the proposed 'right to roam' use.

For Controlled Waters, limited additional investigation is required to investigate possible significant pollutant linkages for TPH, PAH, zinc and cyanide.

The significant pollutant linkages declared by Copeland Borough Council with respect to surfactants, phosphates, arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, and VOCs/SVOCs have been shown to not exist within Plot A.

1. INTRODUCTION

1.1. General Introduction

URS was commissioned by Rhodia on 27 July 2006 to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson site in Whitehaven, Cumbria as detailed in URS Proposal 3033251 (dated 23 June 2006). This work was requested by John Moorhouse (Rhodia) at a meeting with Alistair Wyness (URS) on 10th March 2006.

This project focuses on the soil and groundwater conditions within an area of land identified as "Plot A" within the boundary of the former Rhodia site. Plot A is one of a sequence of plots on the Whitehaven site identified as requiring further investigation in a Site Remediation Statement[1] document. This report formalises the scope, context, and timescales of investigations required on the Rhodia site.

The Rhodia site (including Plot A) has been designated by Copeland Borough Council as statutory "Contaminated Land" under Part IIA of the Environmental Protection Act 1990. The entire site has subsequently been declared a "Special Site" and is now regulated by the Environment Agency.

The location of the former Albright and Wilson Works is presented on Figure 1. The site layout and the boundary of Plot A are presented on Figure 2.

1.2. Project Background

URS has undertaken a variety of investigations on the Rhodia site (formerly Albright & Wilson), dating back to 1995. During this period, Rhodia's operations on the site have diminished, the phosphate business has been closed down and over the past 2 years the remaining production operations have ceased. It is understood that at the time of issue of this report decommissioning of above ground structures relating to former Rhodia operations at the site have now been completed. URS also understands that the only remaining structure relates to a small surfactants production facility (previously operated by Huntsman), located towards the north-eastern corner of the site and is scheduled for demolition during the latter part of 2006.

Following demolition and remediation of the site, it is understood by URS at the time of reporting that the proposed use of the site is as a public open space land use with the minimum of site preparation expected (e.g. such as the removal of protruding trip hazards).

The scope of the previous investigations across the site relate to phosphate and surfactant manufacturing processes and other historic activities comprising coal and anhydrite mining, coke production, tar distillation and firelighter manufacture. A site wide

[1] Former Albright and Wilson Works: Site Remediation Statement. 23 June 2006. URS Corporation. (Ref 44319877/R2234.B01)

investigation was undertaken in 2005 and the resulting report (ref; 44319623. Phase II Investigations and Environmental Assessments at the Former Albright & Wilson Works, Whitehaven, 23 June 2005) contains full details of the site's history and the investigations carried out. The report is presented in the Site Remediation Statement (and it is hereafter referred to as the "Phase II report").

The Site Remediation Statement document included a requirement for additional investigation in key areas of the Rhodia site to address the significant pollutant linkages identified – one of those areas identified was Plot A. Further to this requirement, URS have reported the findings of the Plot A investigation herein in accordance with the Site Remediation Statement. It should be noted that the Site Remediation Statement has yet to be approved by the Environment Agency. However, the scope of this investigation has been discussed with, and agreed by the Environment Agency.

The proposal which defines the scope for the Plot A investigation (ref; 3033251, dated 23 June 2006) and subsequent discussions with the EA are included in Appendix A. The proposal comprises background information, project objectives, scope, approach and rationale on which the investigation has been based. URS' response to comments provided by the Environment Agency on the proposal (ref; 44319877/SAB, dated 1 August 2006 and 20th September 2006) are provided as an Addendum in Appendix A. The comments provided by the Environment Agency and the subsequent URS correspondence have been used as the basis upon which to review and update the proposal. The amendments have been incorporated into the investigation and the reporting herein. Appendix A should therefore be referred to for detailed information on the technical basis of the investigation and assessment.

1.3. Site Investigation Area - Plot A

Plot A comprises an area of the Rhodia site most recently occupied by the "cathedral" and surrounding areas, including part of the fatty alcohol plant, and the wet and dry salts area at the northern end of the site. The "cathedral" housed the site's effluent collection chamber, used to blend effluent prior to discharge to the Irish Sea. Operations in these areas have now ceased, and all above ground structures associated with these historical activities have subsequently been decommissioned and removed and the area is now open ground.

The area of interest has been identified as Plot A (Figure 2). The former layout of the site is presented on Figure 3. The plot is approximately rectangular in shape and is located adjacent to the northern site boundary. The estimated area of the plot is 36,250 m^2.

1.4. Existing Site Investigation Information

1.4.1. Introduction

Previous investigations have provided evidence which indicates the presence of potential contamination within the soils and shallow groundwater. However, due to operational constraints it was not possible to fully characterise the soil and groundwater quality with respect to risk to human health and controlled waters receptors. The following previous investigations have been undertaken within the site boundary identified as Plot A:

- URS investigation on behalf of Rhodia, ref; 44557-021, during 2001. 7No. shallow soil borings advanced as part of site wide assessment (WS115, WS118, WS119, WS120, WS124, WS133, and WS134);

- ERM investigation on behalf of Huntsman ref; PPC Phase 1B/2 Site Condition Report during 2003. 3No. shallow soil borings (SB9, SB13, and SB16);

- URS investigation on behalf of Rhodia, ref; 44319623, during 2005. 5No. trial pits (TP505, TP506, TP507, TP508, TP525) and 2No. shallow soil borings (WS420 and WS406) advanced as part of site wide assessment; and

- URS investigation on behalf of Rhodia, ref; 44319904, during 2006. Continued ongoing monitoring of 6 deep groundwater wells, and four offsite surface water locations. Quarterly groundwater monitoring has been conducted since February 2004; previous report references are 44319646 and 44557-045.

1.4.2. Key Findings

Phase II Soil and Groundwater Investigation Interpretive Report the Former Albright & Wilson Works, Whitehaven (ref;44557-021, 4 February 2002)

URS was commissioned by Rhodia during 2001 to undertake a Phase II Soil and Groundwater Baseline Contamination Investigation at the site. The investigation was designed primarily to provide a baseline assessment of soil and groundwater conditions with regard to current and historical contamination. The site investigation comprised the drilling of 65 shallow boreholes with 35 installed as shallow groundwater monitoring wells across the site. Soil and groundwater samples were subsequently submitted for laboratory analysis.

Seven shallow soil borings were advanced in Plot A as part of site wide assessment. Analysis in soils comprised metals, TPH, VOCs, SVOCs, asbestos, phosphates, PCBs, and total organic carbon. Groundwater samples were limited to WS115 and WS124 that were analysed for metals, TPH, VOCs, SVOCs, phosphate, and surfactant. Remaining boreholes were not installed or were found to be dry. One soil sample was scheduled for metals leachate analysis (WS120).

In WS115, a black staining of the clay strata was noted, along with a diesel type odour in the groundwater. Soil analytical results detected relatively elevated concentrations of selected

Polycyclic Aromatic Hydrocarbons (PAH's). Groundwater analysis detected TPH, benzene, and PAH's. In WS120, soil analytical results detected relatively elevated concentrations of arsenic. In WS124 trace concentrations of VOCs were detected in soils and elevated concentrations of phosphate were detected in groundwater. In WS119, a sulphurous odour was noted from the drilling returns. In WS134, relatively elevated soil concentrations of arsenic, zinc, Polychlorinated Biphenyls, and phosphate were recorded.

Following a generic screening exercise and human health Detailed Quantitative Risk Assessment (DQRA) based on a continued industrial land use, it was considered that no concentrations represented a potentially significant risk to the identified human health receptors in Plot A.

No assessment was made for controlled waters. It was considered that further work was required to determine the extent of any impact to receptors, although leachability results on soils indicated a limited potential for soil impacts.

The data obtained during this investigation has been considered in the Human Health and Controlled Waters risk assessments produced in this report.

PPC Phase 1B/2 Site Condition Report (June 2003)

This report was produced by ERM on behalf of Huntsman in support of a PPC permit application for the surfactant manufacturing facilities, formerly the imidazoline and CAPB plants. The objective of the assessment was to undertake site investigation works to obtain soil and groundwater data to be able to make a statement of the site condition based on the recommendations from an initial Phase 1a desk study report.

Three shallow soil borings were advanced in Plot A as part of site wide assessment. Analysis in soils and groundwaters comprised metals, surfactants, and TPH. No soil samples were scheduled for leachate analysis. The data obtained during this investigation has been considered in the Human Health and Controlled Waters risk assessments produced in this report.

Phase II Investigations and Environmental Assessments at the Former Albright & Wilson Works, Whitehaven (ref: 44319623, 23 June 2005)

The principal aim of this investigation was to develop a comprehensive understanding of the contaminated land liabilities associated with the site and future licensing requirements for Rhodia's proposed forthcoming divestiture. It was identified that Rhodia were proposing to divest the site to potential purchasers for a recreational 'right to roam' end use. However, also that Rhodia required an understanding of the corrective action and costs associated with leaving the site as "derelict" land, with no public access allowed. As such, the assessments carried out by URS for the study were based upon both these proposed end uses. Following a collation of all historic and the recent analytical data, Detailed Quantitative Risk Assessments (DQRA) were performed to assess potentially significant risks to Human Health and Controlled Waters receptors, based on the future end use for the site.

Five trial pits and two soil borings were advanced in Plot A as part of site wide assessment. Analysis in soils comprised surfactants, metals, major cations and anions, VOCs, SVOCs,

PAHs, and TPH. One soil boring (WS406) was not installed as a groundwater monitoring well, and the installed well at WS420 was found to be dry. No soil samples were scheduled for leachate analysis.

Human Health and Controlled Water Risk Assessments were performed on the data obtained during the site investigation, and previous site investigations. The following was concluded for the samples taken within the area now called Plot A:

- Naphthalene concentrations in soil exceeded the controlled waters risk assessment criteria in one location (WS115). However, no observations of naphthalene in groundwater were recorded, which suggested that the partitioning of soil contamination to water was too conservative, and that actual risks are unlikely to exist.

- Following a generic screening exercise and human health Detailed Quantitative Risk Assessment (DQRA) based on a continued industrial land use, it was considered that no concentrations represented a potentially significant risk to the identified human health receptors in Plot A.

The data obtained during this investigation has been considered in the Human Health and Controlled Waters risk assessments produced in this report.

Groundwater Monitoring at the Former Albright & Wilson Works, Whitehaven (ref: 44557-045, 44319646, 44319904, February 2004 to date)

The aim of this project is to provide long term monitoring of the geochemistry of the deep groundwater underlying the Whitehaven site and local surface waters. This project aims to determine trends in the chemistry of the analytes found in the groundwater, some of which are known to be derived from site processes. The locations assessed are as follows:

- **The Byerstead Spring** -sample taken on Saltom Beach, where the spring emerges. The groundwater chemistry of the water monitored at this location has been influenced by a number of sources. These are thought to include leaking site effluent, contaminated soil and groundwater underlying the site, water held within the flooded mine systems in the area, and landfill operations.

- **Groundwater in Whitehaven Sandstone** -BH203, located on the eastern edge of the site (and considered to be up hydraulic gradient of the majority of site activities). BH204 is located in the northern part of the site (and sits on the northern edge of Plot A). BH202 Deep is located towards the northwestern edge of the site (and considered to be downgradient of site operations in the northern part of the site).

- **Groundwater in St. Bees Evaporites** -BH101, located towards the centre of the site. BH202 Shallow, installed at the same location as BH202 Deep, but considered to be representative of conditions within a different horizon, the St. Bees Evaporites.

- **Groundwater in St. Bees Shales** -BH201, located in the south western corner of the site (considered to be down hydraulic gradient of the southern part of the site, and is adjacent to the Hutbank Landfill).

- **Groundwater in Middle Coal Measures** -Bellhouse Gill is considered to be a potential discharge point for the Coal Measures (located approximately 1.5km to the southeast of the site).

- **Sandwith Beck** -Two samples taken from a location close to the site boundary (close to the UFEX landfill) and further downstream (in Sandwith Village). The stream rises to the surface at the site boundary, and drains the southern part of the site.

Table 1 below gives an indication of the most recent concentrations detected at the Byerstead Spring.

Table 1 – Byerstead Spring Concentrations

Analyte	*Tier 1 Controlled Waters (µg/L)*	Byerstead Spring Concentrations (µg/L)			
Anionic Surfactant (MBAS)	200	1,100	640	400	1,100
Total Dissolved Phosphorus	no criterion	17,870	9,171	9,584	11,330
pH value	no criterion	8.2	7.9	7.7	7.7
Copper	5	nd	2	3	2
Total Cyanide	50	nd	ns	nd	ns
Phosphate (Ortho as PO4)	no criterion	59,410	27,890	28,600	35,820
Sulphate (soluble)	250000	977,000	1,109,000	1,184,000	1,047,000
EPH (Mineral Oil)	no criterion	nd	nd	200	nd
Naphthalene	5	nd	0.087	0.350	nd
Acenaphthylene	10	nd	0.000	0.013	nd
Acenaphthene	365	nd	0.032	0.034	nd
Fluorene	243	nd	0.048	0.174	nd
Phenanthrene	10	nd	0.067	0.196	nd
Anthracene	183000	nd	0.020	0.052	nd
Fluoranthene	0.2	nd	0.026	nd	nd

Pyrene	183	nd	0.022	nd	nd
Benzo(a)anthracene	0.0921	nd	nd	nd	nd
Chrysene	9.21	nd	nd	nd	nd
Benzo(k)fluoranthene	no criterion	nd	nd	nd	nd
Benzo(a)pyrene	0.0102	nd	nd	nd	nd
Indeno(1,2,3-cd)pyrene	no criterion	nd	nd	nd	nd
Dibenzo(a,h)anthracene	0.00921	nd	nd	nd	nd
Benzo(g,h,i)perylene	no criterion	nd	nd	nd	nd

Selected analytes detected during the four most recent monitoring rounds (January 06, April 06, July 06, October 06). nd- Analyte not detected above the method detection limit.

Assessment of the condition of the water emanating from the Byerstead Spring has been undertaken sporadically since 2002. Surfactant concentrations have decreased since 2002, and have been below 1200µg/L in the past four monitoring rounds. It is thought that once surfactant production ceases completely on the site (a small surfactants business, operated by Huntsman, still operates onsite, but is due to close), a further decrease is likely to be seen in concentrations of surfactant detected at the Byerstead Spring.

Concentrations of dissolved phosphorus at the Byerstead have shown a substantial decline since monitoring began. This is thought to coincide with the cessation of the Phosphate works in December 2001.

Eight PAH's have been detected from at least one of the samples taken from the Byerstead Spring since January 2006.

The concentration of the analytes at the Byerstead Spring can be affected (diluted) by an increased volume of water emerging at the spring. For example, the low concentration of MBAS detected in the Byerstead sample in November 2005 (950µg/L), was taken during a prolonged period of heavy rainfall (over a period of days before), and it was noted that the discharge from the spring appeared greater than normal. It is thought that there are several sources for the analytes detected at the Byerstead Spring, the two most prevalent of which are the site itself and the flooded mine systems in the area.

The geological and geochemical data obtained during the monitoring regime has been considered in this report.

1.5. Report Format

For ease of reference, the remainder of this report has been structured as follows:

- Section 2 details the objectives of this study

- Section 3 includes a review of the current site conditions and environmental setting, derived from pre-existing information
- Section 4 describes the site-specific ground conditions encountered and observations made during the Study.
- Section 5 describes the Conceptual Site Model
- Section 6 summarises the assessment of risk to human health.
- Section 7 summarises the assessment of risk to water resources
- Section 8 presents a complete list of the pollutant linkages potentially present on site, updated to include the findings of this investigation
- Section 9 presents the remediation strategy, in which the actions to address the significant pollutant linkages are explained.

In addition, the following Appendices are attached to the report:

Appendix A	Proposal for Site Works (Plot A) and correspondence
Appendix B	Field Methodology
Appendix C	Borehole & Trial Pit logs
Appendix D	Analytical Schedules, Tabulated Results, Laboratory Certificates, and Historic Data
Appendix E	Human Health Detailed Quantitative Risk Assessment
Appendix F	URS GAC Advice Note
Appendix G	Controlled Water Detailed Quantitative Risk Assessment
Appendix H	Model Inputs

2. OBJECTIVES

The project objectives listed below are in line with the *Assessment Actions* detailed in the Site Remediation Statement where the area is referred to as "Plot A".

The key objectives of the investigation were therefore to undertake the following;

- To assess the potential extent and significance of contamination in shallow soil and groundwater in the specified area of interest;
- To provide additional data on potential further compounds not previously detected but which may be considered to be present;
- To provide comprehensive and robust data to allow conceptualisation and characterisation of the site area as far as possible;
- To revisit existing data and to supplement this with additional information from the proposed investigation;
- To revise and develop the current Conceptual Site Model;
- To review all the data gathered from the assessments undertaken in the area of interest and to review this against the existing controlled waters and human health site specific risk based screening levels;
- To provide a preliminary evaluation of the need for, and scope of, potential remedial options (if considered appropriate) together with an estimation of potential remedial methodologies and costs.

2.1. Site Investigation Design

The site investigation design was submitted to the Environment Agency for comment prior to commencement of works. It was approved by Peter Bardsley of the Penrith office. Details of the investigation design and rationale are presented in the proposal and subsequent correspondence between URS and the Environment Agency provided in Appendix A to this report.

3. SITE DESCRIPTION AND ENVIRONMENTAL SITE SETTING

3.1. Introduction

The Former Albright and Wilson Works (the site) is located in a coastal setting, on the hill approximately 2 km south of Whitehaven Town Centre. To the north east are residential estates (Woodhouse and Kells) and to the south is the village of Sandwith. The remainder of the site is surrounded by agricultural land. Plot A occupies an area of approximately 36,250m^2 (3.6 hectares) and is located towards the northern end of the site.

Plot A slopes gently from east to west and forms part of the gentle slope which runs to the cliff line approximately 800m to the east, beyond which lies the Irish Sea.

3.2. Plot A Current and Historical Operations

Historical activities undertaken within the Plot A area have included coal mining (the former Ladysmith and Croft mine shafts are located here), and more recently, a rock store, a surfactant smoothing area ('the cathedral'), part of the fatty alcohol plant, and part of the Wet and Dry Salts area. All the buildings have now been demolished to ground level, and some stockpiles of demolition rubble remain. Much of the ground remains coved by concrete hardstanding, relating to floor slabs from the former buildings and foundations and cover from former process areas.

3.3. Environmental Setting

The environmental setting for the site has been previously established during URS's Phase II investigation, a summary of the setting, specific to Plot A, is presented in the sections below. The full Phase II investigation is available as an appendix to the Remediation Statement.

3.3.1. Geology and Hydrogeology

The geology and hydrogeology of the Rhodia site is complex and is described in full in Section 2.3 of the Phase II Investigation. In summary, the main formations comprise:

- Made Ground: the made ground (the man made or disturbed ground formed when the chemical works was built), overlying
- Glacial Till (Boulder Clay) (the "drift"): present across the area in limited thickness, although absent in some other parts of the site, overlying either
- St Bees Evaporite Formation (late Permian): present as either pink grey crystalline limestone or as yellow sandstone at a number of locations across Plot A. This formation is classified as a non aquifer by the Environment Agency. These lithologies are known to have suffered dissolution through historical losses

of acid to ground in certain locations within the vicinity of Plot A. The location of the known voids in the vicinity of Plot A are as follows:

- Three voids are known to exist immediately upgradient (to the east) of the eastern boundary of Plot A. These are in the area formerly containing acid concentrators.
- Two voids are known to exist on the southeastern boundary of Plot A. These are toward the southern end of the Wet and Dry Salts area.
- One void is known to exist on the southwestern boundary of Plot A, on the edge of the fatty alcohol plant.
- Two voids are known to exist down gradient of Plot A, within the Fatty Alcohol Plant.

- The Brockram Formation (early Permian): comprising coarse, well cemented, clast supported breccias, typically only 1 – 2m in thickness is shown to sub crop beneath the northern part of the site in BGS Geological Maps, although it was not encountered in the exploratory holes advanced during this investigation. This formation unconformably overlies the Whitehaven Sandstone Formation. This formation is classified as a minor aquifer by the Environment Agency.

- The Whitehaven Sandstone Formation (Westphalian C to D, Carboniferous) comprises medium to coarse grained purple to purple-brown sandstones which are cross bedded throughout with thin interbeds of mudstones and siltstones bedded with sandstones and siltstone. This sandstone is classified as a minor aquifer by the Environment Agency.

3.3.2. Surface Waters

No surface water bodies are present in the boundaries of Plot A or within its immediate vicinity. However, the Plot A area is serviced by a storm water drainage system which was designed to drain the water within Plot A northwards towards the coast. It is currently proposed that the drains on the whole of the Rhoda site will be blocked and allowed to silt up and that the groundcover within Plot A will be left in its current state.

Once the drains are no longer able to remove significant volumes of water it is assumed that there will be a greater component of overland flow corresponding to the natural watershed which drains the northern part of the Plot A Area (including the cathedral) to the North, and the southern part of Plot A (including the Fatty Alcohol Plant and the Wet Salts Plant) to the south and Sandwith Beck. In addition, it is considered that infiltration of surface water may also increase, potentially adding to the volume of water entering either perched ground water or the aquifers present in the geological sequence.

3.4. Potential Receptors

Based on the environmental site setting and previous conceptual site models developed in the Phase II assessment, URS considers the following to be the receptors likely to be at risk from potential contamination within the Plot A area:

- *Human beings*: Given that the proposed end-use for the Plot A area and the site as a whole is to be a recreational area for open access to the public it is considered by URS that members of the public represent a potential receptor.

- *Deep groundwater and subsequently Coastal Waters*: The groundwater within the St Bees Evaporites/St Bees Evaporite Formation is likely to receive infiltrating rainwater in Plot A. The St Bees Evaporite Formation, which is classified as a major aquifer. Once into the St Bees Evaporite Formation, it has been demonstrated by dye testing experiments that the groundwater migrates rapidly towards the coastline (and is likely to emerge at the Byerstead Spring), which is situated approximately 1.3km to the southwest of Plot A.

3.5. Potential Current and Historical Sources of Contamination

Based on observations and review work undertaken during the Phase II investigation are a number of potential current and historical sources of contamination have been identified. These are shown on Figure 3 and are described below.

Historic on-site sources of potential soil and groundwater contamination:

- The Tanker Washing Area is actually located outside Plot A (and is within Plot B), however it is immediately up hydraulic gradient of the Plot A boundary, and migrating water may have an impact on soil and groundwater conditions within Plot A. Furthermore, the northern half of Plot A lies directly down gradient of Plot B. If contamination is found within Plot A, it may be associated with any surface water runoff or drainage water from Plot B. It is considered likely that the shallow groundwater regime in the vicinity of the Plot A/B boundary is discontinuous, and therefore the potential for significant lateral migration in shallow groundwater may be limited. The main contaminants associated with Plot B are Polycyclic Aromatic Hydrocarbons (PAH's), surfactant, cyanide, sulphate, heavy metals, Volatile Organic Compounds (VOCs), Total Petroleum Hydrocarbons (TPH), and Semi Volatile Organic Compounds (SVOCs);

- The Cathedral (Former Smoothing Chambers and pH balancing area). Historically, a number of site drains led to the cathedral area, the effluent that entered the lagoon came from a number of production areas. The most likely contaminant associated with the operation of the "smoothing chamber" are considered to be surfactants;

- The Catalyst preparation plant and Fatty Alcohol Plant. Likely sources of contamination include VOCs, SVOC's and PAH's;

- Historical workshops/laboratories, from where there may have been leaks, spills or releases to ground;

- The Former Wet and Dry Salts Area. Likely sources of contamination from these processes include TPH.

- The former electrical substation. Likely sources of contamination include polychlorinated biphenyls (PCBs);

- Concentrations of contaminants within imported materials used for ground raising and reclamation (*e.g.* ash and clinker fill which may contain TPH, PAH and heavy metals); and

- Phosphates: Although no specific phosphate source has been identified in Plot A, it is considered likely that phosphates may be present on any part of the site.

4. FIELD OBSERVATIONS AND GROUND CONDITIONS ENCOUNTERED

4.1. Introduction

This section reviews the soil and groundwater conditions observed during the fieldwork and also summarises the field evidence of impact identified as a result of visual/olfactory observations and/or the results of field screening. Interpretations are based on observations noted during the excavation of the 30 trial pits and four boreholes (three of which were installed as monitoring wells) advanced across Plot A during this investigation.

Historically, activities located within Plot A have included coal mining (the former Ladysmith and Croft mine shafts are located here), and more recently, a rock store, a surfactant smoothing area ('the cathedral'), parts of the fatty alcohol plant, and the wet and dry salts area. However, no patterns of ground conditions have emerged to facilitate the discussion of Plot A by dividing it into sub-areas, and as such, it is described as a whole area.

4.2. Soil Conditions

The ground conditions underlying the Plot A area are derived from the inspection of the arisings resulting from excavations and soil borings advanced during the investigation. A summary of the ground conditions encountered is provided in Table 4.1 below.

The rationale for the sampling regime is presented in Appendix A and the field techniques employed during this investigation are detailed in Appendix B. Exploratory hole logs are presented in Appendix C. Exploratory hole locations are shown on Figure 4.

Table 4.1 – Summary of Typical Geological Profile Encountered

Unit	Description	Depth Encountered (m)	Maximum Thickness (m)
Made Ground	Reinforced concrete hardstanding	0 – 0.3	0.3
	Hardcore	0 – 1.6	1.35
	Black or brown sand and gravel with many man made components (fill material)	0 – 2.6	1.9
	Orange red or black brown silt and clay with occasional gravel and cobbles	0.3 – 1.9	1.3
	Black silt layers with clinker, or pockets or lenses of black clinker	0.2 – 2.6	0.8
Natural Ground	Glacial Till Deposits typically comprising red brown silt or dark brown clay with occasional gravel, cobbles and lenses of sand. Occasionally contains layers of yellow brown silty, sand and gravel	0.3 – 5.5	3.5
Bedrock	St Bees Evaporite Formation: typically comprising white, slatey, weathered, calcareous rock.	2.5	Not proven

Geological field observations are presented in Figure 5. A geological map is presented as Figure 6 and a geological cross section in Figure 7. The geological sequence observed is summarised below.

4.2.1. Made Ground

The Made Ground varied in thickness from 0.3m at TP604A to 2.6m at TP614A, with no obvious spatial correlation. Reinforced concrete hardstanding (0.15m – 0.3m thick) was encountered in the areas of former production / storage tanks / foundations: the cathedral area (TP604A, TP607A, TP608A, TP609A), the fatty alcohol plant (TP626A, TP627A, TP628A, TP629A, TP630A) and the storage tank area (TP618A, TP619A, TP620A, TP621A). This concrete hardstanding was occasionally underlain by hardcore. Surrounding these former plant areas, the land appears not to have been recently used for industrial works, and the surface layer comprises grass and topsoil or hardcore.

Beneath the surface layer the Made Ground typically compromised one or more of the following:

- Fill material: Generally brown or black silt, sand and gravel with occasional brick and/or concrete. At TP603A, TP607A, TP614A, TP615A, TP616A, TP621A, TP622A, TP623A, TP625A, TP629A and WS502A the fill also contained man made components such as metal, wood, foundry waste, plastic, glass, rope, cables, pipe, tile, slate, metal girders, black fibres, wire, coal, ash and clinker. This is thought to be associated with the backfilling and levelling operations in the area. Colour variations in this exist at TP618A (grey and red), TP621A (blue and red), TP627A (yellow brown);

- Reworked drift: Typically yellow, red brown or brown silt with gravel and cobbles, or black and brown mottled clay; and

- Clinker: Pockets of black, shiny clinker. This appears to be localised in Plot A, found at TP603A, TP605A, TP609A, TP614A, TP622A and WS502A.

The presence of thick Made Ground is likely associated with levelling activities.

4.2.2. Natural Ground

Glacial Till (Drift/ Boulder Clay)

Drift deposits were encountered over most of Plot A with a maximum proven thickness of 3.5m observed in WS504A.

Drift was not observed in four locations due to difficulties in the excavation of trial pits or boreholes. At WS501A, refusal on rebar (at 1.4m) within the Made Ground prevented further excavation. The presence of thick concrete foundations prevented further excavation at 1.8m at TP615A. At TP617A, water flooded the trial pit from a broken drain; excavation was stopped to prevent any potential contaminants entering the natural ground. No drift was present at TP628A, and the Made Ground was observed to lie directly on top of bedrock.

Where encountered, the drift typically comprised Glacial Till deposits, which included:

- Red brown silt with occasional lenses of yellow fine sand, gravel and cobbles. This was found at several locations across Plot A;
- Brown, clay and silt, often with occasional gravel and cobbles. The colour of this varies from orange brown to dark brown, and is mottled in places. These were found within the central area Plot A; and
- Yellow or red silty sand and gravel. This is found at TP618A between the silt and clay at 1.8m bgl. It was also observed at WS502A (4.4m bgl) and at WS503A (2.3m bgl).

Natural Ground (Bedrock)

Bedrock was encountered at three locations in Plot A between 2.5m bgl and 5.5m bgl. The lithology observed was as follows:

- White, slatey, weathered calcareous rock, encountered at 4.7m in WS502A, at 2.5m in WS503A and at 5.5m in WS504A.

This unit is considered to represent the St Bees Evaporites / St Bees Evaporite Formation. The vertical and lateral extent of this unit is illustrated on Figures 7 and 8.

4.3. Groundwater Conditions

Limited groundwater strikes were observed during the excavation of the trial pits in Plot A with groundwater only observed at 2.6m bgl within the drift deposits in TP629A. Water spilling from broken drains was found in TP617A at 1.5m bgl and TP628A at 0.7m bgl. No groundwater was encountered in the monitoring wells installed in Plot A during this investigation.

The lack of a continuous shallow groundwater system in Plot A is considered likely to be due to presence of only a shallow thickness of boulder clay (less than 3m), combined with a presence of shallow consolidated geology in this area, namely the St.Bees Evaporites. Rockhead has been proven as shallow as 2.3m (WS503A). Therefore, rainfall incident in Plot A may infiltrate directly into the bedrock through the drift.

The St. Bees Evaporites have undergone dissolution in the vicinity of Plot A due to the loss of acids directly to ground in areas of former acid storage. This has resulted in the creation of solution features/voids which may also be present beneath Plot A. It is considered that the dominant groundwater transport mechanism within this unit (in parts of Plot A) is likely to be within these voids, where streams may flow. It is known that one such stream exists directly up hydraulic gradient of Plot A (to the east), where a stream was observed to flow at the base of such a void. This was one of three voids that existed directly under the tank footprints in an area historically containing acid concentrators (located 25m to the north west of the large S7 stores).

It is considered groundwater flow direction is likely to follow dip and topography to the west/south west. As groundwater migrates out of Plot A, it will encounter a north-south trending fault. At the fault, it is thought that the geological sequence has been downthrown on the western side. The water may migrate downwards into the fault plane, before continuing to migrate laterally following the path of least resistance/highest permeability towards the coastline; this may be within old mine adits or continue to be within the partially dissolved St Bees Evaporite Formation strata.

At the coastline, the groundwater is likely to be forced to the surface when it meets the saline water interface. One point known to contain site-derived waters is a spring which emerges on Saltom Beach, known as the Byerstead Spring. Dye tracing has shown that site derived water can reach the Byerstead Spring in less than 10 hours.

It is also likely that some of the rainfall incident on the area will be removed as surface runoff through transport in the site drainage system.

It is considered likely that no continuous shallow groundwater body is present within the drift deposits. Historically, only four installations have provided any shallow groundwater. These are WS115, located approximately 25m north east of the cathedral; WS124 situated close to the south western boundary of Plot A, SB13 located towards the centre of Plot A, and SB9 located 5m to the west of the cathedral. It is likely that these boreholes contain localised pockets of perched groundwater (unconnected underground ponds of water).

4.4. Field Observations of Contamination

Field observations (visual and olfactory evidence) and Photo Ionisation Detector (PID) readings were recorded to provide information on the location and nature of potential contamination. This evidence is presented below in Table 4.2, which summarises areas of potential contamination and likely sources and is shown on Figure 8:

Table 4.2 Field Observations of Contamination

Location	Made Ground	Drift	Bedrock
TP601A	NVO	NVO	-
TP602A	NVO	NVO	-
TP603A	Contains clinker	NVO	-
TP604A	NVO	NVO	-
TP605A	Contains clinker	NVO	-
TP606A	Sulphurous odour	NVO	NVO
TP607A	Surfactant odour	NVO	-
TP608A	Contains ash	NVO	-
TP609A	Faint/moderate chemical odour, contains clinker	NVO	-
TP610A	NVO	NVO	-
TP611A	NVO	NVO	-
TP612A	NVO	NVO	-

Location	Made Ground	Drift	Bedrock
TP613A	NVO	NVO	-
TP614A	Contains clinker	NVO	-
TP615A	Moderate chemical odour, oily sheen	-	-
TP616A	NVO	NVO	-
TP617A	Chemical odour	-	-
TP618A	NVO	PID 14.8ppm at 1.9m and 28.8ppm at 2.8m	-
TP619A	NVO	NVO	-
TP620A	Faint chemical odour	NVO	-
TP621A	NVO	NVO	-
TP622A	Contains clinker	NVO	-
TP623A	NVO	NVO	-
TP624A	NVO	NVO	NVO
TP625A	NVO	NVO	-
TP626A	NVO	NVO	-
TP627A	NVO	Faint fruity odour	-
TP628A	Strong chemical odour and black staining	NVO	-
TP629A	PID 31.4ppm at 0.3m, very strong chemical odour	NVO	-
TP630A	Contains black fibres	NVO	-
WS501A	NVO	-	-
WS502A	PID 147ppm at 1.3m and 91ppm at 1.6m, contains clinker, stale odour	PID 152ppm at 2.5m, 22ppm at 3.5m and 14ppm at 4.5m	NVO
WS503A	PID 385ppm at 1.5m, moderate odour	PID 232ppm at 2.3m	-
WS504A	PID 700ppm at 1.5m	PID 74ppm at 2.4m	-

HC (hydrocarbon); NVO (no visual or olfactory evidence of contamination); PID (photo ionisation detector); - (not observed)

Contamination associated with the composition of the Made Ground

Contamination was observed in the Made Ground, the majority of which is considered likely to be associated with the constituents of the made ground, as opposed to chemical impact sourced from site derived activity.

As to be expected from the long industrial history of the site, the contamination is irregularly distributed over Plot A. The contamination encountered can be grouped into:

- Ash, clinker and foundry waste were observed in TP603A, TP605A, TP608A, TP609A, TP614A, TP622A and WS502A. This covers a large proportion of Plot A;
- Fibres (TP630A). Black fibres were observed within the Made Ground at TP630A; and

- Elevated PID readings were noted in the Made Ground in TP629A, WS502A, WS503A and WS504A.

Contamination potentially derived from Site Processes

At some locations, the nature of the contamination suggests the source of the potential contamination is not associated with the Made Ground present, and is instead likely to have been derived from site activity:

- At TP607A a surfactant odour was observed in the Made Ground. As this is the former location of the surfactant smoothing area, this contamination may be from a loss of water to ground;
- At TP615A the Made Ground was wet, and an oily sheen seen on the surface of the gravel. A chemical odour was also noted. This is likely to have been caused by an hydrocarbon release;
- Chemical odours were observed in TP606A, TP609A, TP617A and TP620A. These may be sourced from contaminated materials being deposited in the Made Ground;
- At TP618A high PID readings were observed in the drift at depth (14.8ppm at 1.9m and 28.8ppm at 2.8m). No evidence of contamination was encountered in the drift, so it seems likely that the contamination has migrated laterally or vertically to this location. Furthermore, this reading was taken in a sand band, the granular nature of this stratum makes it conducive to the migration of vapours. No significant evidence of a source was found in PID readings from locations surrounding TP618A; and
- At TP628A and TP629A strong chemical odours were noted in the Made Ground, together with black staining in TP628A, and a PID reading of 31.4ppm at 0.3m in TP629A.

Unidentified sources of contamination

During the boring of WS502A, WS503A and WS504A, high PID readings were noted in both the Made Ground and the underlying drift as follows:

- WS502A: 167ppm at 1.3m and 91ppm at 1.6m in the Made Ground and 152ppm at 2.5m, 22ppm at 3.5m and 14ppm at 4.5m in the natural ground;
- WS503A: 385ppm at 1.5m in the Made Ground and 232ppm at 2.3m in the natural ground; and
- WS504A: 700ppm at 1.5m in the Made Ground and 74ppm at 2.4m in the natural ground).

No staining or distinctive layer of contamination was observed nor was olfactory evidence present.

No visual or olfactory evidence of contamination

Trial pits with no visual or olfactory evidence of contamination include: TP601A, TP602A, TP604A, TP610A, TP611A, TP613A, TP619A, TP624A, TP626A, TP627A and WS501A. The majority of these are located in areas that do not appear to be former processing or storage areas; the exceptions being TP626A and TP627A that are located in the vicinity of the former fatty alcohol plant.

4.5. Geochemical Results

The analytical schedules and results of chemical analyses are provided in detail in Table 1 and Tables 3 to 13 included in Appendix D to this report (enclosed as a CD). The laboratory certificates are also included in Appendix D to this report.

This section introduces an initial understanding of the distribution of key analytes detected in the soil, leachate and groundwater on the site. The term 'elevated' refers to the comparison between a reported analyte concentration compared to an average concentration for that compound calculated from all data across the investigation area. An assessment of whether the analyte concentration represents a "significant risk" to either controlled waters or human health receptors is made within Sections 6 and 7 in this report.

Volatile Organic Compounds (VOCs)

23 soil samples were scheduled for VOC analysis. No samples were scheduled for leachate analysis. Of the samples analysed, 17 had reported concentrations greater that the laboratory method detection limit (MDL). Elevated concentrations of VOCs are summarised in the Table 4.3 below:

Table 4.3 – Elevated Concentrations of VOCs

VOC in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
1,1,1-Trichloroethane	0.033	0.120	1	Made Ground
Ethylbenzene	0.006	0.024	2	Made Ground
M,P-Xylene	0.014	0.120	1	Made Ground
Toluene	0.002	0.056	6	Made Ground

The samples with elevated VOCs are all located in the south or west parts of Plot A.

Metals

20 soil samples were scheduled for metals analysis and NRA leachate preparation and

analysis. Elevated concentrations are summarised in the Tables 4.4 and 4.5 below:

Table 4.4 – Elevated Concentrations of Metals (Soils)

Metal in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Arsenic	7	65	6	Made Ground (6)
Barium	65	2921	4	Made Ground (2) Drift (2)
Beryllium	1	6	2	Drift (2)
Chromium	7	51	10	Made Ground (6), Drift (3), Bedrock (1)
Copper	4	138	6	Made Ground (5), Drift (1)
Lead	12	165	5	Made Ground
Nickel	8	179	6	Made Ground (4), Drift (2)
Vanadium	11	71	8	Made Ground (6), Drift (2)
Zinc	11	398	7	Made Ground (5), Drift (2)

Table 4.5 – Elevated Concentrations of Metals (Soil Leachate)

Leachable Metal	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Arsenic	2	40	3	Made Ground (3)
Barium	1	208	8	Made Ground (7), Drift (1)
Boron	10	119	7	Made Ground (6), Bedrock (1)
Chromium	1	16	2	Made Ground (1), Drift (1)
Copper	4	64	2	Made Ground (1), Drift (1)
Nickel	1	13	3	Made Ground (2), Drift (1)
Selenium	1	9	3	Made Ground (2), Drift (1)
Vanadium	2	72	3	Made Ground (3)

No obvious spatial correlation of elevated metal concentrations in soils or leachable metal concentrations exists over Plot A. The majority of elevated concentrations of metals were reported in soil samples collected from within the Made Ground. As is typical with any historic industrial facility, ash and clinker were used as fill during levelling ground works on the site and these are typically considered to be a likely source for the increase of concentrations of metals in shallow horizons. Elevated concentrations of metals in soil were also observed in drift. Relatively elevated chromium soil concentrations were observed in silt at TP611A and TP626A, and in siltstone at TP606A. Elevated soil concentrations of a number of metals were observed in clay at 2.8m in TP618A and at 2.5m in TP620A. The

leachate analysis identified some isolated elevated leachable metal concentrations in drift (selenium at TP620A, chromium at TP621A, nickel at TP624A, barium at TP626A and copper at TP627A) and in siltstone (boron at TP606A).

Anionic Surfactants

33 soil samples were scheduled for surfactant analysis in soil, however it was not possible to analyse nine of these due to high clay content (a sample with a high clay content impacts the analytical method). Four soil samples contained surfactants at concentrations above the MDL. The minimum reported concentration was 1.8mg/kg in Made Ground at 1.5m in TP615A, and the maximum reported concentration was 5.3mg/kg in Made Ground at 0.4m in TP605A. These results appear to be clustered in the eastern part of Plot A.

Concentrations of surfactants above the MDL were reported in ten of the 60 samples submitted for NRA leachate preparation and analysis. The minimum reported concentration was 60µg/l and the maximum was 260µg/l in Made Ground from 0.5m at TP630A. Nine of the ten samples where leachable surfactants were detected are located in the southwest of Plot A, in the area of the former fatty alcohol plant.

Semi Volatile Organic Compounds (SVOCs)

53 soil samples were scheduled for SVOC analysis. Of these, 20 returned concentrations above the laboratory MDL. Elevated concentrations are summarised in Table 4.6 below.

Table 4.6 – Elevated Concentrations of SVOCs (Soils)

SVOC in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
2-Methylnaphthalene	0.1	9.0	5	Made Ground (5)
Anthracene	0.1	1.0	2	Made Ground (2)
Benzo(a)anthracene	0.1	1.6	5	Made Ground (5)
Benzo(b)fluoranthene	0.2	1.2	3	Made Ground (3)
Benzo(g,h,i)perylene	0.1	1.3	3	Made Ground (3)
Benzo(a)pyrene	0.1	1.4	5	Made Ground (5)
Benzo(k)fluoranthene	0.1	0.9	5	Made Ground (5)
Carbazole	0.1	0.3	1	Made Ground (1)
Chrysene	0.1	2.3	5	Made Ground (5)
Dibenz(a,h)anthracene	0.1	0.3	1	Made Ground (1)
Dibenzofuran	0.1	3.7	1	Made Ground (1)

SVOC in soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Fluoranthene	0.2	7.6	4	Made Ground (4)
Fluorene	0.1	1.1	1	Made Ground (1)
Indeno(1,2,3cd)pyrene	0.1	1.0	1	Made Ground (1)
Naphthalene	0.1	13.8	1	Made Ground (1)
Phenanthrene	0.2	6.8	5	Made Ground (5)
Pyrene	0.1	6.2	4	Made Ground (4)

The majority of these detections were in the Polycyclic Aromatic Hydrocarbon (PAH) group of analytes in samples collected from Made Ground at 0.4m in TP605A, 1.0m in TP612A, 1.1m in TP620A, 1.3m in WS502A and 1.5m in WS503A. These locations are clustered close to the centre of Plot A, near former roadways.

Four of the 61 samples submitted for NRA leachate preparation and analysis contained concentrations of SVOCs above the MDL. Elevated concentrations were observed in clay at 3.0m in TP619A (dibenzofuran), and in silt at 0.8m in TP606A (acenaphthene, anthracene, carbazole, fluoranthene, fluorine, phenanthrene and pyrene). These locations are found close to the centre of Plot A, and towards the eastern edge of Plot A, respectively.

Total Petroleum Hydrocarbons (TPH)

33 samples were submitted for TPH analysis; 18 for risk based evaluation (RBE) analysis, and 15 for criteria working group (CWG) analysis. TPH was reported at concentrations exceeding the MDL in 25 of these samples. For the samples with CWG analysis, elevated concentrations were reported in Made Ground at 2.3m in TP609A, 1.0m in TP612A and 1.5m in TP615A, with the dominant fractions in the C12-C16, C16-C21, C21-C35 ranges in both aliphatic and aromatic compounds. The maximum value for total TPH was 14,824mg/kg from 1.5m at TP615A. For samples with RBE analysis, elevated concentrations were reported in Made Ground at 0.3m in TP629A and 1.4m in WS502A. The maximum value for total hydrocarbons was 11,977mg/kg from 0.3m at TP629A. There does not appear to be a spatial correlation between these locations.

Four of the thirty samples submitted for NRA leachate analysis and preparation reported concentrations of TPH above the MDL. Elevated concentrations were reported in clay at 0.8m in TP619A (aliphatic C21-C35), in silt at 1.0m at TP624A (total TPH), and in Made Ground at 1.7m in TP628A (aliphatic C21-C35 and total TPH).

Additional Analytes

Ten samples were scheduled for Polychlorinated Biphenyls (PCB) soil and leachate

analysis. Concentrations of PCBs in soil were reported above the MDL in three samples, the most elevated being 0.13mg/kg in Made Ground at 0.8m in TP611A. None of the samples reported concentrations of leachable PCBs above the MDL.

Further additional analytes include: acid soluble sulphide (10 soil, 5 leachate), ammoniacal nitrogen (30 soil, 60 leachate analyses), cyanide (15 soil, 15 leachate), nitrate (33 soil, 30 leachate), phosphate (63 soil, 50 leachate), sulphate (18 soil, 18 leachate), sulphur (10 soil, 5 leachate) and total organic nitrogen (33 soil, 60 leachate). Table 4.7 summarises the elevated concentrations reported for these analytes.

Table 4.7 – Elevated Concentrations of Additional Analytes (Soils)

Analyte	Maximum reported soil concentration (mg/kg)	Maximum reported leachate concentration (µg/l)	Number of samples with elevated soil concentrations	Number of samples with elevated leachate concentrations
Acid soluble sulphide	1,624	Not detected	1 (Made Ground)	-
Ammoniacal Nitrogen	80.2	3000	1 (Made Ground)	5 (Made Ground)
Cyanide	Not detected-	Not detected--	-	-
Nitrate	101	2300	7 (Mixture)	4 (Mixture)
Phosphate	233	157190	3 (Mixture)	4 (Mixture)
Sulphate	62310	1347000	2 (Made Ground)	3 (Made Ground)
Sulphur	2.08	Not detected	3 (Made Ground)	-
Total Organic Nitrogen	25		2 (Drift)	

Summary

Based on the analytical results of this site investigation, it is considered that the majority of samples with relatively elevated concentrations are located within the Made Ground. However, the contamination is not thought to be widespread, instead forming relatively small pockets across Plot A.

5. CONCEPTUAL SITE MODEL

5.1. Introduction

The objective of the conceptual site model is to place the environmental, geological and hydrogeological information obtained to date in the context of a risk-based setting, and produce a conceptual model of the site. The conceptual model of the site will highlight the primary sources of site contamination and the sources of exposure to potential receptors. The conceptual model assumes the site use is public open space.

The findings of this preliminary qualitative assessment will be used to define the extent and nature of the quantitative risk assessment.

Copeland Borough Council determined the site as contaminated land on the basis of the pollutant linkages listed below. These pollutant linkages are of a very general nature, and in order to present a meaningful assessment, URS has carried out a more detailed analysis, presented in the sections below.

Copeland Borough Council Pollutant Linkages
Petroleum Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Poly Aromatic Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Surfactants in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Phosphates in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Arsenic in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Boron in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Cadmium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Chromium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Copper in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Lead in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.

Copeland Borough Council Pollutant Linkages
Mercury in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Nickel in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Selenium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
Zinc in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.
VOC's/SVOCs in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.

5.1.1. Potential Sources

Potential contaminant sources on site associated with current and historical uses, as outlined previously in Section 3.5 and detailed in the Site Remediation Statement (23 June 2006 ref 44319877/R2234.B01), and the proposal and EA correspondence in Appendix A. These comprise the following**;**

Table 5.1a – Summary of potential Sources

Potential Sources	Contaminants of Concern
Tanker Washing Area and other sources in Plot B (Imidazoline, CAPB Plants & Coking works)	PAHs, Surfactant, cyanide, sulphate, heavy metals, VOCs, SVOCs, and TPH
The Cathedral (Former Smoothing Chambers and pH balancing area).	Surfactant and potentially other analytes within process effluent
The Catalyst Preparation Plant and Fatty Alcohol Plant.	Likely sources of contamination include VOCs, SVOC's and PAH's
Workshops and laboratories	Unknown. Analytes are likely to be detected in the site-specific analytical suite scheduled for this investigation.
Former Wet and Dry Salts Area	TPH
Electrical substations	Polychlorinated biphenyls (PCBs)

Potential Sources	Contaminants of Concern
Fill Materials	PAHs, petroleum hydrocarbons and heavy metals associated with ash and clinker fill. Potentially other contaminants associated with other materials.
Historic operation and production products	TPH and phosphate

In their determination of the site as "contaminated land", Copeland Borough Council listed a number of other contaminants which they considered likely to be present on the site as a result of its' previous history. These contaminants were included in Assessment Action to ensure that the possibility of there being Contaminants of Concern is fully evaluated. The sampling suite chosen for the analysis of soil, soil leachate and, where possible, groundwater samples were agreed with the Environment Agency.

5.2. Potential Pathways

Copeland Borough Council's determination of the land as contaminated land refers to only two pathways – the movement of contaminants from soil to groundwater, and the migration of contaminants to controlled waters through drains. In the generation of the Remediation Statement, URS refined the understanding of the pathways. The pathways that are relevant to the land to which this report relates are listed below in Table 5.2a.

Table 5.2a Pathway details

Pathway	Pathway characteristics
Controlled Water 1 (CW1)	a) Infiltration of rainwater through contaminated soil and subsequent leaching and vertical movement to shallow groundwater. b) Migration of rainwater through the drainage system, possibly resulting in dissolution of contaminants and/or the mobilisation of contaminants within the drains, leading to discharge into shallow groundwater at point where the integrity of the drainage lines has been compromised by exposure to acid.
Controlled Water 2 (CW2)	Vertical movement of dissolved or liquid contaminants from shallow groundwater to groundwater within the St.Bees Evaporite Formation. Movement from shallow groundwater to groundwater in the St.Bees Evaporite Formation may be enhanced by engineering earthwork which is likely to have been undertaken in the development of the site (removal of drift,

Pathway	Pathway characteristics
	build up of made ground) and by faulting in certain areas or may also be retarded by the presence of concrete foundations and cellars.
Controlled Water 3 (CW3)	The potentially rapid flow of groundwater within the St.Bees Evaporite Formation via complex pathways in a west/southwest direction towards the coast and the Irish Sea. This occurs through flow in solution features in the St.Bees Evaporite Formation, interaction with faults, and through mine adits).
Human Health 1 (HH1)	Dermal contact/ingestion of contaminated soil.
Human Health 2 (HH2)	Inhalation of vapours from soil and/or groundwater.
Human Health 3 (HH3)	Inhalation of dust from contaminated soil.

5.3. Potential Receptors

Table 5.3a Receptor characteristics

Receptor	Receptor characteristics
Humans: Public using the open space	Mainly local residents, likely to use the site for dog walking and other recreation. The critical receptor (person most likely to come to harm) in the risk assessment was a female child aged 6 or under, visiting the site to play for an estimated average 119 days per year. Other, more probable users, would be at lower risk.
Controlled waters: The Irish Sea.	Groundwater migrates via complex underground pathways towards the Irish Sea. It is likely to discharge via the Byerstead Fault Spring on Saltom Beach, located 1.3km away.

5.4. Pollutant Linkages

For a significant 'pollutant linkage' to exist, a *source* of contamination (e.g. a leaking storage tank) must be connected to via a *pathway* (e.g. surface water) to a receptor (e.g. a nearby stream). Pollutant linkages apply to Controlled Waters and Human Health Receptors.

5.4.1. Controlled Waters

The analytes that were considered to present a potentially significant risk to controlled waters were identified in Section 4.0 of the Site Remediation Statement document. Various pollutant linkages are thought to exist from these contaminant sources. Table 5.4a below shows the significant pollutant linkages considered to exist from the identified potential contaminants of concern to the identified controlled waters receptor (please note that the pathway codes refer to the pathways detailed in Table 5.2a).

Table 5.4a Particulars of Substances and Significant Harm/Pollution of Controlled Waters

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
C1	Surfactant and potentially other analytes within process effluent	The Cathedral (Former Smoothing Chambers and pH balancing area).	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C2	Likely sources of contamination include VOCs, SVOC's and PAH's	The Catalyst Preparation Plant and Fatty Alcohol Plant.	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C3	Unknown. Analytes are likely to be detected in the site-specific analytical suite scheduled for this investigation.	Workshops and laboratories	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C4	TPH	Former Wet and Dry Salts Area	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C5	Polychlorinated biphenyls (PCBs)	Electrical substations	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C6	PAHs, petroleum	Fill Materials	CW1, CW2,	The Irish Sea	-	Potential for entry of contaminant into the

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
	hydrocarbons and heavy metals associated with ash and clinker fill. Potentially other contaminants associated with other materials.		CW3			St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C7	TPH and phosphate	Historic operation and production products	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.
C8	PAHs, Surfactant, cyanide, sulphate, heavy metals, VOCs, SVOCs, and TPH	Analytes associated with surface runoff from the Tanker Washing Area and other sources in Plot B (Imidazoline, CAPB Plants & Coking works)	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.

5.4.2. Human Health

Copeland Borough Council determined the site as contaminated land on the basis of the pollutant linkages with regard to controlled waters receptors. However, based on the additional data provided from the most recent investigation it was considered prudent to revise and update the existing site-wide human health risk assessment to a area-specific assessment for Plot A. Therefore Table 5.4b below shows the significant pollutant linkages considered to exist from the identified potential contaminants of concern to the identified human health receptors (please note that the pathway codes refer to the pathways detailed in Table 5.2a).

Table 5.4b Particulars of Substances and Significant Harm/Pollution of Human Health

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
H1	Surfactant and potentially other analytes within process effluent	The Cathedral (Former Smoothing Chambers and pH balancing area).	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H2	Likely sources of contamination include VOCs, SVOC's and PAH's	The Catalyst Preparation Plant and Fatty Alcohol Plant.	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H3	Unknown. Analytes are likely to be detected in the site-specific analytical suite scheduled for this investigation.	Workshops and laboratories	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H4	TPH	Former Wet and Dry Salts Area	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H5	Polychlorinated biphenyls (PCBs)	Electrical substations	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H6	PAHs, petroleum hydrocarbons and heavy metals associated with ash and clinker fill. Potentially other contaminants associated with other materials.	Fill Materials	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
H7	TPH and phosphate	Historic operation and production products	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater
H8	PAHs, Surfactant, cyanide, sulphate, heavy metals, VOCs, SVOCs, and TPH	Analytes associated with surface runoff from the Tanker Washing Area and other sources in Plot B (Imidazoline, CAPB Plants & Coking works)	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation and dermal contact with contaminated soil. Vapour inhalation of contaminants in soil and groundwater

6. HUMAN HEALTH RISK ASSESSMENT

6.1. Introduction

Details of the rationale, methodology and results of the modelling undertaken for the human health quantitative risk assessment are presented in full in Appendix E and are summarised below.

The primary objective was to assess the potential risk to human health assuming the site is opened to the general public for a right-to-roam open space usage. The screening assessment is based on the current condition of the subsurface soil and groundwater beneath Plot A as detected by investigations undertaken at the site. The URS in-house model, Human7, which is based on the algorithms detailed in CLR10 was used to run the assessment.

6.2. Stage 2 Assessment

A Stage 2 generic screening risk assessment was undertaken using a residential without gardens scenario. A number of substances were identified in soil which exceeded their respective generic screening criteria:

Soil

- **Metals, metalloids and inorganic** – arsenic, barium, lead, nickel, cyanide, thiocyanate[2], mercury;
- **PAH** – acenaphthene, acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, phenanthrene, pyrene, and naphthalene;
- **PCB** – total as Aroclor 1254
- **SVOC** – cis 1,2-dichloroethene, carbazole, dibenzofuran;
- **TPH** – assessed via TPH Criteria Working Group (TPHCWG) fractions; and
- **VOC** – benzene, toluene, xylenes, trichloroethene (TCE).

[2] cyanide and thiocyanate summed together and compared to acute exposure value for generic assessment. Also assessed with DQRA to complete chronic assessment.

6.3. Stage 3 Assessment

Those determinands identified as exceeding the Stage 2 screening criteria were taken forward to Stage 3 detailed quantitative assessment. At Stage 3, site specific assessment criteria (SSAC) were derived for a public open space end use using the URS Human 7 model.

The US_{95} soil concentrations of metals and organic determinands in shallow soils did not exceed the Stage 3 criteria. However, individual concentrations of nickel and benzo(a)pyrene were detected at concentrations exceeding SSAC in shallow soil. Neither of these determinands is considered to present potentially significant risk.

The US_{95} soil concentrations of metals and organic determinands in deep soils did not exceed the Stage 3 criteria. Individual target compounds were not detected at concentrations in excess of the Stage 3 criteria.

6.4. Sensitivity Assessment

The exposure scenario employed for the Stage 3 assessment is considered to be highly conservative for the 'right to roam' end use. Despite this, no risks were identified. The key uncertainties (for which a choice of variable is available in the model)are related to the viability of the pathways to the exposure frequency of the receptor. The effect of reducing exposure frequency is to increase SSACs two to three fold. Further information is provided in Appendix E.

6.5. Summary of Risks to human Health

Based on the outcome of the Stage 3 assessment, shallow and deep soils are considered not to pose a risk to human health for the proposed end use.

Therefore, should the current condition and layout of Plot A be maintained, it is considered that potentially significant risks to human health would be unlikely for a public open space scenario. Plot A is considered suitable for use as public open space without the requirement for further action with the exception of addressing Health and Safety issues (such as the removal of protruding trip hazards etc).

The risks to potential future maintenance, remediation or redevelopment workers who may be involved in subsurface working are not specifically assessed as part of this report. URS advises that separate activity related risk assessments should be carried out as required to comply with the necessary legislation and guidance, which identifies the need for any preventative measures (such as the use of PPE) to be completed prior to such activities being carried out. The results of this human health assessment however could be used to inform decision-making on this issue.

7. CONTROLLED WATERS QUANTITATIVE RISK ASSESSMENT

7.1. Introduction

Details of the rationale, methodology and results of the modelling undertaken for the Controlled Waters Quantitative Risk Assessment are presented in full in Appendix G and summarised below.

7.2. Stage 2 Assessment

A Stage 2 generic quantitative screening risk assessment was undertaken, the results being summarised in Table 7.1.

Table 7.1 – Controlled Waters Stage 2 Summary of Screening Criteria Exceedances

Soil	Soil Leachate	Shallow Groundwater
	Arsenic	
	Azobenzene	
	Benzo(A)Anthracene	Benzo(A)Anthracene
	Benzo(A)Pyrene	Benzo(A)Pyrene
	Carbazole	
	Chromium	
	Copper	
	Fluoranthene	
	Phenanthrene	
	Sulphate	Sulphate
	Sum Of 4 PAHs	
M,P-Xylene, Toluene	TPH (Sum Aliphatics & Aromatics C5-C35)	
	TPH C16-C21 Aliphatic	
	TPH C16-C21 Aromatic	
	TPH C21-C35 Aliphatic	
	TPH Total Aliphatics (C5-C35)	
	TPH Total Aromatics (C6-C35)	
		Cyanide
		Zinc

All of the determinands whose concentrations exceeded their respective Stage 2 criterion were taken forward to Stage 3, detailed quantitative risk assessment.

7.3. Stage 3 Assessment

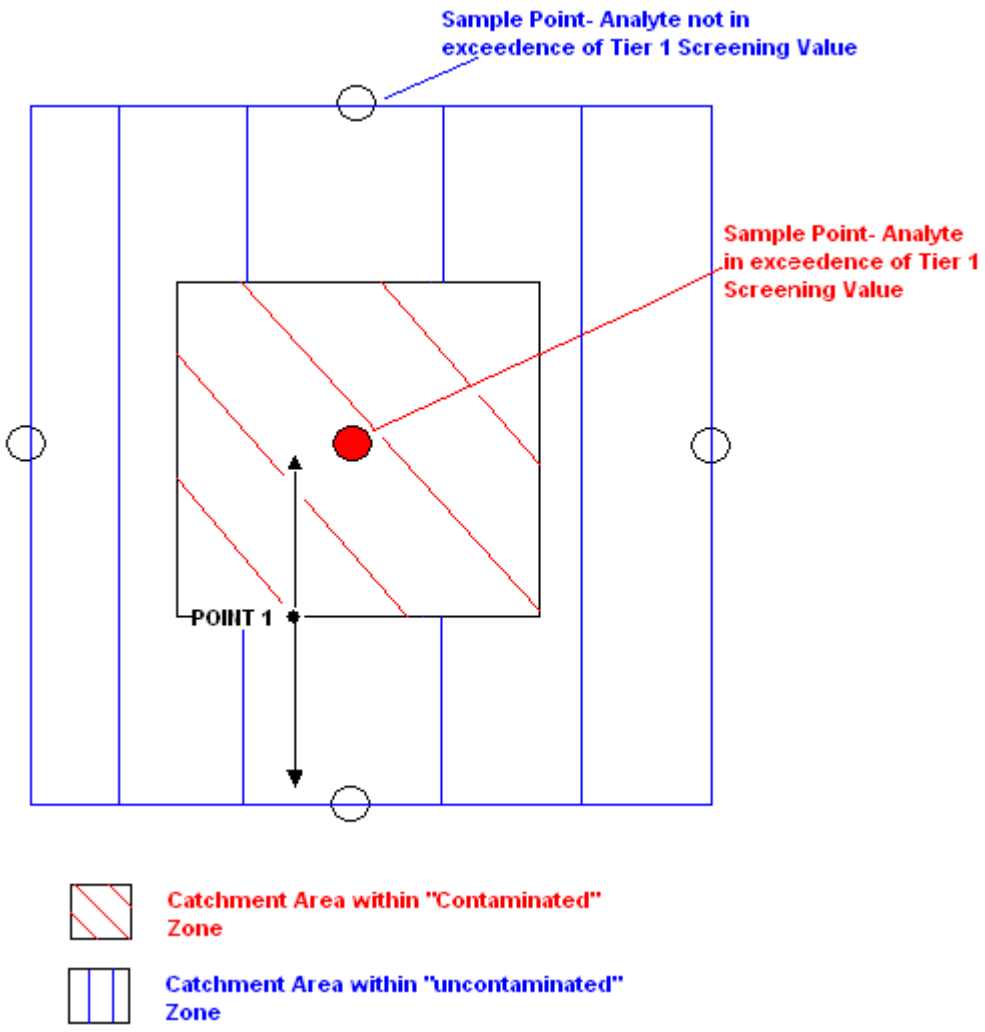
The hydrogeological sequence within Plot A is complex. It has been further compounded by historic site activities, the most prevalent of which has been the deposition of acids into the ground, resulting in voids and channels being created in certain locations, some of which are likely to be in Plot A.

Given the complexity of the geology in Plot A, and the rapid travel times for migration sourced from Plot A, no standard model (e.g. CONSIM, which was used in Plots B and C) was considered to be appropriate. Instead, a mass balance approach was adopted in order to assess potential risks. The principal of the model requires an understanding of the following parameters:

1. Area of inferred "Contaminated" Zone
2. Area of inferred "Uncontaminated " Zone
3. Concentration identified within the source zone

The process for modelling is described below, using arsenic as an example.

Arsenic was measured at a concentration of 40µg/L from soil leachate analysis in TP622A, which exceeds the Marine EQS Screening Value of 25µg/l. In surrounding sample locations, measured concentrations of arsenic were less than the Marine EQS.



The likely contaminated and uncontaminated zones surrounding this sample point have been defined as follows:

- The likely extent of contamination is assumed to extend to the half way distance between the central point (which contains contamination in exceedance of the screening criteria) and the peripheral points (which have been deemed "uncontaminated", based on the screening of the current data set). The halfway distance is defined as "Point 1" on the above diagram. The area contained within the halfway points is assumed to represent the source area (diagonally hatched area).
- The *uncontaminated zone* is defined as the remaining area between the half way distance and the sample points where no exceedances have been measured (vertically hatched area).

The combined catchment areas (i.e. contaminated catchment zone + uncontaminated catchment zone) are then referred to as the "total catchment" for that source.

Precipitation falling on this area is assumed to be uniform, before infiltrating downwards through the Made Ground and Drift. Such infiltration is then assumed to be connected to a solution fissure within the evaporate sequence (thought to be only 3-4m below ground level in Plot A). The solution features and fissures effectively act as drains, collecting all water (contaminated and uncontaminated) within the "total catchment". Given that subsequent transport within the fissure system is rapid with limited dispersion, dilution or degradation, it has conservatively been assumed that an analyte concentration entering the St. Bees Evaporite Formation, directly underneath Plot A, could potentially represent the same concentration that emerges at the coastline. Thus, the calculated concentrations entering the fissures would be compared to the Marine EQS Screening Value.

The calculated concentration entering the fissure network has been estimated by diluting the leachable concentrations from identified contaminated areas by the volume of relatively clean water available from the uncontaminated zone of the catchment. For example, for arsenic:

- Percentage of Contaminated Catchment Infiltrating total catchment = 29%;
- Assumed concentration of arsenic in source zone = 40µg/L.

- Therefore, concentration of arsenic as it enters the fracture = 29% x40µg/L = **12µg/L.**

The calculated concentrations at the compliance point (opening to the fissure system) were compared directly against the Tier 1 screening criteria, in this instance, the simulated arsenic concentration was below the Screening Value (25µg/L), and therefore no longer considered to represent a potential risk.

7.4. Summary of Risks to Controlled Waters

The results of the Stage 3 assessment are summarised in Table 7.2. For simulated contaminant concentrations at the adopted compliance point (in this case, the point directly below the source, where the analyte enters the evaporite sequence) to pose a potentially significant risk to shallow controlled waters, they must be in excess of defined Stage 3 screening criteria (EQS). It can be seen from Table 7.2 that a number of exceedances of the Stage 3 assessment criteria have been identified.

Three areas of the site: an area extending from TP628A to TP630A; the area around TP624A; and the area around WS115 and TP602A will require further invesitgation and assessment to determine whether or not remdial action may be required.

Table 7.2- Controlled Waters Stage 3 Assessment – Summary of Results

Analyte	Measured Concentration (mg/L)	Marine EQS Screening Value (mg/L)	Type of contamination	Location	Infiltration	Estimated catchment area of contamination (m^2)	Estimated catchment area of clean water (m^2)	Total catchment (m^2)	Percentage of Contaminated Catchment Infiltrating Total Catchment	Resultant simulated concentration as analyte enters Evaporites (mg/L)	Marine EQS Screening Value Exceeded
TPH Aliphatic C21-35	73	10	Soil leachate hotspot	TP619A	5.48E-04	6875	6875	10975	17850	38.52%	**Yes**
Fluoranthene	1	0.2	Soil leachate hotspot	TP602A	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Azobenzene	4	0.61119	Soil leachate hotspot	TP606A	5.48E-04	1575	1575	2975	4550	34.62%	**Yes**
Benzo (a) anthracene	6	0.092	Soil leachate hotspot	TP606A	5.48E-04	1575	1575	2975	4550	34.62%	**Yes**
Benzo (a) pyrene	2	0.01	Soil leachate hotspot	TP606A	5.48E-04	1575	1575	2975	4550	34.62%	**Yes**
Carbazole	8	3.36	Soil leachate hotspot	TP606A	5.48E-04	1575	1575	2975	4550	34.62%	No
Fluoranthene	20	0.2	Soil leachate hotspot	TP606A	5.48E-04	1575	1575	2975	4550	34.62%	**Yes**
Phenanthrene	24	10	Soil leachate hotspot	TP606A	5.48E-04	1575	1575	2975	4550	34.62%	No
Sum of 4 PAHs	89	0.1	Soil leachate hotspot	TP606A	5.48E-04	1575	1575	2975	4550	34.62%	**Yes**
Copper	64	5	Soil leachate hotspot	TP608A	5.48E-04	900	900	2700	3600	25.00%	**Yes**
Fluoranthene	2	0.2	Soil leachate hotspot	TP619A	5.48E-04	500	500	725	1225	40.82%	**Yes**
Chromium	16	15	Soil leachate hotspot	TP621A	5.48E-04	1050	1050	2200	3250	32.31%	No
Arsenic	40	25	Soil leachate hotspot	TP622A	5.48E-04	1225	1225	2975	4200	29.17%	No
Copper	34	5	Soil leachate hotspot	TP623A	5.48E-04	437.5	437.5	1312.5	1750	25.00%	**Yes**
Fluoranthene	2	0.2	Soil leachate hotspot	TP623A	5.48E-04	437.5	437.5	1312.5	1750	25.00%	**Yes**
TPH Aliphatic C16-21	22	10	Soil leachate hotspot	TP624A	5.48E-04	1800	1800	1975	3775	47.68%	**Yes**

TPH Aromatic C16-21	38	10	Soil leachate hotspot	TP624A	5.48E-04	1800	1800	1975	3775	47.68%	**Yes**
TPH Aliphatic C21-35	100	10	Soil leachate hotspot	TP624A, 628A, 630A	5.48E-04	6100	6100	3425	9525	64.04%	**Yes**
Copper	39	5	Soil leachate hotspot	TP627A	5.48E-04	600	600	1900	2500	24.00%	**Yes**
Anionic Surfactant	260	200	Soil leachate hotspot	TP630A	5.48E-04	400	400	800	1200	33.33%	No
Benzo (a) anthracene	0.108	0.092	Groundwater hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Benzo (a) pyrene	0.021	0.01	Groundwater hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Cyanide	1670	50	Groundwater hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Fluoranthene	0.7	0.2	Groundwater hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Naphthalene	49	5	Groundwater hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Sulphate	313000	250000	Groundwater hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Thiocyanate	500	50	Groundwater Hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Zinc	83	40	Groundwater hotspot	WS115	5.48E-04	1500	1500	0	1500	100.00%	**Yes**
Zinc	110	40	Groundwater hotspot	WS124	5.48E-04	200	200	325	525	38.10%	**Yes**

8. REFINED POLLUTANT LINKAGE ASSESSMENT

The human health risk assessment for Plot A has indicated that there are no potentially significant risks with regard to a proposed end use of public open space. The controlled waters risk assessment has identified some analytes that pose a theoretical potential risk to the identified receptors. The following section provides a review on the plausibility of the modelled potential pollutant linkages (Section 5.4) as detailed in the Site Remediation Statement.

The controlled waters risk assessment has used a worst case assessment where by each hotspot identified is assessed against meeting the respective EQS on entry into the St Bees Evaporite Formation via theoretical solution features located immediately beneath each hotspot. The assessment assumes rapid flow within the St Bees Evaporite Formation to the Irish Sea, based on the travel times of dye tracing from the vicinity of Plot A to the Byerstead Spring being in the order of 10 hours. The assessment thus makes no allowance for dilution or lateral/vertical attenuation within the unsaturated zone above the St Bees Evaporite Formation, or within the evaporite formation itself. Consequently, a risk is generated where the predicted concentration within the theoretical solution feature beneath the hotspot exceeds the respective EQS.

This model considers the complex hydrogeological regime at the site, and specifically within Plot A, where a number of solution features are thought to exist (solution features are known to exist beyond the plot boundary). However, whilst every effort has been made to develop a reasonably realistic model, there is insufficient detailed information on the precise location and nature of solution features within Plot A, resulting in there being an element of conservatism in the model.

It is considered highly likely that solution features are present within the site, however, it is unlikely that there are as extensive as considered by the model. The model has also assumed that the contaminants are present immediately above the solution features. Physical evidence from the site suggests that an unsaturated zone is present in most areas between the contaminated soils and the theoretical receptor. Consideration has been given to modelling a variety of situations to take this into account, but given the complexity of the geological, and hydrogeological conditions, coupled with the spatial distribution of the modelled hotspots, each model would have its own inherent conservative elements and to remove these would require an enormous amount of additional data gathering. It is doubtful whether such an exercise would add any benefit to the assessment given that the overall picture of the site that has emerged from the investigation is that there is no evidence of widespread contamination.

Whilst the assessment has identified a number of potential risks, we have considered the field and laboratory data in conjunction with the results of the modelling. This has provided a balanced view on the plausibility of pollutant linkages for each identified hotspot.

Table 8.1 – Refined Pollutant Linkage Assessment

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
C1	Surfactant and potentially other analytes within process effluent	The Cathedral (Former Smoothing Chambers and pH balancing area).	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish Sea.	1) Surfactant. No. Source not identified.
							2) Copper. No. Potential linkage identified for copper but not considered significant based on site observations and ground conditions. Furthermore, the soil concentration of copper was 26mg/kg. The maximum soil copper concentration on site was 138mg/kg which produced a leachable concentration of <1ug/l. It is considered unlikely that a pollutant linkage actually exists.
C2	Likely sources of contamination include VOCs, SVOC's and PAH's	The Catalyst Preparation Plant and Fatty Alcohol Plant.	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish Sea.	1) VOCs. No. Source not identified.
							2) SVOCs. No. Source not identified.
							3) PAHs. No. Source not identified.
							4) TPH. Yes. A potential risk has been identified from TPH (Aliphatic 16-21 and 21-35, and Aromatic 16-21) Potential risks associated with TPH from TP628A and TP630A are considered to require further assessment. Additional data is required to delineate the extent of TPH contamination and its potential significance in this area.
							5) Copper. No. Source not identified for copper. The sample that generated high leachable concentration is from dry natural ground.
							6) Zinc. No. Potential linkage identified for zinc but not considered significant. The predicted concentration is only 2ug/l greater than the EQS.
C3	Unknown. Analytes are likely to be detected in the site-specific analytical suite	Workshops and laboratories	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish	1) TPH. Yes- Potential risks associated with TPH from TP624 are considered to require further assessment. Additional data is required to delineate the extent of TPH contamination and its potential significance in this area.

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
	scheduled for this investigation.					Sea.	No further significant pollutant linkages identified.
C4	TPH	Former Wet and Dry Salts Area	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish Sea.	1) TPH. Yes. Potential risks associated with TPH from TP624 are considered to require further assessment. Additional data is required to delineate the extent of TPH contamination and its potential significance in this area.
C5	Polychlorinated biphenyls (PCBs)	Electrical substations	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish Sea.	1) PCBs. No. Source not identified.
							2) Copper. No. Potential linkage identified for copper but not considered significant based on geochemical results. The soil concentration of copper was 12mg/kg. The maximum soil copper concentration on site was 138mg/kg which produced a leachable concentration of <1ug/l. It is considered unlikely that a pollutant linkage actually exists.
							3) PAHs. No. Potential linkage identified for fluoranthene but not considered significant based on the following: The soil concentration of fluoranthene was 0.3mg/kg with no visual or olfactory evidence of contamination. Whilst rockhead was not encountered, the sample was taken from 1.2m and the pit terminated at 3m in natural ground with no evidence of solution features. The pollutant linkage is therefore considered not to exist.
C6	PAHs, petroleum hydrocarbons and heavy metals associated with ash and clinker fill. Potentially other contaminants	Fill Materials	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish Sea.	1) PAHs. Yes. Potential risks associated with PAHs have been identified. These areas require further delineation and assessment.
							2) TPH. Yes. Potential risks associated with TPH have been identified at TP628, TP630 and TP624. These areas require further delineation and assessment.

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
	associated with other materials.						3) Metals. No. Source not identified for metals.
C7	TPH and phosphate	Historic operation and production products	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish Sea.	1) TPH. Yes. Potential risks associated with TPH have been identified at TP628, TP630 and TP624. These areas require further delineation and assessment. 2) Phosphate. Unknown. Screening criteria for phosphate are currently not available based on UK or other legislation. Therefore, the risk assessment cannot determine if a potential risk exists from phosphate.
C8	PAHs, Surfactant, cyanide, sulphate, heavy metals, VOCs, SVOCs, and TPH	Analytes associated with surface runoff from the Tanker Washing Area and other sources in Plot B (Imidazoline, CAPB Plants & Coking works)	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St.Bees Evaporites before rapidly migrating to the Irish Sea.	1) TPH. No. Potential linkage identified for TPH Aliphatic 21-35 but not considered significant based on site observations and ground conditions. There is no visual or olfactory evidence of contamination. Rockhead was encountered and no solution feature was identified. 2) PAHs. West of Plot B (WS115 and TP602A) Yes- A potential risk has been identified from a number of PAHs. Further data gathering and assessment is required to determine whether remedial action is required. 3) Zinc. West of Plot B (WS115 and TP602A) Yes- A potential risk has been identified from zinc. Further data gathering and assessment is required to determine whether remedial action is required. 4) Cyanide. West of Plot B (WS115 and TP602A) Yes- A potential risk has been identified from cyanide. Further data gathering and assessment is required to determine whether remedial action is required. 5) VOCs. No. Source not identified.

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
							6) SVOCs. No. Source not identified.
H1	Surfactant and potentially other analytes within process effluent	The Cathedral (Former Smoothing Chambers and pH balancing area).	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.
H2	Likely sources of contamination include VOCs, SVOC's and PAH's	The Catalyst Preparation Plant and Fatty Alcohol Plant.	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.
H3	Unknown. Analytes are likely to be detected in the site-specific analytical suite scheduled for this investigation.	Workshops and laboratories	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.
H4	TPH	Former Wet and Dry Salts Area	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.
H5	Polychlorinated biphenyls (PCBs)	Electrical substations	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.
H6	PAHs, petroleum hydrocarbons and heavy metals associated with ash and clinker fill. Potentially other contaminants associated with other materials.	Fill Materials	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.
H7	TPH and phosphate	Historic operation and production products	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.

Pollutant Linkage Identifier	Pollutant	Plot A Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters	Does the linkage still exist, and is it still significant based on the recent site investigation and risk assessment? (Y/N)
H8	PAHs, Surfactant, cyanide, sulphate, heavy metals, VOCs, SVOCs, and TPH	Analytes associated with surface runoff from the Tanker Washing Area and other sources in Plot B (Imidazoline, CAPB Plants & Coking works)	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 3 Risk Assessment indicates no significant risk.

9. REMEDIATION ACTIONS

9.1. Summary of remediation actions required relating to Pollutant Linkages Identified specific to Plot A

The majority of potential pollutant linkages have been shown to be not significant, and therefore no remediation actions will be necessary. Some potential linkages have been identified which will require additional investigation in order to assess their significance.

The results of the modelling have indicated that potentially significant risks may be present with regard to controlled waters. Three areas of the site: an area extending from TP628A to TP630A; the area around TP624A; and the area around WS115 and TP602A will require further invesitgation and assessment to determine whether or not remedial action may be required.

The following outline scope of works is recommended to assess the necessity for remedial action.

Area 1- The area in the vicinity of TP628A to TP630A

It is proposed that up to 7 trial pits are advanced to 5mbgl (or bedrock, if shallower) and up to 2 groundwater monitoring wells are installed in the vicinity of TP628A to TP630A. Soil samples shall be taken at approximately 0.5m intervals for subsequent on site headspace analysis. Up to two samples shall be scheduled for analysis from each location; one shallow sample within the made ground and one deeper sample within the underlying strata, where possible). If a significant presence of contamination is detected, additional samples may be scheduled for analysis. Soil analysis shall include total soil and soil leachate tests for the presence of TPH. Groundwater, where present, shall be scheduled for TPH analysis.

Area 2- The area in the vicinity of TP624A

It is proposed that up to 4 trial pits are advanced to 5mbgl (or bedrock, if shallower) and 1 groundwater monitoring well is installed in the vicinity of TP624. Soil samples shall be taken at approximately 0.5m intervals for subsequent on site headspace analysis. Up to two samples shall be scheduled for analysis from each location; one shallow sample within the made ground and one deeper sample within the underlying strata, where possible). If a significant presence of contamination is detected, additional samples may be scheduled for analysis. Soil analysis shall include total soil and soil leachate tests for the presence of TPH. Groundwater, where present, shall be scheduled for TPH analysis.

Area 3- The area in the vicinity of WS115 and TP602A

It is proposed that up to 3 trial pits are advanced to 5mbgl (or bedrock, if shallower) and up to three groundwater monitoring wells are installed in the

vicinity of WS115 andTP602A. Soil samples shall be taken at approximately 0.5m intervals for subsequent on site headspace analysis. Up to two samples shall be scheduled for analysis from each location; one shallow sample within the made ground and one deeper sample within the underlying strata, where possible). If a significant presence of contamination is detected, additional samples may be scheduled for analysis. Soil analysis shall include total soil and soil leachate tests for the presence of PAH's, zinc and cyanide. Groundwater, where present, shall be scheduled for PAHs, zinc and cyanide analysis.

Following completion of the investigation, the Stage 3 risk assessment will be updated and the pollutant linkage assessment refined accordingly.

9.2. Summary of remediation actions required relating to Part IIA Pollutant Linkages for the overall site area

For regulatory purposes it is necessary to explain how each of the pollutant linkages listed by Copeland Borough Council in their determination of the site as statutory Contaminated Land are dealt with. Table 1 below summarises the findings of the investigation and the actions applicable to each pollutant linkage.

Table 9.1 – Summary of Remedial Actions

Copeland Borough Council Pollutant Linkage	***Findings and Remediation Actions for Plot A***
Petroleum Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Yes- Potential risks associated with TPH have been identified at TP628, TP630 and TP624. These areas require further delineation and assessment to determine whether remedial action is required (included in the Scope in Section 9.1).*
Poly Aromatic Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Yes- A potential risk has been identified from a number of PAHs in the vicinity of WS115 and TP602A. Further data gathering and assessment is needed to determine whether remedial action is required (included in the Scope in Section 9.1).*
Surfactants in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Phosphates in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Screening criteria for phosphate are currently not available based on UK or other legislation. Therefore, the risk assessment cannot determine if a potential risk exists from phosphate.*
Arsenic in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Boron in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*

Copeland Borough Council Pollutant Linkage	***Findings and Remediation Actions for Plot A***
Cadmium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	No significant pollutant linkage (no source).
Chromium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	No significant pollutant linkage (no source).
Copper in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkages identified for copper (potential linkage identified but not considered significant based on site observations, ground conditions, and geochemical results).*
Lead in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	No significant pollutant linkage (no source).
Mercury in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	No significant pollutant linkage (no source).
Nickel in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Selenium in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*
Zinc in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*Yes- A potential risk has been identified from zinc in the vicinity of WS115 and TP602A. Further data gathering and assessment is required to determine whether remedial action is required (included in the Scope in Section 9.1).*
VOCs/ **SVOCs** in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	*No significant pollutant linkage (no source).*

TABLES

FIGURES

PHOTOGRAPHS

Appendix A - Proposal For Site Works

Appendix B - Field Methodology

Appendix C - Borehole & Trial Pit Logs

Appendix D - Analytical Schedules, Tabulated Analytical Results and Laboratory Certificates

Appendix E - Human Health Detailed Quantitative Risk Assessment

Appendix F - URS GAC Advice Note

Appendix G - Controlled Waters Detailed Quantitative Risk Assessment

Appendix H - Model Inputs