Remediation Statement
Appendix G

Plot E Soil and Groundwater Investigation, Former Albright and Wilson Works, Whitehaven, Cumbria

17th May 2007
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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 within an area of land identified as "Plot E" - 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 E comprises an area of the site most recently occupied by areas of ancillary services known to include offices, engineering workshops, research buildings, garages, and an area of acid storage tanks and drums. These above ground structures have been demolished and the area is now open ground, with the exception of the security lodge next to the south eastern site entrance.

A trial pitting exercise was undertaken which also allowed detailed visual assessment of the subsurface. A total of 26no. trial pits were excavated. Additionally, four groundwater monitoring wells were installed using the window sampling technique. Soil and groundwater samples were collected and scheduled for a suite of analytes.

The ground conditions observed comprised Made Ground, overlying natural clay deposits subsequently underlain by rock head. Ground cover over the majority of the Plot comprised concrete slab hardstanding with the remaining ground cover comprising topsoil. Made Ground typically comprised a heterogeneous mix of building rubble, ash and clinker. The thickness of these horizons, and depth at which they were encountered varied across the area. The natural clay deposits were typically observed at the majority of locations advanced in Plot E. Where drift deposits were not present, made ground extended to bedrock (typically less than five meters below ground level). Where bedrock was encountered it was identified as a limestone or sandstone, interpreted as part of the St Bees Evaporite Formation. Groundwater was not encountered within Plot E during this investigation. The key receptor identified for the controlled waters assessment was the Irish Sea, located approximately 1.3km south west of the site. A Stage 2 generic screening exercise was completed on both historical and new data collected from within the Plot E boundary. The screening exercise of the site data against the controlled waters generic criteria (Marine Environmental Quality Standards) identified exceedances of trichloroethene in soil, and carbazole, chromium, copper, fluoranthene, and zinc in soil leachate.

A Stage 3 Controlled Waters Risk Assessment was then performed. This site specific assessment modelled groundwater flow towards the coastline through an onsite dilution model (Stage 3A) and a further offsite dilution model (Stage 3B). The Stage 3 Risk Assessment identified that there were no significant risks associated with the contaminants identified at Stage 2.

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.

Furthermore, based on the site data obtained to date, no significant pollutant linkages exist with respect to Controlled Waters.

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 E.

1. INTRODUCTION

1.1. General Introduction

URS was commissioned by Rhodia on 16th February 2007 to undertake an intrusive soil and groundwater investigation at the former Albright & Wilson site in Whitehaven, Cumbria as detailed in URS Proposal 1941NG1111 (dated 19th February 2007). This work was requested by Rhodia UK Limited (Rhodia) at a meeting with URS Corporation Ltd (URS) on 5th February 2007.

This project focuses on the soil and groundwater conditions within an area of land identified as "Plot E" within the boundary of the former Rhodia site. Plot E 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 E) 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 E 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 has 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 2007.

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 with a minimum of site preparation expected (such as the removal of protruding trip hazards).

The scope of previous investigations across the Rhodia site were developed in relation to phosphate and surfactant manufacturing processes and other historic activities comprising: coal and anhydrite mining; coke production: tar distillation; and firelighter manufacture. A

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

site wide 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 environmental investigations previously undertaken. 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 E. Further to this requirement, URS have reported the findings of the Plot E 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.

The proposal that defines the scope for the Plot E investigation (REF: 1941NG1111/MARP0001 (dated 19th February 2007) is included in Appendix A. The proposal comprises background information, project objectives, scope, approach and rationale on which the investigation has been based.

This proposal was submitted to the Environment Agency on 2nd March 2007 for comment. To date, URS has not received a response.

1.3. Site Investigation Area - Plot E

Plot E comprises an area of the site most recently occupied by areas of ancillary services known to include offices, engineering workshops, research buildings, garages, an area of acid storage tanks and drums, and part of the former cement works. 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 (with the exception of the gatehouse at the south eastern site entrance).

The area of interest has been identified as Plot E (Figure 2). The former layout of the site is presented on Figure 3. The plot is approximately triangular in shape and lies in the southeast corner of the Rhodia site. The estimated area of the plot is 2.8hectares.

1.4. Existing Site Investigation Information

1.4.1. Introduction

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

- URS investigation on behalf of Rhodia, ref; 44557-021, during 2001. 2No. shallow soil borings (WS153 and WS163) advanced as part of site wide assessment;

- ERM investigation on behalf of Huntsman ref; PPC Phase 1B/2 Site Condition Report during 2003. 2No. shallow soil borings (SB23 and SB20); and

- URS investigation on behalf of Rhodia, ref; 44319904, during 2006. Continued ongoing monitoring of 6 deep groundwater wells (on the Rhodia site, but not within the boundary of Plot E), 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.

Two shallow soil borings (WS153 and WS163) were advanced in Plot E as part of site wide assessment. One soil boring was not installed as a groundwater monitoring well (WS153). Analysis in soils comprised TPH, VOCs, SVOCs, asbestos, phosphates and pH.

In WS153, a black staining in the Made Ground was noted, along with a slight odour. Slightly elevated concentrations of TPH were identified in the soil analytical results at WS153. No visual or olfactory evidence was noted in WS163. Soil analytical results revealed relatively elevated concentrations of selected Polycyclic Aromatic Hydrocarbons (PAH's) in WS163.

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 E.

No assessment was made for controlled waters. It was considered that further work was required to determine the extent of impact to receptors.

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.

Two shallow soil borings (SB20 and SB23) were advanced in Plot E as part of site wide assessment. One soil boring was not installed as a groundwater monitoring well (SB23), and the installed well at SB20 was found to be dry. Analysis in soils comprised TPH, surfactants, pH and metals.

In SB20, a sewage and hydrocarbon odour was noted in the Made Ground. Elevated concentrations of surfactants and TPH were identified in the soil analytical results. No visual or olfactory evidence was noted in SB23. Soil analytical results revealed slightly elevated concentrations of TPH in SB23.

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 has been to provide long term monitoring of the geochemistry of the deep groundwater underlying the Whitehaven site and local surface waters. The aim of this project has been 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 considered to be representative of the potential receptors in the underling geological formations and surface water features fed either by site runoff of issue from the local geology. These include: The Byerstead Spring; groundwater in the Whitehaven Sandstone; groundwater in the St Bees Evaporites, Groundwater in the St Bees Shales; Groundwater in the Middle Coal Measures; Sandwith Beck; and Bellhouse Gill.

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 six 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.

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 E) 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 E".

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 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 start of works. Details of the investigation design and rationale are presented in the proposal. To date URS has not received a response from the Environment Agency.

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 E occupies an area of approximately 28,000m^2 (2.8 hectares) and is located towards the southeast corner of the site.

Plot E slopes from the eastern boundary down to the former cement tank area near the western boundary of the plot.

3.2. Plot E Current and Historical Operations

Historical activities undertaken within the Plot E have included ancillary services known to include offices, engineering workshops, research buildings, garages, an area of former acid storage tanks and drums, and part of the cement works. These above ground structures have been demolished and the area is now open ground, with the exception of the security lodge next to the south eastern site entrance.

Much of the ground remains covered by concrete hardstanding, relating to floor slabs from the former building foundations, and hardstanding surrounding former process areas. Remaining ground cover is topsoil.

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

- St Bees Evaporite Formation (late Permian): present as either pink grey crystalline limestone or yellow sandstone at a number of locations across Plot E. This formation is classified as a non aquifer by the Environment Agency. Beyond the northwestern boundary of Plot E, these lithologies may have suffered dissolution through historical losses of acid to ground. The lateral or vertical extent of the potential solution features in this area is not known.

- 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 or previous investigations. 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. Thin coal seams, marls and limestone present locally. 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 E or within its immediate vicinity. However, the Plot E area is serviced by a storm water drainage system which was designed to drain the water within Plot E 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 E will be left in its current state.

Once the drains are no longer working it is assumed that there will be a greater component of overland flow corresponding to the natural watershed which drains from Plot E westwards towards the surface water attenuation ponds (north and south pond), which are located in the south western corner of the site. These channel surface waters into a small stream at the southern end of the site (Sandwith Beck). A discussion on the migration of water from Plot E is presented in Section 4.3.

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 E area:

- *Human beings*: Given that the proposed end-use for the Plot E 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 Evaporite Formation is likely to receive infiltrating rainwater in Plot E. Dye testing has demonstrated that groundwater migrates rapidly through enhanced conduits within the evaporite formation (and is likely to emerge at the Byerstead Spring) towards the coastline, which is situated approximately 1.3km to the west of the site.

3.5. Potential Current and Historical Sources of Contamination

Based on observations and review work undertaken during the Phase II investigation, 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:

- Cement Works. Spillages, leaks and releases to ground of raw and finished products. Contaminants of concern are considered to include heavy metals, petroleum hydrocarbons, phosphates and sulphates;

- Garages. Spillages and leaks to ground of hydrocarbon oils. Likely contaminants include petroleum hydrocarbons, VOCs and SVOCs;

- Historical laboratories. Leaks, spills or releases to ground of acids, alcohols and other potential materials. Contaminants of concern are considered to include surfactants, heavy Metals, phosphates, sulphates, petroleum hydrocarbons and nitrates;

- Acid Storage. Leaks, spills or releases to ground of acids. Contaminants of concern are considered to include phosphates, sulphates, nitrates, ammonia and heavy metals; and,

- Concentrations of contaminants within imported materials used for ground raising and reclamation (e.g. ash and clinker fill) which may contain VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates.

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 26 trial pits and four boreholes (which were installed as monitoring wells) advanced across Plot E during this investigation.

No patterns of ground conditions have emerged to facilitate the discussion of Plot E 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 E 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- Top of Stratum (mbgl)	Maximum Thickness (m)
Made Ground	Reinforced concrete hardstanding	0 – 0.2	0.3
	Hardcore	0.1 – 0.2	0.5
	Black, brown or grey sand and gravel with many man made components (fill material)	0.2 –0.4	0.2
	Brown - grey or black - brown silt and clay with occasional gravel and cobbles	0.4 – 0.7	0.5
Natural Ground	Glacial Till Deposits typically comprising firm light brown orange or red brown slightly sandy clay with occasional gravel, cobbles and lenses of sand.	0.5 - 2	3.6
	Occasional Glacial Till Deposits of very soft black mottled brown organic clay.	1.8 - 2.8	1.4
Bedrock	St Bees Evaporite Formation: typically comprising pale grey – pink fine grained, weathered, Limestone.	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 0.15m at TP725E and TP726E to 1m at TP735E and TP736E, with no obvious spatial correlation.

Reinforced concrete hardstanding (0.1m – 0.2m thick) was encountered in the areas of former production / storage tanks / foundations at the following locations: TP720E, TP726E, TP727E, TP728E, TP730E, TP732E, TP735E, TP736E, TP737E, TP738E, TP742E, TP743E, TP745E, TP746E, TP747E, TP748E, TP749E and WS734E. 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 black, brown or grey sand and gravel with occasional brick and/or concrete. At TP728E, TP731E, TP733E, TP739E, TP743E, TP745E, TP747E, TP750E, WS721E and WS734E the fill also contained man made components such as metal, wood, plastic, glass, ceramic, slag, ash and clinker. This is thought to be associated with the backfilling and levelling operations in the western area of Plot E; and

- Reworked drift: Typically Brown - grey or black - brown silt and clay with occasional gravel and cobbles.

4.2.2. Natural Ground

Glacial Till (Drift/ Boulder Clay)

Drift deposits were encountered over most of Plot E with a maximum proven thickness of 3.6m observed in TP723E and WS721E. The thickest drift deposits are located on a grassed area on the western side of Plot E.

No drift was present at TP736E where the Made Ground was observed to lie directly on top of bedrock.

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

- Firm orange brown slightly sandy clay with occasional gravel. This was found at the majority of locations across Plot E;

- Firm red - brown clay with occasional gravel. This was found intermittently across Plot E; and

- Very soft black mottled brown organic clay. This is found across the central part of Plot E below the firm brown orange slightly sandy clay.

Bedrock

Bedrock was encountered at 27 locations in Plot E between 1m bgl and 3.8m bgl. The lithology observed was as follows:

- Pale grey – pink fine-grained weathered limestone was observed at 23 locations.
- Beige fined grained weathered sandstone was observed at four locations in the northwest corner of Plot E.
- This unit is considered to represent the St Bees Evaporite Formation. The vertical and lateral extent of this unit is illustrated on Figures 6 and 7.

4.3. Groundwater Conditions

Few groundwater strikes were observed during the excavation of the trial pits in Plot E, with groundwater observed at TP720E, TP736E, and TP739E in the made ground, and TP743E in the drift deposits. Two wells were installed in Plot E (WS721E and WS740E), and screened within the drift deposits, no groundwater was encountered during the subsequent groundwater monitoring round.

It is thought that no continuous shallow groundwater exists in Plot E. This is due to the presence of clay deposits of less than 3.6m, combined with a presence of shallow bedrock (the St. Bees Evaporites) in this area. Rockhead has been proven as shallow as 1m in TP736E and TP738E. It is considered that this combination of thin drift and shallow bedrock means that infiltrating surface water within Plot E is not likely to be retained within the drift, but migrate vertically into the bedrock. Groundwater that is present within shallow horizons is likely to be in the made ground, perched on top of the drift.

The potential pathways for water migrating from Plot E to surface water receptors is considered to be through either the (potentially limited) movement of groundwater within shallow drift/made ground, or movement of water across the ground surface. Groundwater or surface water from Plot E is likely to follow dip and flow westwards towards north pond, south pond, and Sandwith Beck, located 200, 225, and 325m away (from Plot E) respectively.

The potential for Plot E derived contaminants to migrate into north or south ponds (and subsequently Sandwith Beck) is considered to be unlikely; since

- the surface water is likely to infiltrate to ground prior to reaching the ponds.
- shallow groundwater that may be present between Plot E and the ponds is likely to migrate vertically into the shallow bedrock (St. Bees Evaporites).

The potential pathway for the migration of shallow groundwater and leachate into the St. Bees Evaporites (and subsequent flow to the coastline) is considered to be a potentially significant source-pathway-receptor linkage.

The St. Bees Evaporites have undergone dissolution in the vicinity of Plot E due to the loss of acids directly to ground in areas of former acid storage to the north of Plot E. It is considered likely that this may have resulted in the creation of solution features/voids which may also be present beneath the northern most parts of Plot E. It is also considered that the dominant groundwater transport mechanism within this unit is likely to be through channel flow within these voids.

As groundwater migrates within the St. Bees Evaporite Formation towards the site boundary, it will encounter a north-south trending fault. At the fault 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 the fault plane itself, within old mine adits or continue to be within the partially dissolved St Bees Evaporite Formation.

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.

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
TP720E	NVO	NVO	NVO
TP722E	NVO	Possible staining	-
TP723E	NVO	NVO	NVO
TP724E	NVO	NVO	NVO
TP725E	NVO	NVO	NVO
TP726E	NVO	NVO	NVO
TP727E	NVO	NVO	NVO
TP728E	NVO	NVO	NVO
TP730E	NVO	NVO	NVO
TP731E	NVO	NVO	NVO
TP732E	NVO	NVO	NVO
TP733E	NVO	NVO	NVO
TP735E	Slight hydrocarbon odour	Strong hydrocarbon odour	NVO
TP736E	NVO	NVO	NVO

Location	Made Ground	Drift	Bedrock
TP737E	NVO	NVO	NVO
TP738E	NVO	NVO	NVO
TP739E	NVO	NVO	NVO
TP741E	NVO	NVO	NVO
TP742E	NVO	NVO	NVO
TP743E	NVO	NVO	NVO
TP745E	NVO	NVO	NVO
TP746E	NVO	NVO	NVO
TP747E	NVO	NVO	-
TP748E	NVO	NVO	-
TP749E	NVO	NVO	-
TP750E	NVO	NVO	-
WS721E	PID 20.8ppm at 0.3m	PID 19.5ppm at 2m	NVO
WS729E	NVO	NVO	NVO
WS734E	White staining	NVO	-
WS740E	NVO	NVO	-

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 E. The contamination encountered:

- Elevated PID readings were noted in the Made Ground and drift geology in WS721E located in an area of open ground. No visual or olfactory evidence of contamination was recorded.

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:

- Petrol odour noted in both Made Ground and the drift geology in TP735E. This is located by the weigh bridge; and
- Brown staining was observed in the drift geology at TP722E located on an area of open ground. White chemical staining was observed in the Made Ground at TP734E located by the weigh bridge.

No visual or olfactory evidence of contamination

Trial pits with visual or olfactory evidence of contamination include TP722E, TP735E, WS721E and WS734E. All remaining locations revealed no visual or olfactory evidence

4.5. Geochemical Results

The analytical schedules and results of chemical analyses are provided in detail in Tables 1 to 13 included in Appendix D of 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)

38 soil samples were scheduled for VOC analysis. Of the samples analysed, only 1 (TP745E) had reported a concentration of trichloroethene (TCE) greater that the laboratory method detection limit (MDL).

VOC analysis was not carried out on soil leachates as the leaching methodology is unsuitable for VOCs, i.e. it allows VOCs to escape during the leaching process and thus results obtained would be unrealistically low.

Metals

22 soil samples and 2 water samples were scheduled for metals analysis and 36 were scheduled for NRA leachate preparation and analysis. Elevated concentrations are summarised in the Tables 4.3 and 4.4 below:

Table 4.3 – 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	4	50	8	Drift (3), Made Ground (5)
Boron	-	5.2	1	Made Ground
Chromium	4.1	49	8	Made Ground (3), Drift (5)
Copper	2.4	31	9	Made Ground (5), Drift (4)
Lead	6	370	4	Made Ground (3), Drift (1)
Nickel	9.9	270	4	Made Ground (1) Drift (3)
Selenium	41	64	2	Drift
Zinc	23	280	9	Made Ground (3), Drift (6)

Table 4.4 – 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	8	12	Made Ground (8), Drift (4)
Boron	11	89	10	Made Ground (6), Drift (4)
Chromium	2	25	7	Made Ground (4), Drift (3)
Copper	7	30	11	Made Ground (9), Drift (2)
Lead	2	4	5	Made Ground (3), Drift (2)
Nickel	2	11	4	Made Ground (3), Drift (1)
Selenium	3	7	10	Made Ground (7), Drift (3)
Zinc	8	55	24	Made Ground (9), Drift (15)

No obvious spatial correlation of elevated metal concentrations in soils or leachable metal concentrations exists over Plot E. The majority of elevated concentrations of metals were reported in samples collected from within the Made Ground.

Anionic Surfactants

Concentrations of surfactants above the MDL were reported in six of the 58 samples submitted for NRA leachate preparation and analysis. The minimum reported concentration was 60µg/l in Made Ground at 0.5m in TP749E, and the maximum reported concentration was 860µg/l in Drift at 0.7m in TP720E.

Semi Volatile Organic Compounds (SVOCs)

43 soil samples were scheduled for SVOC analysis. Elevated concentrations are summarised in Table 4.5 below.

Table 4.5 – 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	-	0.18	2	Made Ground
Acenaphthene	0.14	0.51	2	Made Ground
Anthracene	0.16	0.65	3	Made Ground
Benzo(a)anthracene	0.14	2.0	6	Made Ground (5), Drift (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
Benzo(a)pyrene	0.15	1.8	5	Made Ground (4), Drift (1)
Benzo(b)fluoranthene	0.15	2.3	5	Made Ground (4), Drift (1)
Benzo(g,h,i)perylene	0.2	1.1	4	Made Ground
Benzo(k)fluoranthene	0.13	1.0	3	Made Ground
Carbazole	0.2	0.31	2	Made Ground
Chrysene	0.14	1.5	5	Made Ground (4), Drift (1)
Dibenz(a,h)anthracene	0.14	0.32	2	Made Ground
Dibenzofuran	0.12	0.49	2	Made Ground
Fluoranthene	0.13	4.7	5	Made Ground (4), Drift (1)
Indeno(1,2,3cd)pyrene	0.14	1.0	3	Made Ground
Naphthalene	-	0.49	1	Made Ground
Phenanthrene	0.13	4.2	5	Made Ground (54), Drift (1)
Pyrene	0.19	4.1	5	Made Ground (4), Drift (1)

The majority of these detections were in the polycyclic aromatic hydrocarbon (PAH) group of analytes in samples collected from Made Ground at 0.6m in TP731E, 0.3m in TP742E, 0.2m in TP748E, 0.5m in TP749E, 0.6m in TP750E and in drift in 1.0m in TP728m. These locations are clustered close to the centre of Plot E, near the old garage and oil/petrol tap.

Four of the 31 samples submitted for NRA leachate analysis and preparation reported concentrations of SVOCs above the MDL. Elevated concentrations are summarised in Table 4.6 below. The majority of these samples were also taken in the Made Ground in TP742E at 0.3m, TP748E at 0.2m and TP749E at 0.3m, with one from drift at 0.8m in WS734E, and are clustered in the same area as where exceedances were seen in soil samples analysed for SVOCs.

Table 4.6 – Elevated Concentrations of SVOCs (Leachate)

SVOC in Leachate	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Acenaphthene	-	2	2	Made Ground
Carbazole	2	7	3	Made Ground
Dibenzofuran	-	2	2	Made Ground
Diethylphthalate	-	13	1	Drift
Di-N-Butyphthalate	-	2	1	Made Ground
Fluorene	-	2	1	Made Ground
Naphthalene	5	8	2	Made Ground
Phenanthrene	4	6	3	Made Ground
Phenol	3	14	2	Made Ground

Total Petroleum Hydrocarbons (TPH)

35 samples were submitted for TPH analysis. Elevated concentrations are summarised in Table 4.7 below.

Table 4.7 – Elevated Concentrations of TPH (Soil)

TPH in Soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Aromatic C12-C16	1.1	2.5	5	Made Ground (2), Drift (3)
Aromatic C16-C21	0.21	3.6	3	Made Ground (1), Drift (2)
Aromatic C21-C35	0.13	82	3	Made Ground (2), Drift (1)
Total Aromatic	0.49	86	4	Made Ground (1), Drift (3)
Aliphatic C12-C16	0.24	5.5	3	Made Ground (1), Drift (2)
Aliphatic C12-C16	0.65	25	4	Made Ground (3), Drift (1)

TPH in Soil	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Aliphatic C12-C16	0.44	130	3	Made Ground
Total Aliphatic	7.2	130	3	Made Ground

TPH was reported at concentrations exceeding the MDL in ten of these samples. For the samples with TPH-CWG analysis, elevated concentrations were reported in Drift at 1.1m in WS740E, 1.5m in WS721E, 1.8m in TP737E and 2.6m in TP731E, and in Made Ground at 0.3m in TP746E, 0.3m in TP742E, 0.3m in TP741E and 0.35m in TP736E, 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 4547mg/kg from 2.1m at ERM SB20. There does not appear to be a spatial correlation between these locations. Of the 45 samples submitted for NRA leachate analysis and preparation there were no reported concentrations of TPH above the MDL.

Additional Analytes

Thirteen samples were scheduled for Polychlorinated Biphenyls (PCB) soil analysis and eight for leachate analysis. Concentrations of PCBs in soil were reported above the MDL in two samples, the most elevated being 0.035mg/kg in Drift at 1.2m in WS729E.

Further additional analytes include: acid soluble sulphide (10 soil, 5 leachate), ammoniacal nitrogen (21 soil analyses), total cyanide (20 soil, 30 leachate), nitrate (21 soil), phosphate (20 soil, 43 leachate), sulphate (20 soil, 44 leachate), total organic nitrogen (9 leachate) and total organic carbon (2 soil). Tables 4.8 and 4.9 summarise the elevated concentrations reported for these analytes.

Table 4.8 – Elevated Concentrations of Additional Analytes (Soils)

Analyte	Minimum reported concentration (mg/kg)	Maximum reported concentration (mg/kg)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Ammoniacal Nitrogen	-	43	1	Drift
Nitrate (Soluble) as NO3	2	69	6	Made Ground (2). Drift (4)
Phosphate	-	2	1	Made Ground
Total Organic Carbon	-	0.6	1	Drift
Total Sulphate	270	17000	5	Made Ground (4), Drift (1)

Table 4.9 – Elevated Concentrations of Additional Analytes (Leachate)

Analyte	Minimum reported concentration (µg/l)	Maximum reported concentration (µg/l)	Number of samples with elevated concentrations	Strata elevated concentrations located in
Phosphate	90	1400	8	Made Ground (3), Drift (5)
Sulphate	4000	360000	9	Made Ground (5), Drift (4)
Total Organic Nitrogen	2000	3000	3	Made Ground (1), Drift (2)

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 distributed evenly across Plot E, instead forming isolated pockets across the area.

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
Cement Works	heavy metals, petroleum hydrocarbons, phosphates and sulphates;
Garages	petroleum hydrocarbons, VOCs and SVOCs
Historical laboratories	surfactants, heavy metals, phosphates, sulphates, petroleum hydrocarbons and nitrates;
Acid storage tanks	phosphates, sulphates, nitrates, ammonia and heavy metals
Made Ground	VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates

In their determination of the site as "contaminated land", Copeland Borough Council listed a number of 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.

5.1.2. 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, 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).

Pathway	Pathway characteristics
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.

5.2. 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.

Sandwith Beck, a stream located approximately 325m to the south west of Plot E has not been considered as a likely receptor for waters derived from Plot E. This discussion is presented in Section 4.3.

5.3. Pollutant Linkages

For a significant 'pollutant linkage' to exist, a *source* of contamination (e.g. a leaking storage tank) must be connected 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.

5.3.1. 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 E Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
C1	Likely sources of contamination from the cement works include heavy metals, petroleum hydrocarbons, phosphates and sulphates;	Cement 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.
C2	Likely substances from the garages include petroleum hydrocarbons, VOCs and SVOCs	Garages	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	Likely substances from laboratories include surfactants, heavy metals, phosphates, sulphates, petroleum hydrocarbons and nitrates	Historical 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	Likely contamination associated with acid storage tanks includes phosphates, sulphates, nitrates, ammonia and heavy metals	Acid storage tanks	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	Substances associated with fill material VOCs, SVOCs, heavy metals, petroleum	Made Ground comprising ash and clinker and other diffuse	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St Bees Evaporite Formation before rapidly migrating to the Irish Sea.

Pollutant Linkage Identifier	Pollutant	Plot E Source location	Pathway	Main Receptor	Subsequent Receptors	Description of Harm/Pollution of Controlled Waters
	hydrocarbons, ammonium, nitrates, cyanide and sulphates	sources				

5.3.2. 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 E. 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 E Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
H1	Likely sources of contamination from the cement works include heavy metals, petroleum hydrocarbons, phosphates and sulphates;	Cement 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
H2	Likely substances from the garages include petroleum hydrocarbons, VOCs and SVOCs	Garages	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	Likely substances from laboratories include surfactants, heavy metals, phosphates,	Historical 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

Pollutant Linkage Identifier	Pollutant	Plot E Source location	Pathway	Main Receptor	Additional Receptors	Description of Harm/Pollution of Controlled Waters
	sulphates, petroleum hydrocarbons and nitrates					
H4	Substances associated with acid include phosphates, sulphates, nitrates, ammonia and heavy metals	Acid storage tanks	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	Substances associated with fill material VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates	Made Ground comprising ash and clinker and other diffuse sources	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 E as detected by investigations undertaken at the site.

6.2. Stage 2 Assessment

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

Soil

- **Metals** – arsenic, nickel; and
- **PAH** – benzo(a)pyrene, benzo(a)anthracene, benzo(a)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(ghi)perylene.

6.3. Stage 2 Risk Evaluation

Prior to assessing the exceedances at Stage 3 (DQRA) further review has been made with regard to the significance of the contamination in the context of the proposed public open space end use of the site. This has comprised further assessment of the plausibility of the identified pollutant linkages and has taken into consideration factors such as the nature, extent and location of the detected contamination (i.e. the size of the source), the likely pathways for receptor exposure, receptor behaviour, condition and circumstances of the land and other factors which may prevent or enhance potential exposure.

Therefore for the exceedances identified at Stage 2 further assessment has been completed and the significance for potential harm identified. Where appropriate, assessment has also included the use of simple statistical tests in accordance with CLR7 to derive averaging concentrations for the area to which a receptor could potentially be exposed while occupying the site.

It should also be noted that the generic assessment criteria for the Stage 2 assessment are based upon a conceptual exposure model[2] which is highly conservative for the 'right to roam' end use and is designed to be suitably protective of future site users.

The evaluation of each of the Stage 2 potential sources is presented in Tables E4 and E5 in Appendix E.

6.4. Summary of Risks to Human Health

In summary, it is considered that there are no contaminant concentrations detected in this area of the site which are considered to represent a significant possibility of significant harm to the identified receptors based on the proposed end-use of the site.

Therefore, should the current condition and layout of Plot E be maintained, it is considered that potentially significant risks to human health would be unlikely for a public open space scenario. Plot E 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 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.

[2] Residential without gardens

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 are summarised below.

7.2. Stage 2 Assessment

A Stage 2 generic quantitative screening risk assessment was undertaken that incorporated the new March 2007 data, and compared measured concentrations to the generic screening values for the protection of Controlled Waters (in this case, Marine EQS values).

The results are summarised in Table 7.1.

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

Soil	Soil Leachate	Shallow Groundwater
	chromium	
	copper	
	zinc	
trichloroethene		
	carbazole	
	fluoranthene	
	naphthalene	

Each of the determinands whose concentrations exceeded their respective Stage 2 criterion were then assessed to determine whether the potential risk they posed was realistic. As such, the geochemical profile, geological horizons, water strikes, and field observations of contamination were all considered. For example, consider an exceedance from a sample taken in the made ground. If the underlying geology was several meters of dry low permeability clay, and a deep sample from within or below this clay did not detect this analyte, then this risk may be deemed not significant, given the pathway into the underlying evaporites (which forms part of the pollutant linkage) was not realistic. Therefore this analyte may have been discounted and not taken to Stage 3. Conversely, if contamination was found in granular wet made ground, that sat directly onto bedrock, this will have been considered potentially significant, and taken to Stage 3.

If a pollutant linkage was deemed potentially significant or could not be discounted (due to insufficient geochemical and geological evidence) they were taken forward to Stage 3, the detailed quantitative risk assessment.

The evaluation of each of the Stage 2 potential sources is presented in Section 3.5 in Appendix G. The substances that went to 3A modelling were chromium, zinc, fluoranthene, carbazole and naphthalene.

7.3. Stage 3 Assessment

The hydrogeological sequence onsite 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 E.

Given the complexity of the geology in Plot E and the rapid travel times for migration sourced from Plot E, 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. This approach is described in detail, with examples, in Appendix G, a brief overview is given here.

Stage 3a calculates the concentrations of contaminants entering the underlying geology based on contaminated groundwater from the source zone mixing with surrounding clean groundwater prior to entry into the St. Bees Evaporite sequence. This mixing results in dilution of the contaminant concentrations. The diluted concentrations are then compared directly against their respective screening criteria. If the contaminant concentrations have been diluted below their respective Marine EQS values, they are no longer considered to represent a significant risk to controlled waters. However, if they are still in exceedance, they will be entered into the Stage 3B model discussed in Section 7.4.

7.3.1. Summary of Identified Exceedances (Stage 3a)

Only one compound was found to be in exceedance of its EQS at the end of the Stage 3a assessment, this was fluoranthene detected at a depth of 0.5m in TP749E.

7.4. Stage 3B Assessment

The current model builds upon the previous modelling. Specifically, it recognises the potential for an *offsite* dilution of site derived waters. This is due to the infiltration of clean water through the St. Bees Sandstone (located down hydraulic gradient), and its subsequent vertical movement into the underlying units, which includes the St. Bees Evaporites, where the conduits containing the site derived waters are thought to exist. As the clean waters enter the conduits, they dilute the site derived waters.

The model takes the Stage 3a assessment to the next step (through generating a second dilution), by considering rainfall, surface area of infiltration into the St. Bees Sandstone, likely infiltration rates through the geological strata, and combines this with a mass of contamination (a concentration).

As the concentration reduces after this second dilution, the resultant analyte concentrations are then compared to their respective screening criteria.

The results of the Stage 3b assessment are summarised in Section 7.4.1 Further details regarding the methodology, limitations and assumptions are included in Appendix G.

7.4.1. Summary of Identified Exceedances (Stage 3b)

For simulated contaminant concentrations at the adopted compliance point (in this case, the point at which the groundwater rises as a spring on the beach, the Byerstead Spring) to pose a potentially significant risk to controlled waters, they must be in excess of defined screening criteria. The results of the Stage 3b assessment are presented in Table G8 (Appendix G). The analyte identified at Stage 3a (fluoranthene) as potentially posing a risk, has been diluted to a concentration below its EQS before reaching the compliance point and thus is not considered to present a risk to the receptor.

7.5. Summary of Risks to Controlled Waters

The results of the modelling have indicated that there are no potentially significant risks present with regard to controlled waters based on the data gathered from Plot E.

8. REFINED POLLUTANT LINKAGE ASSESSMENT

The human health risk assessment for Plot E 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 indicated that there are no potentially significant risks to the identified controlled waters receptor.

Table 8.1 details the pollutant linkage assessment for Plot E.

Table 8.1 – Refined Pollutant Linkage Assessment

Pollutant Linkage Identifier	Pollutant	Plot E 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	Likely sources of contamination from the cement works include heavy Metals, Petroleum Hydrocarbons, Phosphates and Sulphates;	Cement Works	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	No. Stage 2 Risk Assessment indicates no significant risk. No source identified
C2	Likely substances from the garages include petroleum hydrocarbons, VOCs and SVOCs	Garages	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	1) Carbazole. No. 7µg/l of carbazole was detected at TP749E – 0.5m in a leachate sample. This concentration reduced to below the Stage 2 screening criteria at Stage 3a of the controlled waters risk assessment. Therefore source not considered to be significant
							2) Fluoranthene. No. 1µg/l of fluoranthene was detected at TP749E – 0.5m in a leachate sample. This concentration reduced to below the Stage 2 screening criteria at Stage 3b of the controlled waters risk assessment. Therefore source not considered to be significant
							3) Naphthalene. No. 8µg/l of carbazole was detected at TP748E – 0.2m in a leachate sample. This concentration reduced to below the Stage 2 screening criteria at Stage 3a of the controlled waters risk assessment. Therefore source not considered to be significant
C3	Likely substances from laboratories include surfactants, heavy metals, phosphates, sulphates, petroleum hydrocarbons and nitrates	Historical laboratories	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	No. Stage 2 Risk Assessment indicates no significant risk. No source identified

Pollutant Linkage Identifier	Pollutant	Plot E 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)
C4	Likely contamination associated with acid storage tanks includes phosphates, sulphates, nitrates, ammonia and heavy metals	Acid storage tanks	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	No. Stage 2 Risk Assessment indicates no significant risk. No source identified
C5	Substances associated with fill material VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates	Made Ground comprising ash and clinker and other diffuse sources	CW1, CW2, CW3	The Irish Sea	-	Potential for entry of contaminant into the St. Bees Evaporites before rapidly migrating to the Irish Sea.	1) Chromium. No. 25µg/l of chromium was detected at TP736E – 0.4m in a leachate sample. This concentration reduced to below the Stage 2 screening criteria at Stage 3a of the controlled waters risk assessment. Therefore source not considered to be significant
							2) Zinc. No. 55µg/l of zinc was detected at TP737E – 1.8m in a leachate sample. This concentration was reduced to below the Stage 2 screening criteria at Stage 3a of the controlled waters risk assessment. Therefore source not considered to be significant
H1	Likely sources of contamination from the cement works include heavy Metals, Petroleum Hydrocarbons, Phosphates and Sulphates;	Cement Works	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 2 Risk Assessment indicates no significant risk.
H2	Likely substances from the garages include petroleum hydrocarbons, VOCs and SVOCs	Garages	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 2 Risk Assessment indicates no significant risk.

Pollutant Linkage Identifier	Pollutant	Plot E 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)
H3	Likely substances from laboratories include surfactants, heavy metals, phosphates, sulphates, petroleum hydrocarbons and nitrates	Historical laboratories	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 2 Risk Assessment indicates no significant risk.
H4	Likely contamination associated with acid storage tanks includes phosphates, sulphates, nitrates, ammonia and heavy metals	Acid storage tanks	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 2 Risk Assessment indicates no significant risk.
H5	Substances associated with fill material VOCs, SVOCs, heavy metals, petroleum hydrocarbons, ammonium, nitrates, cyanide and sulphates	Made Ground comprising ash and clinker and other diffuse sources	HH1, HH2, HH3	0-6 yr old female child	Other site users	Incidental ingestion, dust inhalation, dermal contact & vapour inhalation	No. Stage 2 Risk Assessment indicates no significant risk.

9. REMEDIATION ACTIONS

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

The Plot E potential pollutant linkages have been shown not to be significant, and therefore it is considered that further investigation or remediation actions will not be necessary.

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 9.1 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 E***
Petroleum Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	No significant pollutant linkage (no source).
Poly Aromatic Hydrocarbons in soil, migrating from soil to groundwater and through drains impacting undefined controlled waters receptor.	No significant pollutant linkage (no significant source).
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.	No significant pollutant linkage (no source).
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).
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 significant source).
Copper 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 E***
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.	No significant pollutant linkage (no significant source).
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

PLATES

Appendix A - Proposal For Site Works

Appendix B - Field Methodology

Appendix C - Borehole & Trial Pit Logs

Appendix D - Laboratory Certificates (Included on CD)

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