Retail Petrol Filling Station Decommissioning

Closure Report - Priory SS, Nutgrove Avenue, Rathfarnham, Dublin 18.

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LIMITATION

URS Corporation Ltd has prepared this Report in accordance with Agreement S2004/017 dated 10 November 2004 between ABB Ltd and URS Corporation Ltd ("the Agreement") under which our services were performed. Tougher's Oil Distribution Limited, Newhall, Naas, Co. Kildare acknowledges that this Report was prepared for the benefit of Esso Ireland Limited (the "Client") in accordance with the Agreement.

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URS have received published and/or client supplied information, the completeness and accuracy of which has been independently verified by URS Corporation Ltd, unless otherwise stated in the Report.

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

1. INTRODUCTION

URS Corporation Ltd (URS) is pleased to present ABB Ltd (ABB) with a Closure Report for the former Priory Service Station, Nutgrove Avenue, Rathfarnham, Dublin 18 ("the site").

The site location is presented in Figure 1 with the site layout in Figure 2.

1.1. Objectives

The project objectives and scope of work completed were based on the specification provided by ABB (*ABB Limited Environmental Consultancy Services Agreement for work in the Republic of Ireland – Agreement No.: S2004/017*).

The specific objectives of this report were to:

- Assess whether soil and groundwater at the site has been impacted by any potential contaminants used on-site (notably hydrocarbons); and
- Produce a Site Closure Report.

1.2. Scope of Work

The scope of work completed by URS comprised the following tasks:

- Attendance at underground storage tank (UST) and fuel line removal and validation sampling of soils remaining following their removal;
- Attendance at trial pit investigation and collection of soil samples for laboratory analysis;
- Groundwater sampling and analysis before decommissioning works began and again after their completion;
- Development of a Conceptual Site Model (CSM);
- Completion of a human health and controlled waters Quantitative Risk Assessment (QRA) following collation of site investigation data;
- Derivation of Stage 3 Site Specific Target Levels (SSTLs) that are protective of Human Health and Controlled Waters receptors;
- Comparison of analytical results with Stage 3 SSTLs;
- Identification of areas on site where soil and groundwater results significantly exceed the Stage 3 SSTLs; and
- Completion of a Remedial Action Plan (RAP).

Decommissioning works undertaken in January and February 2008 by MSI Ltd (MSI), who were contracted directly by ABB, are understood to have included the following:

- Soft strip, demolition and removal of above ground structures including the shop building and the canopy;
- Degassing and removal of the six (6) underground storage tanks (USTs);
- Removal of off-set filling points, all known fuel lines, vent lines and pump islands;
- Cleaning the forecourt site interceptor with contents disposed of to a licensed waste treatment facility.

1.3. Site Assessments Completed by URS

URS completed the following assessments on the retail service station portion of the site, and produced the following reports:

- Tier 1 Environmental Site Assessment, Priory Service Station, Nutgrove Avenue, Rathfarnham, Dublin 18, ESA Issue 1, 45078281_04201 dated 20 June 2006.
- Quantitative Risk Assessment and Remedial Action Plan, Priory Service Station, Nutgrove Avenue, Rathfarnham, Dublin 18, Issue 1, 45078651.170, dated 26 April 2008.

1.3.1. Site Investigation - 2006

A Tier 1 Environmental Site Assessment was undertaken in 2006[1]. Six (6) bores were drilled using a CME 55 hollow stem auger drilling rig, all of which were installed as monitoring wells (BH01 to BH06) in March 2006. In May 2006 three (3) additional wells were drilled using a hollow stem auger drilling rig on Esso property adjacent to the Priory SS retail site (BH07 to BH09). All boreholes were installed with monitoring wells. Detailed geological and monitoring well construction logs are given in Appendix A. Soil samples were screened in the field for the presence of volatile organic compounds with a calibrated photo-ionisation detector (PID) and submitted for the following laboratory analyses:

- Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG);
- Benzene, Toluene, Ethyl Benzene and Xylene (BTEX);
- Methyl Tert Butyl Ether (MTBE);
- Speciated Polycyclic Aromatic Hydrocarbons (PAHs);
- Exxon Metals Suite;
- Total Organic Carbon (TOC) and pH.

Groundwater samples were also collected and analysed for the above parameters (excluding pH and TOC). Based upon groundwater level data recorded in on-site monitoring boreholes, the inferred direction of groundwater flow was towards the west.

[1] Environmental Site Assessment of Retail Sites. Priory Service Station, Nutgrove Avenue, Rathfarnham, Dublin 18. Dated 20 June 2006. Report Reference 45078281-04201.

Analytical results are tabulated in Appendices B and C.

Based on the findings of the Tier 1 site investigation and the analytical results supplied by the laboratory, the following conclusions were drawn:

- No soil or groundwater impacts were identified that would currently represent a risk to high density residential users of the site.
- There were soil and groundwater exceedences of the Tier 1 Screening Values calculated to be protective of controlled waters receptors. The exceedences indicated a potential risk to controlled waters from metals, aromatic hydrocarbons, and PAHs, and indicated the need for a site-specific QRA with respect to controlled waters.

1.3.2. Decommissioning Site Investigation

During the decommissioning works in January and February 2008, URS conducted soil and groundwater sampling, details of which are presented in Section 3 of this report.

1.3.3. Post-Decommissioning Investigation

The post-decommissioning QRA concluded that there were no significant risks posed to potential human health or controlled waters receptors from soil or groundwater sources and as such, no remedial action was required. Details of the post-decommissioning QRA are presented in Sections 4 and 5 of this report.

1.4. Proposed Future Use of Site

The proposed future use of the site is understood to be high density residential, with basement. It is assumed that the site will be fully encapsulated by structural slabs, sealed roadway or managed landscaped gardens (involving a minimum cover of 1m of imported clean fill) that will be designed and constructed to prevent any direct contact by future site users with current site soil remaining in-situ and that the establishment of vegetable gardens or similar will not be permitted, such that the only viable pathway that could represent a risk to future site users is vapour migration.

2. SITE SETTING

2.1. Site Description

The site details are summarised below:

- Site ID –Priory Service Station
- Site Location – Nutgrove Avenue, Rathfarnham, Dublin 18.
- Current Operation – Decommissioned Retail Petrol Station
- Site Area – 2,830 m^2

2.2. Physical Setting

The physical setting of the site is summarised below.

Physical Feature	Comments
Surface of Site	30% Concrete 15% Cobble-lock 55% Open ground
Topography	The site appears level. The surrounding land slopes gently downward from south to north towards the Dodder River. The site is at an elevation of approximately 50m above Mean Sea Level.
Excavation/Filling on Site	The investigation undertaken as part of this site assessment found 'fill' material to a depth of approximately 1.5 metres below ground level (mbgl) across the site.
Regional Geology	According to the Geological Survey of Ireland (GSI) bedrock at the site is Calp (dark grey to black limestone and shale) (Bedrock Geology 1:100 000 Map Series Sheet 16). The GSI website (www.gsi.ie) indicates that subsoils at the site consist of made ground. Quaternary deposits in the area consist of till chiefly derived from limestone.
Local geology	Site investigation data indicate Made Ground consisting of sandy gravelly clay overlying alternate layers of firm brown gravelly clay and stiff black gravelly clay varying in thickness.
Regional Hydrogeology and Aquifer Classification	According to the GSI the limestone bedrock beneath the site is classified as a Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones. Only an interim study of groundwater vulnerability was carried out on site, indicating high to low vulnerability. Bedrock outcrops are present approximately 1.25 km to the northwest of the site.
Local hydrogeology	The average depth to groundwater at the site is 1.5 mbgl, within the Made Ground and till.

Physical Feature	Comments
Nearby Surface Water Bodies	The River Dodder flows northeastwards approximately 1.25 km to the northwest and north of the site. The following tributaries of the Dodder are also located in the vicinity of the site: • According to site data, the Little Dargle River is culverted under the site and flows to the northwest. It joins the River Dodder approximately 1.25 km to the north of the site. • The Owerdoher River and its unnamed tributary are also culverted underground in this area and their confluence point is located 800 m to the west of the site. The Owerdoher River joins the River Dodder 1.25 km to the northwest of the site.
Nearby Surface Water Abstractions	Drinking water is abstracted from the River Dodder at the Glensamole Reservoir approximately 8.5 km upstream from the site.
Nearby Groundwater Abstraction Wells	According to GSI records, there are 4 wells within a 3 km radius of the site. The closest is located approximately 360 m cross-gradient of the site to the north east. Two of the wells are reported to be used for industrial purposes and two are for unknown uses. It is reported that the wells have good to excellent yields from the limestone bedrock.
Inferred groundwater flow	Based upon groundwater levels obtained before and after decommissioning, inferred groundwater flow direction is generally to the west, towards the River Dodder. A hydraulic gradient of approximately 0.031 was calculated from groundwater levels on 28 May 2006.

2.3. Adjacent Land Use

The land uses adjacent to the site are summarised below.

Site Boundary	Land Use
North	High density residential (houses 30m across the road) and commercial.
South	Low density residential at boundary wall.
East	Recreational (Scout Hall) and low density residential.
West	Low density residential at boundary wall.

2.4. Site History

The history of the site is summarised below:

Year	Site Use	Comments
1910	Residential	There was a house on the site called Nutgrove House.
1970	Residential	According to maps site use remained residential.
1990	Petrol Station	Site bought by Esso.
1992	USTs installed	According to the as built drawings, six 20,000 litre USTs were installed in the eastern portion of the retail site.

2.5. Site Infrastructure

The historical site infrastructure included the following:

Infrastructure	Number	Comments
Underground storage tanks (UST's)	6	Six USTs were removed during decommissioning works. The USTs contained Diesel, Unleaded petrol and Lead Replacement Petrol (LRP). All tanks had off-set fill points.
Above Ground Storage Tanks	0	N/A
Dispensing Pumps	0	All pumps have been removed.
Oil Water Separators	1	Remains in situ.
Car Wash	Yes	Car wash has silt trap and according to site plans this drains to a Kirton JND-25 reclaim unit on the south east corner of the site.
Soak away	None	None observed on site or identified on plans provided by ABB.
Connection to Sewer	Yes	According to site plans, the toilets were connected to the foul sewer via the north west corner of the site.
Connection to Storm Water Drains	Yes	The oil/water separator connected to the storm water drain on the northern end of the site.
Other	None	No waste oil storage tank present.

Available information concerning the storage tanks at the site is summarised below.

Tank	1	2	3	4	5	6
UST/AST	UST	UST	UST	UST	UST	UST
Status	Decommissioned					
Age	14 years	14 years	14 years	14 years	14 years	14 years
Installation Date	1992	1992	1992	1992	1992	1992
Size (kL)	20	20	20	20	20	20
Product	LRP	Unleaded 95	Unleaded 95	Unleaded 95	Superplus Unleaded	Diesel
Abandonment	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

2.6. Potential Pollution Incidents

The Dublin City Council Pollution Officer was contacted during the Tier 1 site investigation. No records of historical pollution incidents were reported.

3. SITE WORKS COMPLETED - 2008

3.1. Site Decommissioning Activities

In January and February 2008 decommissioning activities took place on site including recovery of below ground infrastructure and removal of above ground structures. The demolition contractor was MSI Ltd who was contracted directly by ABB and independently of URS. The demolition contractor undertook site decommissioning activities on behalf of ABB.

Site decommissioning activities reported to URS as completed included:

- Soft strip, demolition and removal of above ground structures including the shop building and the canopy;
- Degassing and removal of the six (6) underground storage tanks (USTs);
- Removal of off-set filling points, all known fuel lines, vent lines and pump islands;
- Cleaning the forecourt site interceptor with contents disposed of to a licensed waste treatment facility. The interceptor was not removed for engineering reasons as it was situated immediately above a culverted stream. Removal of the interceptor may have resulted in damage to the culvert.

Decommissioning of the tank farm, located in the centre of the site, resulted in a single excavation that was approximately 3.0 - 4.0 m deep. The tanks and concrete cradle were removed from the excavation prior to the immediate validation sampling by URS (Figure 3).

The excavation was backfilled with clean imported sand and gravel fill sourced from Roadstone, Belgard Road, Tallaght, Dublin. Three (3) samples of imported granular fill, were collected over the period of decommissioning works (PRIO_IF01, PRIO_IF03 and PRIO_IF04) and were submitted for the following laboratory analyses:

- TPH CWG;
- Speciated PAHs;
- Exxon Metal Suite;
- pH;
- TOC;
- Total Sulphate;
- Phenols.

Soil analytical results are tabulated in Appendices B and C.

Backfill from around the tanks was removed and stockpiled on site. Two (2) samples of site-derived backfill were collected for laboratory analysis (PRIO_BF01 and PRIO_BF03). The samples were analysed for the following:

- TPH CWG;
- Speciated PAHs;
- Exxon Metal Suite;
- pH; and
- TOC.

In addition, samples PRIO_BF01 and PRIO_BF03 were analysed for Waste Acceptance Criteria.

During the trial pitting one of the hydraulic hoses was punctured and a small amount of hydraulic oil sprayed over the trial pit. Visually impacted soil was excavated and placed in a small stockpile. One soil sample (PRIO_SP01) was collected and analysed for the following:

- TPH CWG;
- Speciated PAHs;
- Exxon Metal Suite.

Fuel lines leading from the tank farm to offset fill points, vent pipes and dispensing pumps were removed.

The decommissioning works were completed between 24 January 2007 and 21 February 2007.

3.2. Validation Sampling

A total of 21 tank pit soil validation samples were collected (PRIO_TK01 to PRIO_TK21).

- Six (6) soil samples were collected from beneath the concrete base slab of the tank farm cradle at a depth of approximately 4.0 mbgl (PRIO_TK15 to PRIO_TK20).
- Fourteen (14) soil validation samples were collected from the side walls of the excavation, from a depth of approximately 2.0 mbgl (PRIO_TK01 to PRIO_TK14).
- One (1) validation sample was collected from below the offset fill point at 0.5 mbgl (PRIO_TK21).

Validation sample locations are presented in Figure 3.

Soil samples were screened in the field for the presence of volatile organic compounds with a calibrated photo-ionisation detector. All tank farm validation soil sample headspace PID readings were 0 ppm.

Soil samples were submitted to Alcontrol Laboratories in Chester, UK under a strict chain of custody procedure for the following analytical suites:

- TPHCWG;
- BTEX and MTBE;
- Speciated PAHs;
- Exxon Metal Suite; and
- Selected samples were also analysed for Total Organic Carbon (TOC) and pH.

In addition, samples PRIO_TK07 and PRIO_TK13 were analysed for Waste Acceptance Criteria.

Soil analytical results are tabulated in Appendices B and C.

During tank pit excavation no field evidence of hydrocarbon impact was noted. The generalised geological profile beneath the site observed from this tank pit excavation is summarised as follows:

Depth (m bgl)	Soil Description
0 – 2.5	Made Ground – Concrete and tanks
2.5 - 3.0	Made Ground – Firm brown gravelly clay.

3.3. Trial Pit Investigation

Between 24 January 2008 and 21 February 2008 thirty-seven (37) trial pits were excavated and soil samples were collected from each trial pit at approximately 0.5 mbgl and every metre thereafter. The trial pits were excavated to depths varying between 2.0 m and 4.0 mbgl. MSI Ltd was contracted directly by ABB and independently of URS to excavate the trial pits. All trial pitting was conducted under the environmental supervision of URS.

Due to the presence of large cobbles and stiff clay underlying the site the trial pits were prone to refusal at depths varying between 2.8 m and 4.0 mbgl.

Trial pit locations are presented in Figure 4.

During the trial pit excavations, no observations of hydrocarbon contamination were recorded. All trial pit soil sample headspace PID readings were below 1 ppm.

The generalised geological profile beneath the site observed from these trial pit excavations are summarised as follows:

Depth (m bgl)	Soil Description
0-0.3	Made Ground – concrete/tarmac/cobblelock/grass
0.3-1.5	Made Ground – comprised predominantly of sandy gravel or gravelly clay with occasional brick fragments, scrap metal, plastic and glass.
1.5-3.5	Firm brown gravelly clay
>3.5	Stiff black gravelly clay

Detailed geological logs for the trial pits are presented in Appendix A.

A total of 75 soil samples, including one duplicate sample (as a 'control'), were submitted to Alcontrol Laboratories in Chester, UK under a standard chain of custody procedure for the following analytical suites:

- TPHCWG;
- Speciated PAHs;
- Exxon Metal Suite.
- Selected samples were also analysed for Total Organic Carbon (TOC) and pH.

Soil analytical results are tabulated in Appendices B and C.

3.4. Groundwater Sampling

Two rounds of groundwater sampling were completed, one prior to decommissioning works (21 January 2008) and one following completion of decommissioning works (04 March 2008).

The standing water level in the monitoring wells was gauged using an oil-water interface probe prior to the purging and sampling of the wells.

Relative level and gauging information from the monitoring wells is summarised below. MW07 was not located on 21 January 2008 and was sampled later on 28 January 2008.

The elevations of the groundwater monitoring wells were resurveyed on 04 March 2008 as headworks for wells MW03, MW07 and MW08 were replaced following the decommissioning works.

Installed Well	Relative Level of Top of Well (m SD)	Depth to Water (m toc)	Relative Water Table Level (m SD)	Product Present (y/n)
14 January 2008				
MW01	98.316	1.146	97.170	N
MW02	98.371	1.390	96.981	N
MW03	98.619	1.190	97.429	N
MW04	98.601	1.250	97.351	N
MW05	98.664	1.225	97.439	N
MW06	98.546	1.401	97.145	N
MW07*	99.034	1.350	97.684	N
MW08	99.038	1.500	97.538	N
MW09	98.760	1.310	97.450	N
04 March 2008				
MW01	98.530	1.201	97.329	N
MW02	98.687	1.660	97.027	N
MW03	98.886	1.355	97.531	N
MW04	98.799	1.418	97.381	N
MW05	98.769	1.339	97.430	N
MW06	98.696	1.459	97.237	N
MW07	99.147	1.683	97.464	N
MW08	99.410	1.897	97.513	N
MW09	98.970	1.557	97.413	N

* Measured on 28 January 2008
Note: m SD = metres relative to Site Datum. Site Datum was set to 100 m.

Groundwater contour maps from groundwater levels measured on 21 January 2008 and 04 March 2008 are illustrated in Figures 5 and 6 respectively. Inferred groundwater flow directions are to the northwest on 21 January 2008 and to the southwest on 04 March 2008.

Hydrogeological site observations included the following:

- Groundwater was observed to be brown to grey in colour and of moderate to high turbidity;
- Hydrogen sulphide odour was noted in MW04 on 04 March 2008; and
- No visual or olfactory evidence of hydrocarbon impact was noted during either groundwater sampling round.

Field parameter results for monitoring wells are summarised below:

Well number	EC (µS/cm)	pH	Temperature (°C)	Redox (mV)	Dissolved Oxygen (%)
21 January 2008					
MW01	839	8.25	10.63	116.9	89.9
MW02	965	8.28	10.98	116.8	97.3
MW03	663	7.81	10.29	114.9	77.5
MW04	674	7.69	9.32	113.0	63.3
MW05	600	-	10.93	118.9	83.5
MW06	879	-	11.36	118.7	97.4
MW07*	894	7.73	9.79	129.8	29.9
MW08	843	7.36	9.72	109.5	77.6
MW09	618	7.46	9.70	111.3	72.3
04 March 2008					
MW01	873	7.30	10.57	161.3	21.4
MW02	958	7.35	9.99	143.0	28.5
MW03	661	7.30	10.02	144.9	27.4
MW04	678	7.32	9.26	136.5	26.8
MW05	648	7.33	10.43	141.5	26.4
MW06	840	7.36	10.49	147.5	20.9
MW07	825	7.30	9.01	132.4	33.4
MW08	872	7.25	9.59	131.8	30.9
MW09	771	7.32	9.67	132.7	34.9

* Measured on 28 January 2008

Groundwater samples were submitted to Alcontrol Laboratories in Chester, UK under a strict chain of custody procedure and analysed for the following parameters:

- TPHCWG;
- BTEX and MTBE;
- Speciated PAHs; and
- Exxon Metal Suite.

Analytical results are tabulated in Appendices B and C.

4. DEVELOPMENT OF CONCEPTUAL SITE MODEL

4.1. Background

A Conceptual Site Model (CSM) has been developed which describes viable source-pathway-receptor (SPR) linkages for the site. The CSM has been developed from data reported from site works completed.

The pollutant linkages represent the possible scenarios whereby a particular contaminant, which has been identified on site, could impact a potential receptor - be this human health or controlled waters – via a defined pathway.

This assessment considers that the end use of the site is to be high density residential with basement. It is assumed that the site will be fully encapsulated by structural slabs, sealed roadway or managed landscape with clean imported fill of at least 1m such that direct contact with existing in-situ soil and groundwater is not viable.

The building parameters used in the model are as presented in the UK CLEA model and accompanying briefing notes. In the modelled scenario the residential building is a two-storey property with basement that is not in itself an enclosed space i.e. the air in the basement is assumed to mix freely with the air in the above-ground floors. If the building design to be constructed on this site is significantly different to this then URS recommend that the risk assessment be revised to reflect this change from the default residential property.

Modelling algorithms assume vapour ingress into buildings via foundation cracks only. Given that such cracks would be in the saturated zone at the site, this pathway is not considered viable. However, to acknowledge that vapours may be present in unsaturated shallow soils abutting the sidewalls of the basement and pass through these walls, modelling adopts unsaturated shallow soils beneath foundations.

It is also noted that this model assumes there is no gas barrier incorporated into the basement construction. Further, as the depth to groundwater is shallow on site (approximately 1.3m bgl) the need for a damp proof membrane or tanking membrane will have to be considered during the design of the basement to prevent the ingress of groundwater. The use of a damp proof membrane or tanking membrane would be expected to give added protection to users of the development by blocking or restricting the migration pathway for vapours into the building from the subsurface.

4.2. Potential Sources

The contaminated source areas, pathways and receptors were conceptualised from:

- Observations made on-site;
- Soil (borehole) and groundwater samples taken during intrusive site investigation works in March 2006; and

- Soil trial pit and tank pit validation samples taken during decommissioning works in January and February 2008.
- Groundwater samples taken before and after decommissioning works in 2008.

Decommissioning activities removed hydrocarbon storage and distribution infrastructure from the site. The remaining potential sources at the site include the following:

Potential source	Present (Y/N)	Source area (m^2)	Description/Comments
Residual UST infrastructure	Y	-	The interceptor is still present on site and was not removed for engineering reasons (as it was situated immediately above a culverted stream). Removal of the interceptor may have resulted in damage to the culvert. Soil samples were collected adjacent to the interceptor and from depths below the depth of the interceptor to validate the soil in this area. All other known USTs and associated residual infrastructure was removed from site.
Impacted soils (above URS generic assessment criteria (GAC))	Y	Source 1: Whole site 2,830 m^2 Source 2: Toluene and xylene hotspot 16 m^2 Source 3: PAH hotspot 1996 m^2	Soil samples reporting concentrations of aromatic TPHs, PAHs naphthalene and pyrene and metals above URS Stage 2 Generic Assessment Criteria (GAC) for Controlled Waters were found across the site. A hotspot source for toluene and xylene above URS Stage 2 GACs for Controlled Waters was delineated for an area surrounding tank pit samples TK01, TK02 and TK03. Soil samples reporting concentrations of the following PAHs above URS Stage 2 GACs for Controlled Waters were found in an area encompassing 1648m^2 in the east and southwest of the site: benzo(a)anthracene, benzo(a)pyrene, fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)-anthracene, benzo(b)fluoranthene, phenanthrene and indeno(1,2,3-cd)pyrene. Elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) above the Stage 2 GACs protective of Human Health detected in soil samples collected at the site. In addition, elevated concentrations of total petroleum hydrocarbons (TPH) above the Stage 2 GACs protective of Human Health were detected in soil samples collected from the western portion of the site.

Potential source	Present (Y/N)	Source area (m^2)	Description/Comments
Impacted groundwater (above URS GAC)	Y	Source 1: PAH hotspot 1415 m^2.	Groundwater samples collected from MW08 on 04 March 2008 reported concentrations of PAHs benzo(a)pyrene and dibenzo(a,h)-anthracene above the URS Stage 2 GAC for Controlled Waters. A hotspot encompassing 1415 m^2 was delineated around MW08 for these analytes. No water samples collected at the site exceeded URS Stage 2 GAC protective of human health.
Separate phase hydrocarbons on groundwater	N	-	No separate phase hydrocarbons were detected during groundwater monitoring on-site, neither was any observed in the tank pit excavation.

4.3. Potential Receptors

4.3.1. Human Health (High Density Residential with basement)

A number of potential Human Health receptors exist given the proposed High Density Residential end use. These include:

- Residents on site;
- On-site workers;
- Residents on adjacent properties; and
- Workers undertaking subsurface excavations on site.

For a residential land use, DEFRA and the Environment Agency in the UK identifies the most sensitive receptor as a female child between the ages of 0 and 6 years. This potential receptor has been assumed as the most sensitive Human Health receptor for the proposed development of the site.

There were exceedences of the Stage 2 GACs protective of residential Human Health receptors reported for the soil samples analysed.

There were no exceedences of the Stage 2 GACs protective of residential Human Health receptors reported for water samples analysed. As such, no potential risk to residential Human Health receptors on neighbouring properties was identified as a result of impacted groundwater migrating off site.

4.3.2. Controlled Waters

A number of potential Controlled Waters receptors (points of compliance) exist given the environmental setting of the site. These are summarised below:

Controlled Waters receptors	Present (Y/N)	Potable supply (Y/N)	Description/Comments
Groundwater abstraction within 50m of the site	N	-	There are no known groundwater abstraction wells within 50 m of the site. The closest well is located approximately 360 m cross-gradient of the site to the north east.
Surface water body within 100 m of the site in direct hydraulic connection with groundwater from the site.	Y	-	The nearest surface water body is the Little Dargle River, which is culverted under the site and flows northwestwards.
Groundwater of any Major Aquifer beneath the site for List 1 substances.	Y	Y	According to the GSI the limestone bedrock beneath the site is classified as a Locally Important Aquifer.
Groundwater of any Major or Minor Aquifer within 50 m of the site for List 1 and List 2 substances.	Y	Y	Refer to above.
Surface water body at a distance of 100 m from the site if the groundwater beneath the site is in hydraulic continuity with a Major or Minor Aquifer.	Y	-	The nearest surface water body is the Little Dargle River, which is culverted under the site and flows northwestwards.
Groundwater abstraction borehole within 100 m of the site that is licensed to abstract water from a Major or Minor Aquifer.	N	-	There are no registered groundwater abstraction wells within 100 m of the site.
Surface water body at a distance of 250 m from the site if the groundwater beneath the site is in hydraulic continuity with a 'Non-aquifer'.	N	-	-
Groundwater abstraction borehole within 250 m of the site, which is licensed to abstract water from a 'Non-aquifer'.	N	-	-

The Little Dargle River is understood to be culverted under the site. Due to its location the river is considered a potential controlled waters receptor. According to available data the river is contained in a culvert. It is beyond the scope of this investigation to assess the movement of impacted water through the culvert to the river. As a conservative measure, the river is modelled as a controlled waters receptor at the model default distance of 50m

down-gradient of the site. As a sensitivity analysis, the river is also modelled as a receptor at 5m down-gradient of the site.

The River Dodder, the Owerdoher River and its tributary are not considered significant potential Controlled Waters receptors due to their considerable distance from the site.

The existing groundwater abstraction wells in the vicinity of the site are not considered potential Controlled Waters receptors, as the closest well is located approximately 360 m cross-gradient of the site to the north east. However, there may be unknown groundwater abstraction wells that have not been registered. Therefore, for the purpose of this assessment a theoretical groundwater compliance point 50 m down-hydraulic gradient of the site in the till was selected.

In summary, the culverted Little Dargle River is considered to be the most significant potential Controlled Water receptor.

As a conservative measure, the QRA assessed both vertical, downwards migration of contaminants through the shallow subsoil layers and horizontal migration of contaminants through the saturated till to the receptors.

4.4. Potential Pathways

4.4.1. Human Health (High Density Residential with basement)

Given the high density residential end use proposed for the site, the following potential pathways to human health receptors are considered viable.

Potential pathway	Pathway exists from shallow soil (<1.3m)	Pathway exists from groundwater
Outdoor inhalation of vapours	✓	✓
Indoor inhalation of vapours	✓	✓
Outdoor ingestion of soil and fugitive dust	×	×
Indoor ingestion of fugitive dust	×	×
Ingestion of vegetables grown on site	×	×
Ingestion of soil attached to vegetables grown on site	×	×
Outdoor dermal contact with soil	×	×
Indoor dermal contact with fugitive dust	×	×
Outdoor inhalation of dust	×	×
Indoor inhalation of fugitive dust	×	×

The Human Health Risk Assessment (HHRA) modelled soils impacts from the ground surface (allowing a 20 cm pathway length for the thickness of concrete foundations and inclusive of a 5 cm nominal diffusive path length) to the depth of water table at approximately 1.30 m bgl. Stage 3 SSTLs are derived for unsaturated shallow soil and groundwater.

The proposed future use of the site is understood to be high density residential where the site will be fully encapsulated by structural slabs, sealed roadway or managed landscaped gardens (i.e. involving a minimum cover of 1 m of imported clean fill) that will prevent direct contact with existing in-situ soil and groundwater and will not permit the establishment of vegetable gardens or similar. On this basis, the only viable pathway to Human Health receptors on the site is assumed to be via vapour migration.

The Human Health Risk Assessment (HHRA) modelled soils impacts from the ground surface (allowing a 20 cm pathway length for the thickness of concrete foundations and inclusive of a 5 cm nominal diffusive path length) to the depth of water table at approximately 1.30 m bgl. Stage 3 SSTLs are derived for unsaturated shallow soil and groundwater

4.4.2. Controlled Waters

The following potential pathways to controlled waters receptors are considered viable.

Potential pathway	Pathway exists
Partitioning of soil contamination between soil, pore water and air.	✓
Vertical migration of impacted water from a soil source through the unsaturated zone to the shallow groundwater table.	✓
Dilution of impacted water directly entering saturated zone.	✓
Vertical migration of impacted water through the till to an underlying aquifer.	x
Horizontal migration of impacted water through the saturated zone towards a receptor.	✓

A thickness of 5 m of slightly sandy slightly gravelly clay (till) was observed during the soil investigation with a shallow depth to groundwater of approximately 1.5 m.

Bedrock was not encountered at the site during intrusive site investigations. It is not assumed that the till overburden is in hydraulic continuity with the Locally Important limestone aquifer and hence the limestone is not considered a viable potential pathway for the purposes of this risk assessment.

4.5. Summary of Viable SPR linkages

On the basis of the CSM described above, active source-pathway-receptor (SPR) linkages are present for Human Health and Controlled Waters receptors and potential impacts were assessed further in the subsequent QRA.

Issue	Details	Comments
Potential Sources	Historic activity on the site; Made Ground imported for filling material (prior to site operations); Soil concentrations exceeding Stage 2 GACs; and Groundwater concentrations exceeding Stage 2 GACs.	No visual or olfactory evidence of hydrocarbon contamination was noted in soil or groundwater samples during trail pitting, tank pit excavation and groundwater monitoring in January and March 2008.
Potential Human Health Pathways	Outdoor inhalation of vapours Indoor inhalation of vapours	The surface of the site will be fully encapsulated by structural slabs, sealed roadway or managed landscaped gardens (i.e. involving a minimum cover of 1 m of imported clean fill) that will be designed and constructed to prevent any direct contact with existing in-situ soil and will not permit the establishment of vegetable gardens or similar. On the basis of this understanding, the only viable pathway to human health receptors is assumed to be vapour migration.
Potential Human Health Receptors	Residents on site; On-site Workers; Residents on adjacent sites; Workers undertaking subsurface excavations on site.	Risks are considered greatest to the future on-site residents. Potential risks are also significant for those involved in the redevelopment of the site. Exposure for the on-site workers will be controlled during construction activities through appropriate health and safety procedures defined by the construction company and is not considered here.
Potential Controlled Waters Pathways	Potential vertical migration (downward) of hydrocarbons present within the impacted soil through the Made Ground to the groundwater within the underlying till. Potential horizontal migration of contaminated groundwater to a specified down-gradient groundwater receptor.	The potential for vertical migration of contaminants from impacted shallow soil through to the underlying aquifer is considered low.

Issue	Details	Comments
Potential Controlled Waters Receptors	The Little Dargle River, culverted under the site. Shallow groundwater in till at a distance of 50m from the site.	The most sensitive Controlled Waters receptor is considered to be the Little Dargle River.

On the basis of the CSM described above, the impacts upon the identified potential Human Health and Controlled Waters receptors, via the specified potentially active SPR linkages, are assessed further in the subsequent QRA.

5. QUANTITATIVE RISK ASSESSMENT

5.1. Background

The project procedures for completing the Quantitative Risk Assessment (QRA) are described in the URS Draft Report Exxon Mobil Petroleum Facility Assessment Methodology (URS report R1941).

The procedures follow the "source-pathway-receptor" (SPR) methodology as defined in Part IIA of the UK Environmental Protection Act 1990 (as inserted by Section 57 of the Environment Act 1995). The methods developed to quantify the risks are based on standard and approved methods: the use of the Contaminated Land Exposure Assessment method (CLEA) for human health and the "Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources" (Environment Agency R&D Publication 20, 1999) for controlled waters.

Human Health

For the Human Health Risk Assessment, the procedure involves making quantitative estimates of the risks posed to human receptors via each of the viable SPR linkages. The significance of these can then be evaluated using internationally recognised acceptability criteria. Where such risks are deemed significant, then it would normally be the case that remediation would be required, where such contaminant pathways were deemed viable for the site in question. In such circumstances SSTLs can then be developed. These represent theoretical soil or water concentrations, below which the risks posed by the contaminant are not considered significant. As such, they can be used as target concentrations or 'standards' for remediation.

As the risks from TPH are considered additive on a sample by sample basis (in accordance with the Environment Agency's framework for evaluating TPH risks in soil: *The UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons in Soils*. Science Report P5-080/TR3. Environment Agency 2005), the Hazard Quotient for each sample has been calculated using the following methodology:

1. Calculate a Hazard Quotient (HQ) for each reported TPH fraction in relation to its screening criteria; and

2. Sum the calculated HQs for each sample to derive a Hazard Index (HI).

Where a HI is greater than unity (1.0), the risk from TPH for that sample is potentially not tolerable (the screening criteria is "exceeded").

Controlled Waters

For the Controlled Waters Risk Assessment, the procedure involves the use of a probabilistic model that incorporates estimates of the degree of attenuation of the contaminant concentration along the pathways defined in the CSM in order to assess its concentration at the receptor. Such attenuation mechanisms include dilution within

surface water and groundwater features, dispersion and biological decay. The simulated concentrations at the receptor can then be compared against appropriate water quality standard that may be protective of either drinking water or environmental quality.

As with the Human Health Risk Assessment, SSTLs are calculated which represent concentrations of contaminants on site that would result in concentrations below the adopted water quality standard at the relevant receptor.

5.2. Input Parameters

5.2.1. Input Parameters Specific to Human Health Assessment

The generalised geological profile at the site is described in Section 3.3.

This profile has been modelled for input into the QRA as follows:

Soil Layer	Soil Type	Fraction Organic Carbon (FOC)
Unsaturated soils	Sand (UK CLR10): Review of borehole and trial pit logs indicate that shallow soil/Made Ground generally comprises sandy gravel and gravel with some clay.	FOC (1.43%) - laboratory derived FOC values for 16 samples of site shallow soils and Made Ground.
Deep natural soils	SSTLs for deep soil were not derived due to the presence of a shallow water table at the site (approximately 1.3 mbgl).	N/A

Summary of Inputs

The following details have been modelled for the identified source areas:

Parameter	Input	Comment
Source Area	225 m^2	Based on Johnson and Ettinger/American Standard Technical Method default values.
Depth to Impact	0.2 m	Allowance made for a nominal diffusive pathway length of 5 cm below nominal foundation thickness of 15 cm.
Thickness of soil contamination	1.1 mbgl	Laboratory information indicates contamination present from the surface to the water table.
Depth to contamination (for derivation of groundwater SSTL's)	1.3 m	Average standing water level for monitoring rounds carried out in March 2006, November 2007, January and March 2008 was 1.3 mbgl. Water levels varied between 0.745 m and 2.045 mbgl over this period.

Parameter	Input	Comment
Vapour model used (Finite / Infinite)	Finite/Infinite	Modelling of shallow and deep soils assumes a finite source, whilst modelling of groundwater assumes an infinite source.

More detailed information on the parameters used in the High Density Residential Human Health Risk Assessment is presented in Appendix D.

5.2.2. Parameters Specific to Controlled Waters Assessment

Geological Inputs

This profile has been modelled for input into the QRA as follows:

Soil Layer	Soil Type	Fraction Organic Carbon (FOC)
Shallow soil and Made Ground.	Sand (UK CLR10): Review of borehole and trial pit logs indicates that shallow soil/Made Ground generally comprises sandy gravel and gravelly clays.	FOC (1.43%) measured from 16 samples of site shallow soils and Made Ground.
Deep natural soils	Review of borehole and trial pit logs indicates that deep natural soils generally comprises sandy gravelly clays (till).	FOC (0.5%) measured from 51 samples of deep natural soils.

Hydrogeological Inputs

This information has been modelled for input as follows:

Parameter	Input	Comment
Thickness of attenuation zone in unsaturated soil	0m	Impacted soil has been detected down to and below the depth of shallow perched groundwater onsite.
Water filled porosity	16%	Effective porosity value for till (Kruseman & de Ridder 2000[2])

[2] Kruseman, G.P. & de Ridder, N.A. (2000) Analysis and evaluation of pumping test data. 2nd ed. RRI Publication.

Soil Sources

In consideration of the impacts identified onsite, the soil impacts were modelled as a single-source area across the whole site for aromatic TPHs, PAHs (naphthalene and pyrene) and metals. Therefore, the model was run with the upper 95th percentile mean concentration (CLR approach) for these analytes adopting the entire site area as the source area.

Two soil source hotspots were identified on site. A hotspot source (source 2) for toluene and xylene was delineated in a 16m^2 area surrounding tank pit samples TK01, TK02 and TK03. Ten PAH compounds exceeded URS Stage 2 GAC for Controlled Waters in borehole, tank pit and trial pit samples in areas in the east and southwest of the site encompassing 1996m^2 (source 3).

As a conservative measure, the model was run with the maximum concentration (CLR approach) for the contaminants of concern in hotspot sources 2 and 3.

The model source parameters are attached as QRA Parameters in Appendix D.

Groundwater Sources

In consideration of the impacts identified onsite, the groundwater impacts were modelled as a single-source area around MW08 for PAHs (benzo(a)pyrene and dibenzo(a,h)-anthracene).

As a conservative measure, the model was run with the maximum concentration (CLR approach) for the contaminants of concern in a 1415m^2 area around MW08.

The model source parameters are presented in Appendix D.

5.2.3. Summary of Inputs

Input parameters used specifically in the controlled waters assessment and justification of the values used are summarised below.

Parameter	Input	Comment
Compliance points	Little Dargle River	The Little Dargle River is culverted under the site and is considered as a compliance point protective of potential Controlled Waters receptors using the clay pathway.
	Theoretical groundwater well (50m downgradient)	A theoretical groundwater well (50 m downgradient) is considered as a compliance point (receptor) protective of potential Controlled Waters receptors using the clay pathway.

- Due to the urban setting of the Little Dargle River, water quality in the river is expected to be poor.

5.4.3. Future Construction or Excavation

It is expected that any redevelopment or construction activity will involve short-term exposure pathways to construction workers. An assessment of impacts to construction workers is outside the current scope of work. It is recommended that during any construction or excavation works at the site that appropriate safe methods of work and PPE be employed to limit any impacts to workers arising from soil and groundwater.

Excavation works may encounter visually impacted and odorous soils and shallow groundwater at the site. Any excavation, stockpiling, transport or off-site disposal of the soils should be carried out in accordance with relevant regulations.

6. REMEDIAL EXCAVATIONS

6.1. Remedial Objectives

The remedial objectives are as follows:

- Address any impacted soils;
- Address any impacted groundwater; and
- Complete validation sampling.

6.2. Remedial Action Plan

The following remedial action plan is based on a high density residential end use of the site.

6.2.1. Site Infrastructure

In terms of residual infrastructure, the site interceptor remains in situ. Trial pits were excavated adjacent to the interceptor and soil samples were collected from depths below the depth of the interceptor to validate the soil in this area. Based on the information collected, removal of the site interceptor is not considered necessary.

6.2.2. Impacted Soils

As simulated risks arising from the identified soil impacts to potential controlled water and human health receptors are considered acceptable no remedial soil excavation is considered necessary.

6.2.3. Impacted Groundwater

There are no significant risks posed to potential human health or controlled waters receptors from groundwater sources. No remedial action is required in respect of groundwater at the site.

6.2.4. Imported Fill Material

Three (3) samples of imported granular fill, were collected over the period of decommissioning works (PRIO_IF01, PRIO_IF03 and PRIO_IF04). The analytical results (Appendices B and C) indicate that the material is suitable for backfill at the site.

6.2.5. Waste Classification

Site-derived backfill was classified as inert.

In-situ tank pit validation samples PRIO_TK07 and PRIO_TK13 were classified as inert.

7. COMPLETION STATEMENT

7.1. General

On the basis of the available analytical results, field observations and subject to the assumptions described in this report, URS provide the following completion statements.

These statements should be read in conjunction with the remainder of the report.

7.2. Principal Contractor's Completion Statement

A copy of the Principal Contractor's Completion Statement is attached in Appendix E.

7.3. Environmental Completion Statement

Following completion of the investigation and assessment, URS considers the site to be free of contamination to the degree necessary for high density residential (with basement) development, as determined by URS in accordance with a risk based assessment that should, in the professional opinion of URS, be acceptable, at the time of assessment, to all relevant regulatory authorities and the relevant planning authority, subject to appropriate building design, controls and safeguards.